Original Research Article

BIM-based process management model for building design and refurbishment

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ABSTRACT

A conceptual model of BIM-based design and refurbishment, based on pre-built indicators and allowing the assessment of the building energy demand and eco-building parameters, is presented. The new approach presented in this model creates a knowledge-based decision-making environment for refurbishment strategies and quality control, in this way creating the preconditions to bridge the gap between expected and actual energy performance. The model with integration of new BIM-based optimization subsystems enables energy management and optimization processes. For a comprehensive evaluation of refurbishment measures, it is suggested to include energy efficiency, eco-efficiency, and economic parameters.

1. Introduction

The current exchange of information between the energy modelling of buildings and their design has many problems, including defects in the parameters of object information, geometric false images, and the confusion of re-entry data. These problems cause great losses of money, time and effort [1]. Building Information Modelling (BIM) is a collaborative way of working, supported by digital technologies, which unlocks more efficient methods of designing [2]. A computer model that has several 'dimensions' can be used for the effective management of information throughout a project's lifecycle – from the earliest concept of operation [3]. BIM-based processes are 'mainstream' for new buildings, infrastructure, and have potential in refurbishment projects when complementary workflows such as laser scanning and rapid energy, economic and eco-efficiency analyses are employed [4,5]. Li et al. [6] refer to 1874 BIM-related articles identifying 60 key research topics as the knowledge base of BIM. The most important ones

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include information systems, 3D/*n*D modelling applications, design, sustainability, IFCs and interoperability, BIM implementation, multi-dimensional (*n*D) BIM, real-time communication, and BIM education. In addition, 10 knowledge clusters are identified, including architectural design studio, building information, lean construction, different discipline, augmented reality, unified building model, point cloud, multi-standpoint framework, CEM curriculum, and existing buildings.

So far, BIM technology is developing very quickly and it has been used in many construction projects, which have proven that great benefits can be achieved [7]. In this context BIM technology creates the opportunities for synergies of construction, energy sectors and software industries [8]. Construction projects face many risks, which have negative effects on a project, in terms of, e.g. time, cost and quality [9]. In current BIM, various subsystems are installed, e.g. the cost of construction can be calculated using the designed building model, the same system can be applied when creating timetables, the calculation of current material amount can be performed, and so on [10,11]. Of course, the use of the process approach to the management of a construction enterprise helps to achieve tangible results in the form of an increase in the efficiency of operation, and improvements in productivity and competitiveness [12]. Despite the fast development and diffusion of the standards, challenging research opportunities arise from process automation and BIM adaptation for the requirements of existing buildings [13]. For example, Saoud et al. [14] examines the problem of the management of design changes caused by the complexity of the design process and the lack of knowledge of all aspects of the design dependencies, presenting a method to predict the propagation of changes through the building information model and providing a concept of visual technology to help designers predict the changes.

Volk et al. [13] presents a review of over 180 recent publications on the topic of BIM. There is little implementation of BIM for existing buildings. While BIM processes are established for new buildings, the majority of existing buildings are not yet maintained, refurbished or deconstructed with BIM [15]. Research areas, such as: (1) integration of BIM-Sustainability issues; (2) using BIM for environmental and socio-economic evaluations; (3) integrating BIM and augmented reality during the construction phase; (4) Ontology and semantic web; (5) Mapping of BIM & domain knowledge; and (5) information extraction are currently not receiving adequate consideration from researchers [16]. Chong et al. [17] show that although there has been a significant amount of research and development about the use of BIM during various project phases, little work has been done on how it could be applied in refurbishment and demolition. A search of the Web of Science Core Collection data base made by the present authors in November 2017 on the topic "BIM + renovation" gave in total only 37 results, a search on the topic "BIM + refurbishment" gave in total only 18 results, and a search on the topic "BIM + modernization" gave in total only 5 results including articles, proceedings papers, and reviews.

Although the question of energy efficiency and selecting the most efficient alternative arises, there is nothing that would enable comparing the efficiency and quality of different alternatives and allowing pre-built model optimization [18].

Due to new developments, decision-makers can optimize and create a connection with a database of legal requirements and receive the opportunity to select the highest quality option, the most cost effective, eco-efficient and energy saving one matching current legal requirements [19]. In order to calculate the energy balance, various energy simulation programmes are adopted, which may result in higher measurement accuracy for building energy efficient buildings. However, these energy simulation programmes and energy-saving methods are essentially confined to the construction phases [20]. In the case of building energy performance simulation, up to 80% of the effort of input preparation may be consumed by the definition of the building geometry [21]. The new technology of computer vision is a method that allows identifying real-world objects. Real-time photogrammetric measurement systems are being developed with high-speed computers, but they are not widely used in the industry. Photogrammetry is a viable alternative to conventional measurement systems [22].

The pressure to build or refurbish buildings to nearly zero-energy means that the building sector needs to significantly upgrade its working practices. However, non-technological barriers hamper the implementation of these provisions. The heterogeneity of the construction industry, the large number of companies, and the relative lack of quality standards, inspection protocols and guidelines, limit the number and impact of large-scale energy efficiency investments and effective integration of renewable energy. The primary goals of analysis, comprehensiveness and ease of implementation of the results are very important [23]. The supply side, demand side and public authorities need to cooperate and find solutions that drive compelling offers for building owners, and simultaneously lift as many barriers as possible. Technology plays an important role in the interaction between entities, society and nature [24].

The refurbishment of old buildings using BIM technologies will have a great influence on the obligation undertaken by communities to reduce CO_2 emissions, as the application of a BIM based energy management model in the early stages of the building life cycle will ensure the selection of the best energy efficient solutions. As currently there is a limited articulated demand from building owners for significant energy performance improvements in existing buildings, the product resulting from the project will lift the significant barriers to sound, transparent, and high quality refurbishment processes. Moreover, the construction materials market offers newer and "better" insulation materials for construction sites [25]. An intense increase in the number of products made from nanomaterials provides an opportunity for the reduction of the use of non-renewable resources and energy, reducing the amount of waste generated [26]. It is hoped that the present article, as a good example, will influence the fostering of large-scale refurbishment, because the presented approach could, with some modifications, easily be applied in different climatic zones.

The present article presents a model of BIM-based design and refurbishment which is based on pre-built indicators and allows assessing the building energy demand and eco-building parameters. A previous study [27] presented a decision model for selecting alternative combinations of modernization measures, while the present paper presents an approach that