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MULTICRITERION DECISION AND USAGE OF BUILDINGS OF INDUSTRY AREA WITH REGARD TO BUILDING –ENERGY CONCEPTION

Abstract

When regenerating an industrial site area, care should be taken after buildings located there. Within development of the region and city, reconstruction, rehabilitation or conversion of buildings is planned. Any action relating to the building includes, among others, a new building energy concept based on heat and energy laws in force. The new building and energy concept of the buildings could be assessed using a multi-criterion analysis.

Keywords

Building, construction, heat engineering, management, maintenance.

Abstrakt

Nedílnou součástí regenerace každého industriálního sídla je péče o budovy, které se na těchto postižených územích nacházejí. V rámci rozvoje kraje a města jsou tyto budovy určeny k rekonstrukcím a sanacím, konverzi. Součástí všech zásahů u těchto budov je mj. stanovení nové stavebně energetické koncepce, s ohledem na platnou tepelně technickou a energetickou legislativu. Pro hodnocení budov, z hlediska jejich nové stavebně energetické koncepce, lze využít hodnotící nástroj, který využívá vícekriteriální analýzy.

Klíčová slova

Budovy, konstrukce, tepelná technika, řízení, údržba.

1 INTRODUCTION

When regenerating an area affected by increased industrial activities, care should be taken after buildings located there. Within development of the region and city, reconstruction, rehabilitation or conversion of buildings is planned. Territories exposed to intensive industrial activities represent an urgent issue in the Czech Republic. This problem is pressing because not only territories but also the buildings located on those sites are being damaged.

1.1 Assessment of buildings in territories with intensive industrial activities

A particular attention should be paid to methods relating to applicability of the buildings in the industrial sites. Regeneration of territories affected by increased industrial activities influences other areas such as social issues or technology. When assessing the industrial site as an area (which is also known as a "brownfield“), the buildings on the site should be also taken into account.

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The assessment of the sites affected by increased industrial activities should consider the possible future use. Two basic components should be taken into account: the building technology and building energy concept [1].

The buildings located on the site with intensive industrial activities can be divided into three groups. Table 1 gives classification of the buildings.

Table 1: Buildings in brownfields and their basic classification

	Building and its value	
Building group No. 1	**Building group No. 2**	**Building group No. 3**
Listed buildings (e.g. because of machines or technology which was located there in past...)	Not-listed buildings – they were built typically in the second half of the 20th century. They are maintained, have got their new investors and their new functions.	Not-listed buildings – they were built mostly at the beginning of the 20th century or in the second half of the last century, They are often considerably dilapidated and have no investors. This means, their new functions do not exist at all.
The buildings are parts of museum and excursions are organised there, such as the Landek Museum.	These buildings include administrative buildings, living houses, or panel block house development.	These buildings should be demolished in the future or their refurbishment is not economical.
Mostly cultural, social or economic values.	Economic value. Refurbished and reconstructed buildings still give some profits and benefits.	Almost zero value. No social, cultural or economic benefits.

2 MULTI-CRITERION ANALYSIS

A possible approach to the assessment of the buildings on sites affected by intensive industrial activities is to apply tasks resulting from the multi-criterion decision making process. The multi-criterion analysis is based on a mathematic model. The final, optimum decision consists in the selection of the only one alternative listed among alternatives that would be available for that situation. The multi-criterion decision-making process exists everywhere where the decision-maker evaluates consequences of his work by several criteria. Such criteria are quantitative (which are typically expressed using a natural scale and are also referred to as numerical criteria) or qualitative (where typically a suitable scale is introduced – either a classification scale or a scale defining very high-high-average-low-very low levels). At the same time, the best assessment direction should be defined. This means it is necessary to decide whether the maximum or minimum value is better. Such a task can include the requirement to sort out the decision-making alternatives by their order [2].

Key motives for introduction of exact approaches to the decision-making process are typical of areas where the risk of incorrect decisions needs to be minimised and where some experiments are welcomed in respect of economic, technical/economic and social aspects. Decisions are made based on a single criterion, or multi criteria could be taken into account.

