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Assessment of buildings redevelopment possibilities using MCDM and BIM techniques

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Abstract

The paper deals with abandoned former industrial buildings problem and buildings' redevelopment possibilities with emphasis on sustainable development. A complex decision-making model for redevelopment of abandoned buildings, combining Building Information Modelling (BIM) and Multiple Criteria Decision Making (MCDM) techniques, is proposed. A case study of a former measurement equipment factory is presented. Ranking of possible redevelopment alternatives of the building using Weighted Aggregated Sum Product Assessment method with grey attributes scores (WASPAS-G) is proposed and the most rational projects are selected. While BIM techniques supports an effective selection process and allows implementation of full lifetime management strategy of a project and then of a real object.

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Keywords: building conversion; industrial building; BIM; MCDM; WASPAS-G.

1. Introduction

Objectives and desirable beneficial results of redevelopment of assets are analyzed as a complex process with emphasis on sustainable development. The aspiration of sustainable development is not to build new urban areas, but to develop abandoned territories. Due to such development both the buildings are being modernized and the whole infrastructure is transformed, thereby making it more attractive to live or to invest [1,2].

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Complex decisions in construction can be supported by Building Information Modelling (BIM) methodology and different Digital Construction techniques [3]. The modelling can be treated as new project quality ensuring technique [4, 5] and can be used in any project life cycle phase with all possible benefits both for new and existing buildings [6,7]. In the refurbishment and maintenance phases the changes of building must be evaluated with respect to both the building heritage and the sustainability [8]. Alternative building redevelopment solutions can be successfully assessed applying Multiple Criteria Decision Making (MCDM) methods [9,10].

The aim of the current research is to suggest a complex model for redevelopment of abandoned buildings, combining BIM and MCDM techniques. Different building redevelopment concepts are analyzed, including property refurbishment, conversion or dismantling an old structure and building a new one. It is proposed to apply complex criteria system, consisting of technological, economic and environmental sub-systems. Selecting the best alternative concept using Weighted Aggregated Sum Product Assessment method with grey attributes scores (WASPAS-G) is proposed. Digital construction techniques are suggested to be applied for supporting selection process and further implementing full lifetime management strategy of a project.

2. Methodology for assessment of buildings redevelopment decisions

2.1. Decision-making model using MCDM and BIM techniques

The current paper proposes a complex building redevelopment model of abandoned buildings (Figure 1).

When deciding abandoned manufacturing and industrial buildings redevelopment capabilities, it is necessary to determine what type of project is suitable for a particular structure. At first, diverse and comprehensive information about a building and its site should be collected and analyzed, including building location; technical state and depreciation of a building; site contamination; historical, cultural and architectural value; needs of the community.

Different building redevelopment concepts can be analyzed: refurbishment, conversion of assets, or dismantling an old structure and building a new one. It is suggested to select the best concept considering a set of quantitative and qualitative criteria, emphasizing sustainable development. Ranking of possible redevelopment alternatives of the building using MCDM methodology is proposed. BIM techniques supports an effective selection process and further implementation of a project.

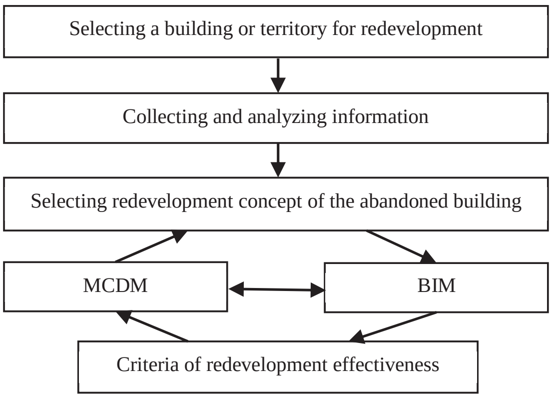

Fig. 1. Complex building redevelopment decision-making model.

2.2. Criteria system for assessment of buildings redevelopment

Demolition and new construction or reconstruction? Analyzing from the aspects of sustainable development, a decision is influenced by a number of technical, economic, social and environmental indicators, such as physical condition of load-bearing structures, historical and architectural value of the building, location, infrastructure, potentially contaminated areas, and others. Conversion of buildings is more appropriate because of the longer life of materials and reduced consumption of energy and other resources, reduced CO_2 emissions. However, such works are of greater technological complexity. Also, one can face with limited old building application to contemporary needs. The listed factors have an impact on the return on investment.

Accordingly, it is proposed to apply complex criteria system, consisting of three sub-systems: technological criteria sub-system, economic criteria sub-system, and environmental criteria system. Composition of the system is presented in Table 1.

Table 1. Criteria system for assessment of buildings redevelopment with emphasis on sustainability.

