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RANKING REDEVELOPMENT DECISIONS OF DERELICT BUILDINGS AND ANALYSIS OF RANKING RESULTS

Abstract. *Redevelopment of derelict buildings is examined from the aspects of sustainable development and a lot of conflicting criteria are involved. Fuzzified MCDM (multiple criteria decision making) methods, i.e. TOPSIS-F (the Technique for Order Preference by Similarity to Ideal Solution) based on vector as well as linear normalization of initial criteria values, COPRAS-F (a method of multiple criteria COmplex PRoportional ASsessment of projects), and VIKOR-F (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian) are applied for evaluating the rational use of buildings. A methodology for measuring the objective congruence (incongruence) of the ranking results of different MCDM methods as well as criteria of consistency (inconsistency) of ranking results are developed and applied for a particular case study of Lithuania.*

Key words: *redevelopment of derelict buildings, MCDM, Fuzzy sets, TOPSIS-F, COPRAS-F, VIKOR-F, rank correlation, comparison of ranking results.*

JEL Classification: C44, D81, Q01.

1. Introduction

The importance of derelict buildings regeneration is appreciated in many cities and countries. Most countries recognize that abandoned sites and buildings cause many problems that are associated with economic depression, social conflicts and poor living conditions, contamination of land and inefficient use of property. The question arises how to select the optimal strategy for building redevelopment?

Decision making concerning construction or reconstruction and redevelopment of buildings, ranking of potential decision alternatives and selection of rational strategies has been always complicated especially if there were a lot of conflicting criteria under consideration. According to the modern viewpoint of sustainable development, revitalization and redevelopment of buildings should be a contribution towards sustainable construction, incorporating protection of natural and social environmental, improvement of life quality and implementation of economic goals. Accordingly, there are many aspects that need to be considered and integrated into the actions that are necessary to achieve effective redevelopment solutions.

Multiple criteria decision making can be applied for complex decisions when a lot of criteria are involved. There is a variety of MCDM methods developed as well as case studies of their application presented. However, it was observed that different MCDM methods can produce diverse, not always coinciding ranking results. Therefore, the authors suggest applying TOPSIS-F based on vector as well as linear normalization of initial criteria values, COPRAS-F and VIKOR-F methods for ranking redevelopment decisions of derelict buildings in rural areas of Lithuania. The ranking results are compared and analyzed in the paper.

2. Literature review: decision making applying TOPSIS, COPRAS and VIKOR methods

The essence and the basic algorithm of TOPSIS are presented with reference to Hwang and Yoon (1981), Zavadskas *et al.* (1994), Triantaphyllou (2000). The basic concept of the TOPSIS method is that the selected alternative should have the shortest distance from the ideal solution and the longest distance from the negative-ideal solution, in a geometrical sense. Usual crisp TOPSIS as developed by Hwang and Yoon in 1981 (Hwang, Yoon 1981) or fuzzy TOPSIS (TOPSIS-F) has been widely applied for ranking of construction-technological alternatives, selecting of resource-saving decisions, accepting other technological, facility management or economic decisions (Zavadskas, Turskis, 2011). The above method was successfully applied for selection of various projects (Amiri, 2010), suppliers (Boran *et al.*, 2009), partners or contractors (Marzouk, 2008; Ye, 2010) and consultants (Saremi *et al.*, 2009). A method for selecting projects and related contractors simultaneously was proposed (Mahdi, Hossein, 2008) in which firstly contractors that have not minimal qualifications are eliminated from consideration, then closeness coefficient of contractors to each proposal is computed applying TOPSIS-F method and finally these coefficients as successful indicators for each contractor are fed into a linear programming to select the most profitable projects and contractors. As in project development it is rather hard to get exhaustive and accurate information and the situations occur the consequences of which can be very damaging to the project, assessment of investment risk and construction risk has been widely performed by applying usual and extended TOPSIS (Zavadskas *et al.*, 2010a, 2010b). The aim of the study of Onut *et al.* (2010) was to model shopping center site selection problem for a real world application in Istanbul by applying TOPSIS-F methodology to determine the most suitable alternative. The aim of the research of Zavadskas and Antucheviciene (2006) was to rank derelict buildings' redevelopment alternatives from the multiple sustainability approach. Other territory planning decisions, i.e. road design and transport systems were evaluated applying TOPSIS method (Jakimavicius, Burinskiene, 2009). Choosing the most suitable structure for a highway bridge design, considering numerous attributes that are evaluated in terms of many different conflicting criteria was held also by applying the above method of multiple criteria decision making in a fuzzy environment (Malekly *et al.*, 2010). Technique for Order Preference by Similarity to Ideal Solution for prioritizing the strategies of Iranian mining sector was applied by Fouladgar *et al.* (2011). The paper of Laskhari *et al.* (2011) intended to use the combination of analytical hierarchy process and TOPSIS methods under fuzzy environment in order to select a proper shaft sinking method. Also multi-attribute decision making models based on TOPSIS method as well as their application for construction, engineering, location prioritization were presented in some other works (Liu, 2009; Kucas, 2010; Čokorilo *et al.*, 2010; Rudzianskaite-Kvaraciejiene *et al.*, 2010; Kalibatas *et al.*, 2011).

In some papers the application of extended TOPSIS has been analyzed. In (Zavadskas *et al.*, 2006) the methodology for measuring the accuracy of determining the relative significance of alternatives as a function of the criteria values was developed. An algorithm of TOPSIS that applies criteria values' transformation through a normalization of vectors and the linear transformation was considered. An application of methodology for building management problem was presented. A new decision approach based on entropy weight and TOPSIS was proposed by Han, Liu (2011). An attempt to use extended TOPSIS method with different distance approaches for mutual funds' performance was published (Chang *et al.*, 2010). Two different distance ideas, namely Minkowski's metric and Mahalanobis distance, were applied. Multiple criteria decision making theory was supplemented by the elements of mathematical statistics and the methodology, based on TOPSIS method that considered statistical relations between criteria was developed and applied for construction management decisions in the paper of Antucheviciene *et al.* (2010).