The multi-criterion decision-making process is discussed by many scientific and scholar publications. The multi-criterion decision making process is known abroad as Multi-criterion Decision Analysis.

The multi-criterion analyses and decision-making processes are used within activities carried out by CIDEAS, Department of Building Constructions, Faculty of Civil Enginerering in the University of Technology Ostrava, for its research task "Assessment of buildings in territories with intensive industrial activities in terms of the building and energy concept" (see www.cideas.cz, task No. 1.2.3 "Management and maintenance of buildings on the territories with intensive industrial activities" and task No. 1.2.3.2 "Multi-criterion decision-making process in determination of applicability of the buildings on the territories with intensive industrial activities.

Five buildings were chosen to represent the buildings in the territory affected by industrial activities, this means – in Ostrava. The buildings under assessment are from various materials and different structural systems were used for the construction. These buildings were built mainly in the second half of the 20th century. These are typically prefabricated structures assembled in a wall and skeleton structural system. Other structures are wall/brick systems. Table 2 gives an overview of the buildings No. 1 to 5.

Table 2: Buildings under assessment

Building	Original application of the building/structural system	Location	New application of the building
1.	Administrative building/an assembled skeleton system	Ostrava - Přívoz	Administration and living
2.	Grammar school, an assembled skeleton system	Ostrava - Poruba	University building
3.	Dwelling house, an assembled wall system (panel segments)	Ostrava - Poruba	Dwelling house
4.	Dwelling house, a wall/masonry structural system (a listed building)	Ostrava - Hrabůvka	Dwelling house
5.	Administrative building, a wall/masonry structural system	Ostrava - Přívoz	Dwelling house

The current condition of the buildings No. 1 to 5 (see Table 2) was assessed first on the basis of the building and technical survey. It was necessary to define whether the building would be suitable for further rehabilitations and conversions. Then, the existing energy concept was considered and a new building and energy concept was discussed. The new concept comprises both possible improvement alternatives in accordance with the laws on technology and energy in force. The result of the assessment should be general information about the building in terms of future use and estimated investment costs for improved building and technical conditions. In particular, information should be acquired about the building and energy condition when the building requires an energy performance certificate ("EPC") for the current situation and for the two alternatives which should improve the building and energy concept of the building. According to the alternatives, the classification should be A to C after rehabilitation is completed. (The classes are A to G - see [3], [7]. As of 1 January 2009, EPC is a part of the project documentation, part D – Documentation, in line with Decree No. 499/2006 Coll.). A potential investor will acquire information about estimated investment costs for rehabilitation and about return on investment. An example of the outcome of the assessment is given in Fig. 1. For each building under assessment on the site affected by industrial activities, possible impacts of the industrial sites can be defined. They include undermined territories, occurrence of methane, increased ground level, or contamination of soil.

2.1 Using the multi-criterion analysis and building and energy concept for assessment of energy performance of buildings in territories with intensive industrial activities

Using the multi-criterion analysis and building and energy concept for assessment of energy performance of buildings in territories with intensive industrial activities has not been a random choice. This concept is based on the current legislative and objectives of the company – in case of new, reconstructed and rehabilitated buildings, it is necessary to take such building/technical/energy measures so that energy savings could be achieved. The new building and energy concept for the buildings located in territories with intensive industrial activities reduces consumption of energy and this is in accordance with the energy concept objectives of the Czech Republic as well as all EU member states. Currently, the requirements set forth in the Energy Performance Building Directive should be fulfilled. This Directive does not determine any criteria but requires the EU member states to evaluate the energy performance of the buildings [3], [5]. This concept supports good energy performance of panel block buildings after modernisation and rehabilitation on territories with intensive industrial activities.