Technological criteria	Environmental criteria	Economic criteria
Project preparation and coordination	Energy efficiency by class	Investments
Construction work duration	CO_2 emissions	Net Present Value
Number of employees	Waste prevention	Payback period
Building lifetime	Removal of contaminated soil and material	Profitability
Possibilities of building adaptation to current needs	Preservation of historical value	Average rate of return and internal rate of return

2.3. Multiple-criteria decision-making methodology

Zavadskas et al. [11] proposed and originally described Weighted Aggregated Sum Product Assessment method extended with the grey attributes scores – WASPAS-G method.

To extend the WASPAS method in vague environment with the help of grey numbers, initial decision making matrix should be presented as a grey decision-making matrix. Let $\otimes x = [\alpha, \beta]$, where $\otimes x$ consists of two real numbers (α is the lower limit and β is the upper limit), and is called the grey number. The matrix is composed on the basis of preferences of decision alternatives rated on attributes $\otimes x_{ij}$, where $i = 1,\dots, m$; $j = 1,\dots, n$; m – number of alternatives, n – number of attributes. Next, a decision maker works with grey arithmetic. Values of attributes are normalized by applying a linear method, adapted for grey values [11].

The grey value $\otimes S_i$ of additive optimality function for i alternative is calculated as follows:

$$\otimes S_i = \sum_{j=1}^{n} \otimes \hat{x}_{ij},\ j = 1,\dots,m, \text{ or } \otimes S_i = 0.5 \sum_{j=1}^{n} \left(\hat{x}_{ij\alpha} + \hat{x}_{ij\beta} \right), \tag{1}$$

where $\otimes \hat{x}_{ij}$ is normalized weighted value of the attribute. It is calculated multiplying the grey normalized rating $\otimes \bar{x}_{ij}$ by the weight of the j attribute $\otimes w_j$.

The grey value $\otimes P_i$ of additive optimality function is calculated as follows:

$$\otimes P_i = \prod_{j=1}^{n} \otimes \bar{x}^{\otimes w_j},\ j = 1,\dots,m, \text{ or } \otimes P_i = \prod_{j=1}^{n} 0.5 \left(\otimes \bar{x}_{j\alpha}^{\otimes w_j} + \otimes \bar{x}_{j\beta}^{\otimes w_j} \right). \tag{2}$$

The weighted aggregation of grey functions [11]:

$$\otimes Q_i = \lambda \sum_{j=1}^{n} \otimes \hat{x}_{ij} + (1-\lambda) \prod_{j=1}^{n} \otimes \bar{x}^{\otimes w_j},\ \lambda = 0.5 \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} S_i}. \tag{3}$$

Finally, the grey values are transformed to crisp values by the centre-of-area method. The decreasing preference order of the alternatives is determined according to the decreasing sequence of Q_i.

2.4. BIM technique to assist building redevelopment

This specific subtopic of the implementation of new Digital Construction techniques (like GIS, 3D Laser Scan and BIM) was found as new research field partially analyzed in some scientific works [6–8,12]. The best practice, knowledge, experience and "know-how" leads world to new approach of connecting traditional survey methods with design process and innovative technologies in construction industry.

Different types of strategies can be used to combine the most advanced ICT (Information and communications technologies and techniques) in building industry for every stage of asset implementation, i.e. for new design of asset, for asset construction quality, and for existing asset. All strategies can be used simultaneously with assessment of alternative design solutions with MCDM techniques including precise criteria information from BIM model (such as quantity take-offs, implementation time and project cost). Also at completion of any stage of asset project implementation, received the information (collected during design, construction, maintenance or refurbishment) is interconnected and transferred to an integrated GIS, BIM and AIM (facility or asset management) system to support redevelopment activities and asset management.

In this research the ICT technologies and BIM techniques are used for existing building. The strategy of combining the most advanced ICT for existing asset consists of several steps. The first step is to choose GIS positions and perform 3D laser scanning of existing building, engineering object/system or other asset and this especially helpful without available as-built drawings or records. The second step is to combine collected point cloud data and to make identified 3D model from primitives. The third step is to connect 3D model with all accessible information and also interconnect GIS and BIM models. The forth step is to make new BIM design and implementation of redeveloped asset.

In the current paper the data of completed digitalization procedures and prepared information model of a case study building was used for building redevelopment alternatives' evaluation as presented in the following Chapter.

3. Case study: ranking of alternatives

Former measurement equipment repair factory "Matas", located in Vilnius (a capital of Lithuania), was selected for the case study. The prepared information model of the existing abandoned building is presented in Figure 2.

Three redevelopment alternatives are considered, including building refurbishment and adaptation to current needs while maintaining or slightly changing the original object and its historically established purpose (a_1), conversion of the building into loft-type housing, preserving its architectural-urban expression (a_2), demolition of the existing building and implementing a new construction project (a_3).

Selection of the most preferable alternative is analyzed regarding a set of criteria as listed in Table 1. Data for criteria values is derived from the prepared information model. The results applying WASPAS-G method are presented in Table 2.