Zavadskas and Kaklauskas developed a method of multiple criteria complex proportional assessment of projects for determining the priority and the utility degree of alternatives in 1996 (Zavadskas, Kaklauskas, 1996). The COPRAS method assumes direct and proportional dependence of relative significance and priority of the investigated alternatives on a system of criteria that adequately describes the alternatives and is based on the criteria values and weights. Consequently it is convenient to evaluate and rank decision alternatives when this method is used. Lithuanian as well as foreign scientists have been applying the original or expanded method for solving different construction and engineering multi-attribute problems in the period of 1996–2012 (Mazumdar *et al.*, 2010; Podvezko *et al.*, 2010; Chatterjee *et al.*, 2011; Chatterjee, Chakraborty, 2012; Maity *et al.*, 2012; et. al.), management capabilities within the construction sector in a time of crisis (Kildiene *et al.*, 2011) or evaluating building renovation decisions (Medineckiene, Björk, 2011). The paper of Ginevicius and Podvezko analysed quantitative evaluation of the relationship between housing, the level of economic development and social environment of particular regions that requires the integration of all criteria describing housing both quantitatively and qualitatively into a single criterion. This was achieved by using the COPRAS method (Ginevicius, Podvezo, 2008). Banaitiene *et al.* (2008) considered the multivariant design and multiple criteria analysis of the life cycle of a building. In the above paper the theoretical basis of the methodology was developed. A proposed methodology allows everyone (i.e. client, investor, contractor, etc.), who has to make the decisions, to design alternatives of the building life cycle and to evaluate its qualitative and quantitative aspects. The procedure of the evaluating of a building's life cycle was discussed using an example and applying COPRAS method. The paper (Zavadskas *et al.*, 2009a) presented the comparative analysis of dwelling maintenance contractors aimed at determining the degree of their utility for users and bidding price of services by applying the above method.

Some other authors have been applying modified COPRAS method. If the type of uncertainty relating to incomplete and inconsistent information needs to be considered, it is referred to as fuzzy uncertainty. The theory of fuzzy sets can be used when working with imprecise data and solving multiple criteria decision-making problems (Triantaphyllou, Lin, 1996). Consequently, Zavadskas and Antucheviciene (2007) applied fuzzified method (COPRAS-F) and performed a multiple criteria analysis of abandoned building's regeneration alternatives in Lithuanian rural areas. Priorities of alternatives and utility degrees were determined. Recommendations considering sustainable reuse of buildings were suggested. Zavadskas *et al.* (2008a) analyzed alternative solutions of external walls and wall insulation as well as estimated effective variants of walls. The paper considered the application of grey relations methodology for defining the utility of an alternative and was proposed as a method of multiple criteria complex proportional assessment of alternatives with Grey relations (COPRAS-G). In the paper (Zavadskas *et al.*, 2008b) the model based on multiple criteria evaluation of project managers was proposed. This paper considered the application of grey relations methodology to define the utility of alternatives and offered COPRAS-G method for analysis. The model of the above method was presented as well as the application for construction contractor selection was demonstrated in (Zavadskas *et al.*, 2009b). Datta *et al.* (2009) used the compromise ranking method with grey numbers for supervisor selection. The compromise ranking method with grey numbers was also used by Bindu Madhuri *et al.* (2010); Bindu Madhuri, Anand Chandulal (2010).

Compromise ranking method VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje in Serbian, which means Multicriteria Optimization and Compromise Solution) was developed and presented by Opricovic (1998) as well as Opricovic, Tzeng (2004). VIKOR and TOPSIS methods were compared (Opricovic, Tzeng, 2007). According to Opricovic and Tzeng, the values normalized by vector normalization and applied in TOPSIS may depend on the evaluation unit. Moreover, these two methods introduce different aggregating functions for ranking. The considered compromise ranking method introduces a concept of relative importance of the criteria and a balance between total and individual satisfaction, while the distances from the ideal and negative-ideal points in the technique for order preference by similarity to ideal solution are simply summed, without considering their relative importance. Therefore, the authors of the current paper suggested applying the VIKOR method for ranking redevelopment alternatives of derelict buildings. In (Antucheviciene, Zavadskas,

2008) a case study was presented and redevelopment problems relating to derelict buildings in Lithuanian rural areas were analyzed by the proposed techniques. The VIKOR-F method has been developed to solve fuzzy multiple criteria problem with conflicting and noncommensurable criteria (Opricovic, 2007). Also in recent years there were some more publications where VIKOR or VIKOR-F was applied for some management decisions, for example supplier selection under fuzzy environment was held in (Sanayei *et al.*, 2010; Sasikumar, Haq, 2011).

However, combination of VIKOR with some other MCDM methods has been more often applied and handling of a proper MCDM technique has been discussed. Ginevicius *et al.* (2008) applied COPRAS, TOPSIS and VIKOR and some other methods for analysing alternative solutions of external walls and wall insulation. Correlation coefficients were calculated between final values of alternatives obtained by SAW (Simple Additive Weighing) and other MCDM methods under consideration. Selection of proper methods considering their advantages and disadvantages in qualitative manner was discussed for multiple criteria evaluation of real estate projects' efficiency in (Ginevicius, Zubrecovas, 2009). Also for sustainable development problems Ginevicius, Podvezko (2009) used multiple criteria evaluation methods that took into consideration the major aspects of economic, social and environmental development of the region as well as multidimensional character of the development criteria. COPRAS and TOPSIS methods were applied among others. In order to determine the ultimate rank of the region the authors simply took the average estimate of the values obtained in applying all the considered methods. TOPSIS and VIKOR were applied for evaluating of environment of enterprises (Ginevicius *et al.*, 2010). The paper of Tupenaite *et al.* (2010) described the concept of the integrated analysis of built and human environment renovation and presented the multiple criteria assessment of alternatives of renovation projects applying several MCDM methods, including TOPSIS and COPRAS. The Comparative Analysis of SAW and COPRAS was carried out by Podvezko (2011). The current multiple criteria evaluation method was combined with the analytic hierarchy process in Tsai *et al.* (2011); Fu *et al.*, (2011) papers. IC, Yurdakul (2010) compared results of decision support system based on TOPSIS-F with experts' opinion. Spearman's correlation was used for that purpose. Hajkowicz, Higgins (2008) applied some other multiple criteria assessment methods to water management decision problems and showed that different methods were in strong agreement with high correlations amongst rankings.

The aim of the current research is to measure objective congruence (incongruence) as well as consistency (inconsistency) of the results obtained in a process of multiple criteria analysis when applying different MCDM methods. The methodology for evaluation of ranking results is developed on the ground of a case study of derelict buildings' redevelopment in Lithuania as well as on composed experimental tasks. Calculation results are evaluated by applying mathematical statistics methods. A new methodology for measuring the congruence (incongruence) of the relative significances of buildings' redevelopment alternatives is proposed. As well as criteria of consistency (inconsistency) of the results are developed and applied. The above methodology is applicable for analyzing the results of different multi-attribute tasks.