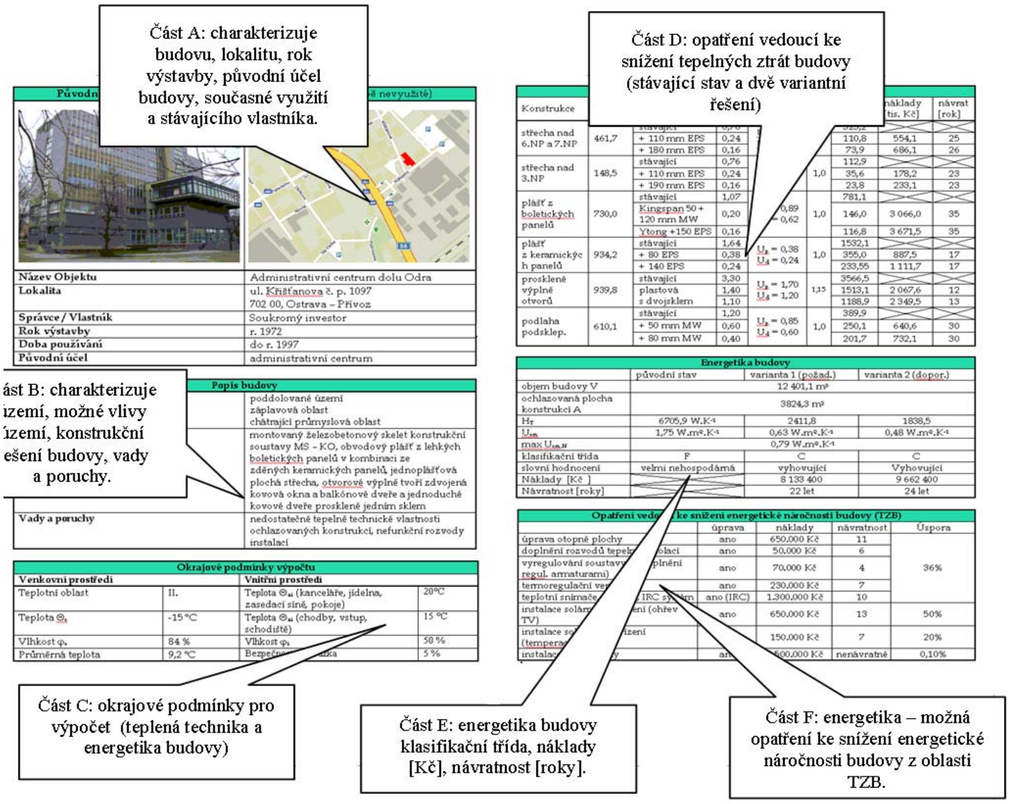

Fig. 1 Example of a catalogue sheet of a building on the territory with intensive industrial activities in terms of the existing and new building energy concept (the figure shows the building No.1 pursuant to Table 2, [3]

(Each catalogue sheet consists of the basic parts A through F, where A through C are descriptive texts, while D through F contain calculations.)

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2.1.1 Assessment model

On each territory with intensive industrial activities, there is *n* buildings. In order to assess *n* buildings on the territory, an assessment model was prepared (see Fig..2) [4]. The model is based on the multi-criterion assessment and multi-criterion decision-making process.

The assessment model is open to users and can be utilised by state bodies, owners of the buildings as well as by potential investors. The outcome of the assessment model provides overview of costs for rehabilitation of a panel block building, total savings, return, efficiency (which is the total savings-to-costs ratio), order of the buildings, and total investment costs.

The assessment can be done only if catalogue sheets are available for the buildings on the territories with intensive industrial activities (see Fig. 1). This means, the assessment is supported by MS Excel. Teamwork, however, is essential, and one assessor at least should coordinate works with the model in accordance with the legislative that is in force for the building technical concepts, construction aspects and building energy performance. Fig. 2 shows the assessment model which comprises three basic levels.

Level 1

- Definition of such building construction and material measures that would decrease heat losses in the building and save energy. For each building, the measures relate to following parts of the construction: Roof, external cladding, windows and doors, floors in the level above the under-ground floor.
- When assessing the energy of the building, the original condition is considered and alternative measures are taken into account so that the building energy concept could improve and so that the classification of the building could be in line with the legislative in force. Finally, the costs (in CZK) and return on investment (in years) will be defined as well.
- Definition of measures that would decrease the energy performance of the building (in particular, the measures connected with the building services and facilities). Such measures include possible modifications, introduction of heat insulation for pipes, regulation of a heating system, installation of heat control valves or a regulation unit at the building footing. The result will be an overview of improvement costs (in CZK), return on investment (in years) and savings (in per cent).