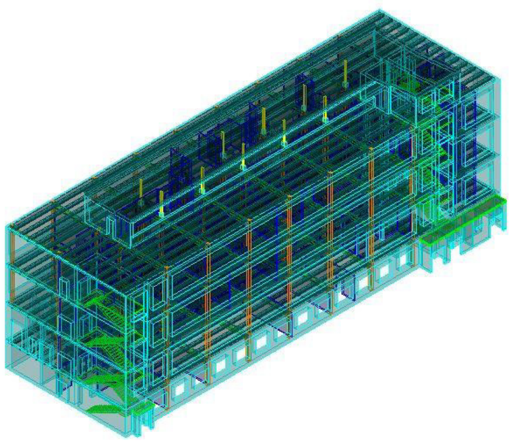

Fig. 2. Information model of the former measurement equipment repair factory "Matas" (prepared by authors).

Table 2. Ranking results: optimality functions and final weighted aggregated results.

Alternatives	P_i	S_i	Q_i	Rank
a_1	0.563	0.564	0.564	3
a_2	0.612	0.616	0.614	1
a_3	0.567	0.581	0.574	2
	$\sum P_i = 1.742$	$\sum S_i = 1.761$	$\lambda = 0.495$	

It is found that the most profitable is demolition of the existing building and implementing a new construction project. Technological complexity of construction or refurbishment works are assessed as almost equal. While emphasizing environmental aspects and applying complex evaluation, the best alternative is conversion of the industrial building into loft-type housing. It comprises a positive impact on the urban and the natural environment. If implemented, the selected engineering solution would be friendly to environment both in production and in operation.

4. Conclusions

The presented case study as well as analysis of scientific literature and the successfully implemented projects leads to the conclusion that the old industrial buildings are highly attractive for conversion.

Analyzing in terms of sustainable development, it is ascertained that redevelopment of industrial buildings is a multifaceted problem, therefore MCDM methods are proved to be highly suitable to support selection of the most effective decisions.

BIM technique is suggested to be applied to support the multiple-criteria selection process and further implementation of a project and afterwards a full lifetime management strategy of a real object, which is based on the simulation of virtual prototypes with assigned static and dynamic information.

It is concluded that combining of GIS and scanning is mostly applied to existing buildings and other asset, but applications for new construction or redevelopment project works are necessary to complete the integrated BIM cycle and to provide an added value of the integrated BIM workflow.

References

[1] A. Chan, E. Cheung, I. Wong, Revitalizing industrial buildings in Hong Kong-a Case Review, Sustainable Cities and Society 15 (2015) 57–63.

[2] M. Pavlovskis, J. Antucheviciene, D. Migilinskas, Conversion of industrial buildings and areas in terms of sustainable development by using BIM technology: analysis and further developments, Science – Future of Lithuania 7(5) (2015) 505–513 (in Lithuanian).

[3] L. Ustinovičius, V. Popov, D. Migilinskas, Automated management, modeling and choosing of economically effective variant in construction, Transport and Telecommunication 6(1) (2005) 183–189.

[4] V. Popov, S. Mikalauskas, D. Migilinskas, P. Vainiūnas, Complex usage of 4D information modelling concept for building design, estimation, scheduling and determination of effective variant, Technological and Economic Development of Economy 12 (2) (2006) 91–98.

[5] M. Murphy, E. McGovern, S. Pavia, Historic building information modeling (HBIM), ISPRS Journal of Photogrammetry and Remote Sensing 76 (2013), 89–102.

[6] H. Penttilä, M. Rajala, S. Freese, Building Information Modelling of modern historic buildings, Case Study of HUT, Architectural Department by Alvar Aalto, eCAADe 25 - Session 13: Modelling, 2007, pp. 607–613.

[7] R. Volk, J. Stengel, F. Schultmann, Building Information Modeling (BIM) for existing buildings — Literature review and future needs, Automation in Construction 38 (2014) 109–127.

[8] D. Ilter, E. Ergen, BIM for building refurbishment and maintenance: Current status and research directions, structural survey, Journal of Building Pathology and Refurbishment 33(3) (2015) 228–256.

[9] E.K. Zavadskas, J. Antucheviciene, 2008. Modelling multidimensional redevelopment of derelict buildings, International Journal of Environment and Pollution 35(2/3/4) (2008) 331–344.

[10] E. Siozinyte, J. Antucheviciene, V. Kutut, Upgrading the old vernacular building to contemporary norms: multiple criteria approach, Journal of Civil Engineering and Management 20(2) (2014) 291–298.

[11] E.K. Zavadskas, Z. Turskis, J. Antucheviciene, Selecting a contractor by using a novel method for multiple attribute analysis: Weighted Aggregated Sum Product Assessment with grey values (WASPAS-G), Studies in Informatics and Control 24(2) (2015) 141–150.

[12] D. Migilinskas, V. Popov, V. Juocevicius, L. Ustinovichius, The benefits, obstacles and problems of practical BIM implementation, Procedia Engineering 57 (2013) 767–774.