3. Redevelopment decisions of derelict buildings: a case study of Lithuania

Revitalization of derelict and mismanaged buildings in rural areas of Lithuania is analyzed and multiple criteria evaluation of building redevelopment decisions is presented in the current chapter. These structures were built during the Socialist Years, mostly for farming and, partly, for rural infrastructure. Due to political and economic changes as well as restructuring of the agricultural sector, they have become derelict and are mismanaged at present. Today, many of rural buildings, due to their large parameters, energy susceptibility, and technological and economic depreciation do not meet contemporary production requirements. These buildings are not used for any kind of activity and many of them are in a poor state. Large investments are required to make these objects useful. Such contaminated and abandoned sites are negatively influencing the environment and landscape, threatening people's safety and wasting the full potential of the immovable property as they decay further and irreversibly. Therefore, there is an urgent need for redevelopment of buildings.

Accordingly, based to the theoretical assumptions and a study of the existing situation as presented in previous papers of the authors (Zavadskas, Antucheviciene, 2006, 2007; Antucheviciene, Zavadskas, 2008), three potential alternative decisions for the regeneration of rural property are suggested and implicated in the future multiple criteria evaluation. The alternatives include reconstruction of rural buildings and adapting them to production (or commercial) activities (alternative A_1), improving and using them for farming (alternative A_2) or dismantling and recycling the demolition waste materials (alternative A_3).

The second stage is to develop the system of criteria, describing the suggested alternatives. The authors use sustainable development approach for identifying rational development trends of abandoned rural buildings. For this purpose, a model of an indicator system and a set of criteria were developed according to the principles of sustainable construction and sustainable development. The component systems of the model involved the environmental impact of derelict, renovated or dismantled buildings, the economic benefits and changes in the local population's quality of life after the implementation of restoration variants and the outlook of business namely, i.e. three groups of criteria (indicators), based on classification of the indicators according to the typology, were suggested: existing *state*, *development possibilities* and *impact*. All suggested subsystems consisted of a number of indicators and were selected from the available and approved sustainability indicator systems and then adapted to local singularities and to the peculiarities of the problem (see the previous research of the authors (Antucheviciene, Zavadskas 2008; Zavadskas, Antucheviciene 2006, 2007)).

The following fifteen criteria (or sustainability indicators) in evaluating a building's regeneration alternatives have been taken into consideration, including the average soil fertility in the area X_1 (points), quality of life of the local population X_2 (points), population activity index X_3 (%), GDP proportion with respect to the average GDP of the country X_4 (%), material investment in the area X_5 (Lt per resident), foreign investments in the area X_6 (Lt×10^3 per resident), building redevelopment costs X_7 (Lt ×10^6), increase of the local population's income X_8 (Lt×10^6 per year), increase of sales in the area X_9 (%), increase of employment in the area X_{10} (%), state income from business and property taxes X_{11} (Lt×10^6 per year), business outlook X_{12}, difficulties in changing the original purpose of a site X_{13}, degree of contamination X_{14}, attractiveness of the countryside (i.e. image, landscape, etc.) X_{15}. Among the criteria considered X_2, X_7, X_{13} and X_{14} are associated with cost/loss and so their lower value is better, while the remaining criteria are associated with benefit and their greater value is better.

Data is presented as the decision matrix F, which refers to n alternatives that are evaluated in terms of m criteria. The system of criteria and alternatives as well as the initial values and weights of criteria are determined.

Suppose, there is the initial decision-making matrix:

$$F = \begin{pmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{pmatrix}, \tag{1}$$

where m is a number of criteria and n is a number of alternatives. The member f_{ij} denotes the performance measure of the j-th alternative in terms of the i-th criterion, $i = 1, \ldots, m; j = 1, \ldots, n$.

The values of the criteria f_{ij}, $i = 1, \ldots, m; j = 1, \ldots, n$ are estimated according to official statistical data and on the basis of previous research by the authors.

However, the decision requires the fusion of internal, external, objective, subjective, quantitative and qualitative variables (Ulubeyli *et al.*, 2010; Plebankiewicz, 2010; Balezentis, Balezentis, 2011). Same data can be represented in ordinary real numbers, whereas other data can be obtained only in linguistic form. Considering the fuzziness of the available data and the decision-making procedures, fuzzy numbers are used to assess the values of all criteria and provide the relative significances of each alternative with respect to each criterion. Moreover, fuzzy sets and fuzzy logic are powerful mathematical tools for modeling uncertain systems (Badescu *et al.*, 2010; Turskis, Zavadskas, 2010a, 2010b). Fuzzy number can store a wide variety of information (Behret, Kahraman, 2010; Zhang, Liu, 2010).

Hereby, we can convert the decision making matrix (1) into a fuzzy decision making matrix (Chen, 2000; Triantaphyllou, Lin, 1996).

The triangular fuzzy numbers are used for fuzzy numbers in the current paper. A triangular fuzzy number $\tilde{f}$ can be defined by a triplet (f_1, f_2, f_3).

The membership function $\mu_{\tilde{f}}$ of $\tilde{f}$ is defined as (Hwang, Yoon, 1981; Sanayei *et al.*, 2010):

$$\mu_{\tilde{f}}(x)=\begin{cases}0, x<f_1,\\ \dfrac{x-f_1}{f_2-f_1}, (f_1\le x\le f_2),\\ \dfrac{x-f_3}{f_2-f_3}, (f_2\le x\le f_3),\\ 0, x>f_3.\end{cases} \tag{2}$$

As the crisp data is fuzzyfied at the presented research, the lower and the upper values of a triplet $(f_{1_{ij}}; f_{2_{ij}}; f_{3_{ij}})$, $i = 1, \ldots, m; j = 1, \ldots, n$ of the *state* criteria are set according to the best and the worst possible values in the area considered, enabling one to determine smaller characteristic segments in the research, while both the above-mentioned values of the *development possibilities* and the *impact* criteria are established by considering the range of buildings to be redeveloped, minimum and maximum cost of alternative solutions' implementation, presumptive limits of possible workplaces and income, possible alterations of landscape quality and environmental contamination.

Development possibilities and the impact criteria are considered to be of equal importance, while weights are determined for state criteria. The weights q_i, $i = 1, \ldots, m$; $j = 1, \ldots, n$ are determined according to the estimated statistical relations between factors in the course of the correlation analysis (Antucheviciene, 2003).