Level 2

- Preparation of the assessment model and entering of input information. Entering of the weight, classification and work with the model. The assessment model is based on the multi-criterion assessment which is a part of the **A**nalytic **H**ierarchy **P**rocess.

When working with the assessment model:

a) theoretical background should be studied and alternatives resulting from the multi - criterion assessment should be discussed.

b) Criteria should be defined, described and characterised (*n* criteria).

c) Data should be transformed within the modelling.

d) Criterion weights should be defined, Saaty's approach and matrixes should be considered and the weight should be determined from the matching matrices. When matching $S = (a_{ij})$, $i, j = 1,2,3\ldots\ldots k,$ the series 1,2,3……9 and reciprocal values are frequently used. The matrix elements in s_{ij} are presented as an estimated ratio of the weights of the i^{th} and j^{th} criteria [6].

$$s_{ij} = \frac{v_i}{v_j} \quad i,j = 1,2\ldots..k$$

(1)

This is the Satty´s matrix. For each matrix element, one has:

$$s_{ii} = 1 \; i = 1,2\ldots\ldots k$$

$$s_{ji} = 1/s_{ij} \quad i,j = 1,2\ldots..k$$

(2)

A verbal scale is also available for the assessment:

1 The criteria *i* and *j* are equal

3 The *i* criterion is slightly preferred to *j*

5 The *i* criterion is strongly preferred to *j*

7 The *i* criterion is very strongly preferred to *j*

9 The *i* criterion is absolutely preferred to *j*

The values 2, 4, 6, 8 are the intermediate levels of the verbal scale. The elements in the *A* matrix, being the estimate of the weight ratios, are not, in general, fully consistent. This means $s_{hj}= s_{hi}s_{ij}$ is not valid for *h, i, j* = 1, 2….*k*. Let us create the *V* matrix = (v_{ij}), the elements of which are real ratios of the weight:

$$v_{ij} = \frac{v_i}{v_j} \quad i,j = 1,2\ldots k$$

(3)

e) Then, $v_{hj} = v_{hi}\, v_{ij}$ for all elements and for all *h,i,j* = 1,2….*k*, [6].

For estimation of the weights, Saaty introduces a vector which corresponds to the biggest characteristic number of the *A* matrix. Saaty´s method ranks among the most frequently used methods in the multi-criterion analysis. This method is used also in the **A**nalytic **H**ierarchy **P**rocess, AHP [6].

Level 3

- |Input values are taken from the catalogue sheets (see the example in Fig. 1) created in line with the guideline used for assessment of the buildings on the industrial sites (see www.cideas.cz, Technical Sheet TL 1.2.3 and Technical Sheet TL 1.2.3.2 and outcomes of interim research reports drafted in 2007 to 2008). Data from the catalogue sheets are defined as a matrix table with general input data according to results listed in the catalogue sheets.
- The matrix table with the input data is divided into two basic parts: the building energy concept and the building services and facilities see Table 3).
- The classification scale of the multi-criterion assessment is from 1 to 10.
- When determining the weight and when applying the multi-criterion assessment in a set of criterion indicators, each element out of the set has a different relative importance for a specific issue which is being investigated into. The relative "relevance" is identified as the weight of the criterion for w_j (parameter weights). This weight provides information about relative relevance of individual indications within the set $P_1,\ldots. P_n$, [4].

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Table 3 Matrix table – input data (data from the catalogue sheets) [3],[4]

B	**B1**			**B2**			**B3**			**B4**			**B5**					**SEK**		
	T06B	r	%	**MS-OB**	r	%	**MSKO**	r	%	Jub.	r	%	**Kok.**	r	%	Na	Np	Ue	Npr	Ž
O1	30,000	4	35	70,000	4	38	50,000	6	36				35,000	5	33	7	8	8	10	10
O2	25,000	2	35	35,000	3	38										10	8	10	8	5
O3	30,000	3	35	45,000	4	38	70,000	4	36				25,000	2	33	9	8	9	6	4
O4	60,000	4	35	180,000	7	38	230,000	7	36				45,000	4	33	8	8	7	9	7
O5				1,100,000	9	38	1,300,000	10	36				170,000	11	33	6	7	3	8	4
O6							650,000	11	36				150,000	11	33	4	6	4	10	8
O7							650,000	13	50	220,000	13	50	250,000	13	50	5	10	5	8	10
O8							150,000	7	20							3	3	6	8	10
O9							2,500,000									1	1	1	9	8
																	K	=	Ú	

Definition of possible measures:

O1 Overcladding for distribution lines
O2 Installation of a control node at the footing of the building
O3 Regulation of the system
O4 Heat regulation valves
O5 Heat sensors, cabling
O6 Modifications of the heating area
O7 Installation of a solar unit (hot water heating)
O8 Installation of a solar unit (maintaining a stable temperature in the building)
O9 Installation of a photo-voltaic unit

U1 Rate of return [years]
U2 Purchase/installation costs [CZK]
U3 Energy savings [%]
U4 Operation costs [CZK]
U5 Service life [years]

$B1$ to B_n Buildings under assessment, SEK Building and energy concept

After the input data are entered (see Table 3), the assessment model can be regarded as a tool which supports objective decision-making. The weights of the savings and the weights of the actions are same in the model. The weights of relative importance of some measures can be higher, for certain measures, that those of other measures, the same being the case of the savings. (This means, the weights could be easily changed). For correct adjustments, matching is used (it is also possible to use software such as Expert Choice).

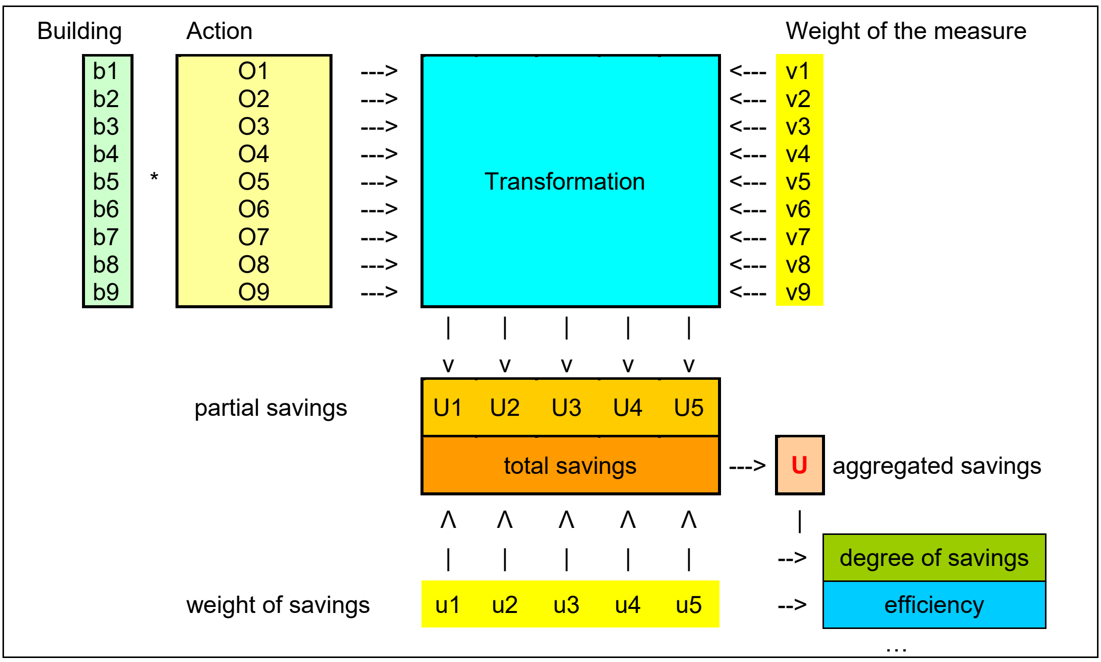

Fig. 2. Preparation of the model and data transformation (Kubečková Skulinová, D., Ramík, J, [4].)