The data is grouped in three regions according to a concept of the country's spatial development: i.e. areas of active development, areas of regressing development and 'buffer' areas. The largest amount of facilities, the greatest variety of activities and the maximum internal as well as foreign investment was found to be characteristic of areas with active development. The largest cities, the main industrial, scientific, cultural and facilities centers as well as major highways were found to be located in the above-mentioned territories, and in contradistinction to areas of regressive development. The economic basis of areas with regressing development includes agricultural, forestry and recreational activities. Such areas cover the northern-eastern and southern parts of Lithuania. 'Buffer' areas take a middle place according to the characteristic of activity, geographical and environmental situation and the peculiarities of the local population. They are also situated in territories that are not strongly influenced by the largest cities.

Matrices of initial data for evaluation of derelict buildings redevelopment alternatives in areas of different development activity applying fuzzy MCDM is presented in Tables 1–3.

Ranking of building redevelopment alternatives is made according to solutions suggested by the Master Plan of the Territory Development of the Republic of

Lithuania, which aims at forming and implementing national social, economic and ecological policy by 2020 and is based on the principles of sustainable development. The two main strategies presented in the Master Plan, that refer to the *maintenance of the existing economic potential of a region* and the *harmonization of regional development*, and are evaluated in linguistic terms are shown in Table 4, with reference to (Zavadskas, Antucheviciene, 2007).

The qualitative attributes X_{12}, X_{13}, X_{14} and X_{15} and their ratings (Tables 1–3) as well as redevelopment strategies (Table 4) are expressed by linguistic variables, as used in fuzzy decision-making (Zadeh, 1975). The relations between linguistic variables and triangular fuzzy numbers as applied in the current paper are given in Table 5.

Table 1. Initial data for derelict buildings regeneration in areas of active development

Criteria	Units of measure	*	Weights	Value of criteria $(f_{ij_1}; f_{ij_2}; f_{ij_3})$		
				Alternative A_1	Alternative A_2	Alternative A_3
Quantitative criteria						
X_1	points	+	0.0600	(30.9; 39.9; 50.0)	(30.9; 39.9; 50.0)	(30.9; 39.9; 50.0)
X_2	points	-	0.0727	(39.3; 31.7; 23.1)	(39.3; 31.7; 23.1)	(39.3; 31.7; 23.1)
X_3	percent	+	0.0747	(39.8; 51.7; 68.1)	(39.8; 51.7; 68.1)	(39.8; 51.7; 68.1)
X_4	percent	+	0.0627	(73.9; 98.4; 137.3)	(73.9; 98.4; 137.3)	(73.9; 98.4; 137.3)
X_5	Lt×10^3 per resident	+	0.0673	(552.0; 1304.0; 3561.0)	(552.0; 1304.0; 3561.0)	(552.0; 1304.0; 3561.0)
X_6	Lt×10^3 per resident	+	0.0627	(73.2; 1028.7; 4160.0)	(73.2; 1028.7; 4160.0)	(73.2; 1028.7; 4160.0)
X_7	Lt×10^6	-	0.0667	(766.1; 273.6; 35.6)	(144.9; 59.4; 28.5)	(20.2; 14.4; 8.6)
X_8	Lt×10^6 per year	+	0.0667	(31.1; 69.1; 241.9)	(7.8; 25.9; 48.4)	(0.3; 0.4; 1.2)
X_9	percent	+	0.0667	(2.3; 14.0; 39.1)	(0.7; 2.2; 4.7)	(0; 0; 0)
X_{10}	percent	+	0.0667	(2.1; 3.4; 9.6)	(0.5; 1.7; 2.4)	(0; 0; 0)
X_{11}	Lt×10^6 per year	+	0.0667	(8.6; 21.6; 50.4)	(2.2; 5.4; 10.1)	(0.1; 0.2; 0.5)
Qualitative criteria						
X_{12}	linguistic	+	0.0667	very good	poor	good
X_{13}	linguistic	-	0.0667	very difficult	very light	difficult
X_{14}	linguistic	-	0.0667	hard	fair	very light
X_{15}	linguistic	+	0.0667	good	fair	poor

* The sign + (-) indicates that accordingly higher (lower) value of criteria conforms to customer's requirements

Table 2. Initial data for derelict buildings regeneration in areas of regressing development

Criteria	Units of measure	*	Weights	Value of criteria $(f_{ij_1}; f_{ij_2}; f_{ij_3})$		
				Alternative A_1	Alternative A_2	Alternative A_3
Quantitative criteria						
X_1	points	+	0.0740	(31.1; 34.8; 44.3)	(31.1; 34.8; 44.3)	(31.1; 34.8; 44.3)
X_2	points	-	0.0613	(37.78; 29.1; 20.78)	(37.78; 29.1; 20.78)	(37.78; 29.1; 20.78)
X_3	percent	+	0.0626	(47.1; 55.9; 66.2)	(47.1; 55.9; 66.2)	(47.1; 55.9; 66.2)
X_4	percent	+	0.0613	(79.5; 94.7; 137.3)	(79.5; 94.7; 137.3)	(79.5; 94.7; 137.3)
X_5	Lt×10^3 per resident	+	0.0740	(212.0; 962.9; 3504.0)	(212.0; 962.9; 3504.0)	(212.0; 962.9; 3504.0)
X_6	Lt×10^3 per resident	+	0.0673	(8.14; 833.1; 3550.5)	(8.14; 833.1; 3550.5)	(8.14; 833.1; 3550.5)
X_7	Lt×10^6	-	0.0666	(667.3; 238.6; 31.0)	(100.1; 51.8; 24.8)	(17.6; 12.6; 7.6)
X_8	Lt×10^6 per year	+	0.0666	(27.1; 60.3; 210.7)	(6.8; 22.6; 42.1)	(0.2; 0.4; 1.1)
X_9	percent	+	0.0666	(12.7; 75.8; 212.1)	(3.6; 12.1; 25.4)	(0; 0; 0)
X_{10}	percent	+	0.0666	(1.6; 2.6; 7.3)	(0.4; 1.3; 1.8)	(0; 0; 0)

X_{11}	Lt×10^6 per year	+	0.0666	(7.5; 22.0; 43.9)	(1.9; 4.7; 8.8)	(0.1; 0.2; 0.4)
Qualitative criteria						
X_{12}	linguistic	+	0.0666	poor	fair	very poor
X_{13}	linguistic	-	0.0666	fair	very light	very light
X_{14}	linguistic	-	0.0666	fair	very light	very light
X_{15}	linguistic	+	0.0666	good	good	fair

* The sign + (-) indicates that accordingly higher (lower) value of criteria conforms to customer's requirements

Table 3. Initial data for derelict buildings regeneration in "buffer" areas

Criteria	Units of measure	*	Weights	Value of criteria $\left(f_{ij_1}; f_{ij_2}; f_{ij_3}\right)$		
				Alternative A_1	Alternative A_2	Alternative A_3
Quantitative criteria						
X_1	points	+	0.0553	(30.4; 40.0; 48.2)	(30.4; 40.0; 48.2)	(30.4; 40.0; 48.2)
X_2	points	-	0.0567	(32.9; 30.3; 26.8)	(32.9; 30.3; 26.8)	(32.9; 30.3; 26.8)
X_3	percent	+	0.0833	(47.3; 55.8; 61.2)	(47.3; 55.8; 61.2)	(47.3; 55.8; 61.2)
X_4	percent	+	0.0553	(59.9; 78.1; 97.8)	(59.9; 78.1; 97.8)	(59.9; 78.1; 97.8)
X_5	Lt×10^3 per resident	+	0.0747	(356.5; 663.5; 1398.6)	(356.5; 663.5; 1398.6)	(356.5; 663.5; 1398.6)
X_6	Lt×10^3 per resident	+	0.0747	(0.41; 244.0; 607.8)	(0.41; 244.0; 607.8)	(0.41; 244.0; 607.8)
X_7	Lt×10^6	-	0.0667	(808.6; 288.8; 37.6)	(121.3; 62.7; 30.1)	(21.3; 15.2; 9.1)
X_8	Lt×10^6 per year	+	0.0667	(32.8; 73.0; 255.4)	(8.2; 27.4; 51.1)	(0.3; 0.5; 1.3)
X_9	percent	+	0.0667	(14.4; 85.5; 239.3)	(4.1; 13.7; 28.7)	(0; 0; 0)
X_{10}	percent	+	0.0667	(23.0; 3.8; 10.6)	(0.6; 1.9; 2.7)	(0; 0; 0)
X_{11}	Lt×10^6 per year	+	0.0667	(9.1; 26.6; 53.2)	(2.3; 5.7; 10.6)	(0.1; 0.2; 0.5)
Qualitative criteria						
X_{12}	linguistic	+	0.0667	fair	poor	poor
X_{13}	linguistic	-	0.0667	very difficult	very light	fair
X_{14}	linguistic	-	0.0667	light	very light	very light
X_{15}	linguistic	+	0.0667	very good	fair	very good

* The sign + (-) indicates that accordingly higher (lower) value of criteria conforms to customer's requirements

Based on presented initial data (Tables 1–3) and described methodology of the research, six initial fuzzified decision making matrices are formed, i.e. potential redevelopment decisions are evaluated separately in three areas of different development activity as well as two development strategies, as presented in Table 4, are considered.

After the initial data is prepared, calculations are performed applying fuzzified TOPSIS based on vector (Hwang, Yoon, 1981; Zavadskas *et al.*, 1994; Triantaphyllou, 2000) as well as linear normalization (Lai, Hwang, 1994) of initial criteria values, COPRAS (Zavadskas, Kaklauskas, 1996) and VIKOR (Opricovic, Tzeng, 2004) methods.

Concerning the peculiarities of this study where the crisp ranking methods have been applied, a defuzzification was performed. Various methods of defuzzification are available. In this research the center-of-area method was applied (Van Leekwijck, Kerre, 1999). The defuzzified value of a fuzzy number was obtained by applying the equation:

$$BNP = \left[\left(f_3 - f_1\right) + \left(f_2 - f_1\right)\right]/3 + f_1, \quad (3)$$

where BNP is the Best Non-fuzzy Performance value, f_2 is a mode, f_1 and f_3 are the lower and the upper limits of fuzzy triangular number $\tilde{f}$, respectively.

Final multiple criteria analysis results obtained for Lithuanian derelict rural building regeneration alternatives in areas of diverse development activities after the implementation of two main strategies for the regional policy and applying different MCDM methods are presented in Table 6.

Table 4. Linguistic evaluation of redevelopment strategies

Alternatives	Areas of active development	Areas of regressing development	'Buffer' areas
Maintenance of existing economic potential in a region			
A_1	very good	poor	good
A_2	poor	very good	good
A_3	very good	good	fair
Harmonization of regional development			
A_1	very good	very good	very good
A_2	fair	poor	very good
A_3	poor	very good	fair

Table 5. The relations between linguistic variables and triangular fuzzy numbers

Linguistic variables	Triangular fuzzy numbers
Very poor (very light)	(0; 0.1; 0.2)
Poor (light)	(0.2; 0.3; 0.4)
Fair	(0.4; 0.5; 0.6)
Good (difficult)	(0.6; 0.7; 0.8)
Very good (very difficult)	(0.8; 0.9; 1)

Table 6. Results of multiple criteria analysis

MCDM method	Significance of alternatives			Priority order
	A_1	A_2	A_3	
➢ Areas of active development				
Maintenance of existing economic potential in a region				
TOPSIS-F vector normalization	0.61	0.41	0.36	$A_1 \succ A_2 \succ A_3$
TOPSIS-F linear normalization	0.62	0.42	0.37	$A_1 \succ A_2 \succ A_3$
COPRAS-F	0.52	0.24	0.23	$A_1 \succ A_2 \approx A_3$
VIKOR-F	0.38	0.36	1.00	$A_2 \approx A_1 \succ A_3$
Harmonization of regional development				
TOPSIS-F vector normalization	0.53	0.49	0.36	$A_1 \succ A_2 \succ A_3$
TOPSIS-F linear normalization	0.49	0.54	0.37	$A_2 \succ A_1 \succ A_3$
COPRAS-F	0.35	0.36	0.29	$A_2 \approx A_1 \succ A_3$
VIKOR-F	0.65	0.00	1.00	$A_2 \succ A_1 \succ A_3$
➢ Areas of regressing development				
Maintenance of existing economic potential in a region				
TOPSIS-F vector normalization	0.50	0.56	0.46	$A_2 \succ A_1 \succ A_3$
TOPSIS-F linear normalization	0.46	0.64	0.48	$A_2 \succ A_3 \approx A_1$