Comparison in the assessment model can be set in two ways:

1. absolute comparison where alternatives are confronted with a standard resulting either from experience or from sample values. The key criterion for absolute assessment is a cardinal criterion. This is absolute assessment of elements from the k^{th} level of the hierarchical level L_k for the element from the upper level L_{k-1}, [4].
2. relative comparison where alternatives are confronted in pairs. The result is relative assessment of the weights w_{ki} for each element i from the k^{th} level L_k for the element from the upper level L_{k-1}. In the matching process, i and j elements from L_k are compared in terms of properties which are common. The result is the estimated ratio w_{ki} / w_{kj} ,(v) by means of the basic scale. By gradual comparison, we obtain a matching matrix and the maximum characteristic number. This also gives an own vector which can be normalised to receive own weight w_{ki}.

Table 4 Assessment model data - an absolute model

Action	Weight	U1	U2	U3	U4	U5
	Action	Rate of return	Procurement savings	Energy savings	Operation cost savings	Service life
O1	1	7	8	8	10	10
O2	1	10	8	10	8	5
O3	1	9	8	9	6	4
O4	1	8	8	7	9	7
O5	1	6	7	3	8	4
O6	1	4	6	4	10	8
O7	1	5	10	5	8	10
O8	1	3	3	6	8	10
O9	1	1	1	1	9	8
Sums	9	53	59	53	76	66
Weights of savings		1	1	1	1	1

The weights of the actions and savings are scaled 1 to 10.

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Table 5 Buildings B1 to B5 (according to Table 2)

Buildings (,000 CZK)					
	B1	B2	B3	B4	B5
	T06B	MO-OB	MS-KO	Jubilejní street	Koksární street
1	30	70	50	0	35
2	25	35	0	0	0
3	30	45	70	0	25
4	60	180	230	0	45
5	0	1 100	1 300	0	170
6	0	0	650	0	150
7	0	0	650	220	250
8	0	0	150	0	0
9	0	0	2 500	0	0
$\sum$	145	1430	5 600	220	675
Volume of the building	2 574	353 366	12 411	2 056	1 330
Surface to be cooled	966,2	14 981	381	735,5	1 159

On the basis of Table 5, the matrix of the buildings can be defines (the buildings / ,000 CZK)

- ✓ Absolute model of savings

Table 6. Model of savings with the weight

W = savings matrix						
Action	**V** = weights					
	Action	Rate of return	Procurement savings	Energy savings	Operation savings	Service life
O1	0,11111	7	8	8	10	10
O2	0,11111	10	8	10	8	5
O3	0,11111	9	8	9	6	4
O4	0,11111	8	8	7	9	7
O5	0,11111	6	7	3	8	4
O6	0,11111	4	6	4	10	8
O7	0,11111	5	10	5	8	10
O8	0,11111	3	3	6	8	10
O9	0,11111	1	1	1	9	8
u = weight of savings		0,2	0,2	0,2	0,2	0,2

In the model of savings (see Table 6) the weight in the matrix is 0.1.

The assessment model gives us an overview for better rehabilitation and reconstruction in order to reach maximum energy savings and the minimum possible return on investment. The new building and energy concept should be taken into account as much as possible (see Table 7 to Table 9).