COPRAS-F	0.28	0.44	0.29	$A_2 \succ A_3 \approx A_1$
VIKOR-F	1.00	0.00	0.64	$A_2 \succ A_3 \succ A_1$
Harmonization of regional development				
TOPSIS-F vector normalization	0.61	0.45	0.46	$A_1 \succ A_3 \approx A_2$
TOPSIS-F linear normalization	0.62	0.46	0.48	$A_1 \succ A_3 \approx A_2$
COPRAS-F	0.50	0.26	0.24	$A_1 \succ A_2 \approx A_3$
VIKOR-F	0.00	1.00	0.45	$A_1 \succ A_3 \succ A_2$
➢ "Buffer" areas				
Maintenance of existing economic potential in a region				
TOPSIS-F vector normalization	0.59	0.43	0.38	$A_1 \succ A_2 \succ A_3$
TOPSIS-F linear normalization	0.47	0.37	0.53	$A_3 \succ A_1 \succ A_2$
COPRAS-F	0.44	0.31	0.24	$A_1 \succ A_2 \succ A_3$
VIKOR-F	0.67	1.00	0.00	$A_3 \succ A_1 \succ A_2$
Harmonization of regional development				
TOPSIS-F vector normalization	0.61	0.47	0.36	$A_1 \succ A_2 \succ A_3$
TOPSIS-F linear normalization	0.64	0.55	0.35	$A_1 \succ A_2 \succ A_3$
COPRAS-F	0.45	0.31	0.24	$A_1 \succ A_2 \succ A_3$
VIKOR-F	0.00	0.17	1.00	$A_1 \succ A_2 \succ A_3$

The established regeneration peculiarities of derelict rural buildings in Lithuania demonstrate that the same solution is hardly suitable to any building and for the whole territory of the country. The results of multiple criteria analysis, according to the concept of the country's spatial development, presented in the Master Plan of the territorial development of Lithuania, outline the possible differences of building restorations in particular areas of the country.

Moreover, it is found that relative significances and even the priority order of alternatives is not always the same for a particular region when different above methods are applied. Consequently, a comparative analysis of results is performed.

4. Comparison and analysis of ranking results

According to calculation results as presented in Table 6 we can formulate six conclusions concerning rural building redevelopment in Lithuania, i.e. different recommendations can be made in three areas of different development activity and applying two redevelopment strategies in every area. However, when analysing multiple criteria evaluation of alternatives, one can observe that relative significances of alternatives and sometimes even the priority order of redevelopment alternatives differs when several MCDM methods are applied. The aim of the presented case study is to determine priorities as well as to produce some recommendations concerning rational redevelopment of buildings. For the above reason particular relative significances of alternatives Q_j, $j = 1, \ldots, n$ are not analyzed in detail. The main attention is paid to priority orders of alternatives, established by applying different MCDM methods.

Congruence (incongruence) of ranks that were computed by using different MCDM methods is measured as well as consistency (inconsistency) of results is analysed further in the paper. A methodology for measuring the congruence (incongruence) of the relative significances of buildings' management alternatives is developed and presented.

4.1. Evaluation of congruence (incongruence) of ranking results

Correlation coefficients are calculated and objective congruence (incongruence) of ranks that were computed by using different MCDM methods is measured. In order to increase the reliability of correlation analysis, 234 experimental variants of building redevelopment initial decision making matrixes are composed. Multiple criteria analysis of described experimental variants is performed applying all analyzed methods (COPRAS-F, TOPSIS-F based on vector as well as linear normalization of initial criteria values and VIKOR-F). Calculation results are compared.

Method of non-parametrical correlation is applied to measure statistical relation of ranks of alternatives that were computed by using different MCDM methods (Raju, Pillai, 1999; Sarkis, 2000; Yurdakul, IC, 2009; Raju, Kumar, 2010). Spearman's rank correlation coefficients are calculated for the ranks provided by every pair of the applied fuzzified multiple criteria decision making methods.

In the case if x_j and y_j are ranks of the same alternative $f_j, j = 1,...,n$ that are obtained by using two different MCDM methods, Spearman's rank correlation coefficient r_s is calculated as follows (Aivazian, Mkhitarian, 1998):

$$r_s = \frac{\sum_{j=1}^{n}\left(x_j - \frac{n+1}{2}\right)\left(y_j - \frac{n+1}{2}\right)}{\sqrt{\sum_{j=1}^{n}\left(x_j - \frac{n+1}{2}\right)^2}\sqrt{\sum_{j=1}^{n}\left(y_j - \frac{n+1}{2}\right)^2}}. \quad (4)$$

In the case if all values of x_j and y_j are different, Spearman's rank correlation coefficient r_s can be calculated applying the Equation (5) (Raju, Kumar, 2010):

$$r_s = 1 - \frac{6\sum_{j=1}^{n} d_j^2}{n\left(n^2 - 1\right)}, \quad (5)$$

where $d_j = x_j - y_j$.

Spearman's correlation coefficient is similar to Pirson's correlation coefficient. Spearman's correlation coefficient differs only because relations are calculated not among values of variables themselves, but among ranks of variables. Accordingly, the current coefficient best fits the aim of the presented research, because the aim of this research is to compare priorities (ranks) of alternative decisions obtained in a process of multiple criteria analysis when applying different MCDM methods.

Confidence intervals of correlation coefficients with the probability $p = 1 - q$ (Aivazian, Mkhitarian, 1998) are as follows:

$$r_s + t_q \times m_r \leq r_s \leq r_s - t_q \times m_r \ , \tag{6}$$

where t_q is a multiplier depending on the normal distribution law of errors, on the credibility level q and on the number of members in the sample n; m_r are mean square errors of calculated correlation coefficients:

$$m_r = \frac{1 - r_s^{\ 2}}{\sqrt{n}}, \tag{7}$$

where n is the number of members in the sample.

Accordingly we can state that true values of Spearman's correlation coefficients with the probability $p = 1 - q$ are obtained within the limits of Eq. 6.

Spearman's rank correlation coefficients are calculated (Eq. 4) for the ranks provided by every possible pairs of the applied multiple criteria decision making algorithms. It is found that all correlation coefficients are statistically significant with the probability of 95 percent. Accordingly, we can state that the ranks in the every pair of compared methods have statistically significant relations. There are any cases identified without statistical relationship among priorities of decision alternatives when comparing in pairs the outcomes of the particular methods.

Empirical Pirson's correlation coefficients of particular comparative variants are calculated in order to check the results. Incongruence of empirical correlation coefficients and Spearman's rank correlation coefficients is not higher than 10 percent in all analyzed cases. The average incongruence is 4 percent.

Confidence intervals of correlation coefficients with the credibility levels q_1 = 0.05 and q_2 = 0.01 are calculated according to Eq. (6–7). Some kind of analysis with the credibility level of q_1 = 0.05 was presented in a paper of Antucheviciene *et al*. (2011). While, two credibility levels are analyzed in the current research. The particular credibility levels are applied to reduce the probability of "the first kind" and "the second kind" errors (Aivazian, Mkhitarian, 1998). The less is the level of credibility, the less is probability to reject random values that meet the hypothesis, respectively. Accordingly, the less is the level of credibility, the less is probability to reject correlation coefficients, because they fall into the confidence interval. That means the less probability of "the first kind" error. But, on the other hand, sensibility of the function decreases if credibility level is increased. The range of allowable values increases and probability of "the second kind" error increases, respectively. It means that the availability to embrace not suitable values to the confidence interval increases.

For the reason above, two kinds of confidence intervals with two different credibility levels are calculated: q_1 = 0.05 and q_2 = 0.01. Calculation results are presented in Fig. 1. There we can observe that some of the results have higher rank correlation relationship and some have the lower one when a particular pairs of multiple criteria decision making methods are analyzed.

Priorities of alternatives, computed by TOPSIS-F method, applying vector as well as linear normalization methods to eliminate the units of the criteria values, provide the stronger statistical relations. However, the results are not identical and congruence of 100 percent is not observed. The value of Spearman's rank correlation coefficient is high enough (0.83) and is statistically significant, but not equals to 1. Consequently, experimental calculations prove the theoretical presumption that normalization methods applied to eliminate the units of the criteria values influence the final ranking results.

TOPSIS-F and COPRAS-F ranking results also have significant relations. Correlation coefficients are 0.58 and 0.54, applying vector and linear normalization, respectively.

The lowest correlation relation is established when congruence (incongruence) of COPRAS-F and VIKOR-F methods is analyzed. Estimated Spearman's rank correlation coefficient is 0.36.

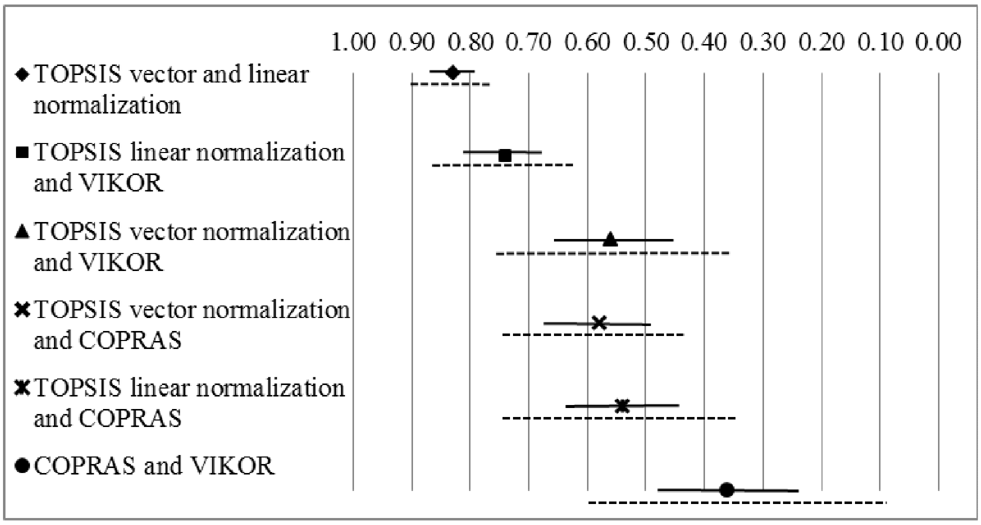

Figure 1. Rank correlation coefficients and confidence intervals with the credibility level $q_1 = 0.05$ and $q_2 = 0.01$.

The above Spearman's rank correlation coefficients are calculated with a particular level of credibility. We can state that the real values of Spearman's rank correlation coefficients are within the limits of confidence intervals that are defined according to Eq. (6) with the probability $p = 1 - q$. In Fig. 1 we can observe that the major part of confidence intervals overlap, especially in a case of credibility level q_2=0.01. Then the question arises if rank correlation coefficients of particular pairs of MCDM methods are really different. Are the calculated differences significant? The above dilemma is solved by the authors not by subjective evaluation but applying methods of mathematical statistics as presented further in the paper.

Statistical identity (or nonidentity) of values of correlation coefficients, calculated for N_1, N_2, …, N_s samples of data pairs, is checked not only based on confidence intervals according to Eq. 6, but also applying statistics (Aivazian, Mkhitarian, 1998):

$$V = \sum_{i=1}^{s} z_i^2 \left(N_i - 3\right) + \frac{\left(\sum_{i=1}^{s} z_i \left(N_i - 3\right)\right)^2}{\sum_{i=1}^{s} \left(N_i - 3\right)}, \tag{8}$$

where z is Fisher's transformation:

$$z_i = \frac{1}{2} \times \ln \frac{1 + r_i}{1 - r_i}. \tag{9}$$

Hypothesis that all correlation coefficients, calculated for particular samples of data pairs, are identical with the probability $p = 1 - q$ (i. e. calculated incongruence is within the limits of random errors) can be accepted in a case if

$$V \le \chi^2_{k,q}, \tag{10}$$

where $\chi^2_{k,q}$ – Pirson's distribution with the credibility q and $k = s - 1$ degrees of freedom, where s – number of compared correlation coefficients.

Overall Fisher's transformation of correlation set (Eq. 9) is calculated as follows:

$$\bar{z} = \frac{\sum_{i=1}^{s} z_i \left(N_i - 3\right)}{\sum_{i=1}^{s} \left(N_i - 3\right)}. \tag{11}$$

Value r of correlation coefficient generalized for all correlation set is calculated according to Eq. 9.

Calculations are made applying Eq. (8 – 11). First of all, Spearman's rank correlation coefficients as calculated for six pairs of data samples are compared, i.e. r_1 – TOPSIS-F, applying vector, and TOPSIS-F, applying linear normalization; r_2 – TOPSIS-F, linear normalization, and VIKOR-F; r_3– TOPSIS-F, vector normalization, and VIKOR-F; r_4 – TOPSIS-F, vector normalization, and COPRAS-F; r_5 – TOPSIS-F, linear normalization, and COPRAS-F; r_6 – COPRAS-F and VIKOR-F.

Hypothesis that all six correlation coefficients are identical, i.e. calculated incongruence is within the limits of random errors, is not accepted after calculations, because requirement according to Eq. (10) is not fulfilled.

As the primary hypothesis was not accepted, the research is proceeded by variously grouping calculated correlation coefficients and verifying the hypothesis. The main results of the current research are presented in Table 7.

First of all, correlation coefficient with the lower value is eliminated, showing connections between VIKOR-F and TOPSIS-F results. Correlation coefficient for an entire set slightly increases (from 0.63 to 0.67), but the hypothesis is still unaccepted.

Then the authors intended to eliminate the results of evaluation of derelict rural buildings redevelopment alternatives applying VIKOR-F method. Therefore all coefficients describing relations with VIKOR-F results are rejected in the next step of calculation. But any positive effect is observed. Correlation coefficient for an entire set remains the same (0.67).