Table 7. Degree of savings in respect of the volume of the building and efficiency order

	Savings in respect of the volume of the building,				
Building	T06B	MS-OB	MS-KO	Jubilejní street	Koksární street
Total savings	**127**	**975**	**3334**	**186**	**516**
Relative value	**0,050**	**0,028**	**0,269**	**0,090**	**0,388**
Order	4	5	2	3	1
Costs	145	1430	5600	220	675
Total savings =	diag(v)*W*u*Bi				
Relative value =	diag(v)*W*u*Bi/volumeBi				
Efficiency	**0,879**	**0,682**	**0,595**	**0,844**	**0,764**
Order	1	4	5	2	3
Efficiency = Total savings/Costs					

✓ Relative model

Table 8. Relative value of the degree of savings

	Degree of savings =10000* **diag(v)*W*u***Bi				
Building	T06B	MS-OB	MS-KO	Jubilejní street	Koksární street
Value	**146,3**	**111,4**	**93,3**	**136,7**	**123,7**
Order	1	4	5	2	3
Value	= 10000* diag(v)*W*u*Bi				

Table 9 General overview of outcomes

Building	T06B	MS-OB	MS-KO	Jubilejní street	Koksární street
Total savings	127	975	3334	186	516
Relative value	0,050	0,028	0,269	0,090	0,338
Order	4	5	2	3	1
Costs	145	1430	5600	220	675
Total savings = diag (v)*W*u*B_i					
Relative value = diag(v)*W*u*B_i / objem B_i					
Efficiency	0,879	0,682	0,595	0,844	0,764
Order	1	4	5	2	3
Efficiency = Total savings / Costs					
Degree of savings =10000* diag(v)*W*u*Bi					
Value	146,3	114,4	93,3	136,7	123,7
Order	1	4	5	2	3
Value = 10000* diag(v)*W*u*Bi					

3 CONCLUSION

The multi-criterion assessment has been used for the evaluation of many projects, for instance for the evaluation of flood protection and revitalisation actions in small water courses and lakes and for the selection of a compromise alternative [Říha, "Applying the risk analysis for assessment of flood protection measures" 2001] or for evaluation of impacts of the investments onto the environment [Říha, "Evaluating impacts of investments on environment - multi-criterion analysis" 1995], and other projects. The multi-criterion assessment and multi-criterion decision can be used for evaluation of rehabilitation projects in territories with intensive industrial activities.

It follows from the multi-criterion analysis and outcomes of the assessment model, that this approach provides a general insight into the complex topic. At the same time, it makes it possible to decide on an objective basis how the panel block housing stock will be treated, regenerated and rehabilitated.

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REFERENCES

[1] KUBEČKOVÁ SKULINOVÁ, D., KUBENKOVÁ, D.: *Snižování energetické náročnosti budov, udržitelná výstavba*, Vyadala Polska Akademia Nauk, oddzial w Katowicach, Komisija Inžynierii Budowlanej, Roczniki Inženierii Budowlanej, Zeszyt 6, Katovice-Opole, ISSN 1505-8425, str.117-125, 2006

[2] KUBEČKOVÁ SKULINOVÁ, D.: *Management a údržba panelového bytového fondu, posuzování investičních projektů vícekriteriální analýzou*, Sborník vědeckých prací FAST VŠB-TUO, 12/2005, ISBN 80-248-0997-4

[3] KUBEČKOVÁ SKULINOVÁ, D., KUBENKOVÁ, K., GALDA, Z.: Technické listy z let 2005-2008, www.cideas.cz, řešení úkolu 1.2.3 *Management a údržba budov na územích se zvýšenou průmyslovou činností*, ISBN 80-01-03631-6

[4] KUBEČKOVÁ SKULINOVÁ, D., RAMÍK, J.: *Hodnotící model pro hodnocení budov na územích se zvýšenou proslovu činností z hlediska stavebně energetické koncepce*, Technický list 1.2.3.2, www.cideas.cz, 2008-2009

[5] KUBEČKOVÁ, D.: *Bytová výstavba v Ostravě v druhé polovině minulého století, vady a poruchy*, FAST VŠB-TUO, 02/2008 ISBN 978-80-248-1718-7, Ostrava

[6] Fiala, P., Jablonský, J., Maňas, M.: *Vícekriteriální rozhodování,* VŠE Praha, 1997

[7] ČSN 73 0540 Tepelná ochrana budov. Část 2: Požadavky, 2002-2007

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