Connections of COPRAS-F results with the results of other analyzed methods are checked in the next step. For that reason calculations are performed using all correlation coefficients showing statistical connections between COPRAS-F and the other three methods (TOPSIS-F with vector as well as linear normalization and VIKOR-F). We can state that correlation coefficients are different with the credibility level $q_1 = 0.05$. But with the credibility level $q_2 = 0.01$ the hypothesis can be accepted. The conclusion is that COPRAS-F results when evaluating ranks of alternatives have the same correlations with ranking results of TOPSIS-F and VIKOR-F with the probability $p = 1 - q_2$.

In a case when VIKOR-F method is eliminated, the hypothesis concerning congruence of Spearman's rank correlation coefficients between COPRAS-F and TOPSIS-F results is accepted with the credibility levels $q_1 = 0.05$ and $q_2 = 0.01$. The results are more reliable when comparing with the previously analyzed case, because the probability of "the first kind" error is small and the probability of "the second kind" error also decreases.

Table 7. Hypothesis testing: congruence of correlation coefficients and estimating correlation coefficient generalized for an entire correlation set

Correlation coefficients r_i	Statistics V	Credibility level q	$\chi^2_{k,q}$	Fisher's transformation $\bar{z}$	Correlation for an entire set r
$r_1 = 0.83$ $r_2 = 0.74$ $r_3 = 0.56$ $r_4 = 0.58$ $r_5 = 0.54$ $r_6 = 0.36$	85.77	0.05 0.01	11.07 15.09	0.75	0.63
$r_1 = 0.83$ $r_2 = 0.74$ $r_3 = 0.56$	57.05	0.05 0.01	9.48 13.28	0.81	0.67

$r_4 = 0.58$ $r_5 = 0.54$					
$r_1 = 0.83$ $r_4 = 0.58$ $r_5 = 0.54$	47.80	0.05 0.01	5.99 9.21	0.82	0.67
$r_4 = 0.58$ $r_5 = 0.54$ $r_6 = 0.36$	**8.91**	0.05 **0.01**	5.99 **9.21**	0.56	0.51
$r_4 = 0.58$ $r_5 = 0.54$	**0.39**	**0.05** **0.01**	**3.84** **6.64**	0.63	0.56
$r_1 = 0.83$ $r_2 = 0.74$ $r_3 = 0.56$	31.20	0.05 0.01	5.99 9.21	0.94	0.74

Also, an attempt to eliminate COPRAS-F method is made. Spearman's rank correlation coefficients between ranks in TOPSIS and VIKOR methods are compared. Unfortunately, the hypothesis concerning congruence of coefficients is not accepted.

The general conclusion based on the research is that Spearman's rank correlation coefficients between ranking results of COPRAS-F and TOPSIS-F methods (using vector as well as linear criteria values normalization) can be considered to be identical with the probability $p \geq 0.95$. Ranking results of the particular methods can be considered to be congruous with the same probability.

4.2. Evaluation of consistency (inconsistency) of ranking results

Two criteria are proposed based on various criteria for evaluation of robustness and consistency of results of multiple criteria decision making methods as developed previously by several researchers (Raju, Pillai, 1999; Triantaphyllou, 2000). The proposed criteria are verified by experimental calculations. Multiple criteria analysis of 234 experimental variants of initial decision making matrixes for building redevelopment problem is performed applying all analyzed methods (COPRAS-F, TOPSIS-F based on vector as well as linear normalization of initial criteria values and VIKOR-F). Calculation results are compared, analyzed and two proposed criteria assessed:

a) Consistency of all ranks in percent (criteria of robustness and consistency of ranking results according to Raju, Pillai (1999); Triantaphyllou (2000)).
b) Consistency of the best ranked alternative in percent (strength of the efficient solution according to Raju, Pillai (1999)).

Percent of consistency of rankings are calculated (Table 8) for the numerous experimental samples as well as for a particular building redevelopment task based on the ranking results applying different MCDM methods (as presented in Table 6).

It is observed that only 16 percent of all ranks match between four analyzed methods for an experimental sample (as we can see in the Table 8). However, scattering of results is much more less in the case of a smaller data sample. Analyzing six groups of results (i. e. when three regions of different development activity are distinguished as well as two development strategies are applied as presented in the Table 6) matching off all ranks is better (33 percent).

Consistency of the best ranked alternatives is observed to be greater comparing with congruence of all ranks. But the percent is also rather small in the experimental sample (31 percent). The same criterion in a case of a particular six groups of data is better and reaches 67 percent. That means that in four cases from the analyzed six ones the best building redevelopment alternatives coincide.

It is observed that matching between ranks of four analyzed methods is rather small. Consequently, the methods are grouped and search for better matching is performed.

Table 8. Consistency (inconsistency) of results of multiple criteria analysis of derelict building redevelopment alternatives

MCDM methods	Experimental sample		Evaluation of rational use of derelict rural buildings (based on Table 6)	
	Consistency of all ranks (percent)	Consistency of the best ranked alternative (percent)	Consistency of all ranks (percent)	Consistency of the best ranked alternative (percent)
1 – 2 – 3 – 4*	16	31	33	67
1 – 2	55	69	67	67
1 – 3	28	57	50	67
1 – 4	64	74	67	83
2 – 3	34	67	100	100
2 – 4	46	63	67	83
3 – 4	19	41	67	83
1 – 2 – 3	26	53	50	67
1 – 2 – 4	43	59	50	67

* 1 – TOPSIS-F, applying vector normalization; 2 – TOPSIS-F, applying linear normalization; 3 – VIKOR-F, 4 – COPRAS-F.

The presumption that the applied initial values normalization method has an influence on final ranking results is proved again. Neither all ranks, nor the best alternatives coincide for 100 percent in a case when TOPSIS-F with vector as well as linear normalization is applied. Congruence varies from 55 percent to 69 percent. Ranking results applying VIKOR-F method match more between TOPSIS-F with linear normalization. The rankings of the latter methods are always consistent (100 percent) in a case of analyzing rational reuse of derelict buildings in Lithuanian rural areas. While ranks of COPRAS-F match better with usual TOPSIS-F when vector normalization is applied. The best ranked alternatives and all ranks matched 74 percent and 64 percent for an experimental sample respectively. While the best building redevelopment alternatives coincide in five cases from analyzed six ones and in four cases all ranks are similar when a smaller sample is analyzed.

The less consistency of rankings is observed between COPRAS-F and VIKOR-F (3 – 4 pair of methods in Table 8), also VIKOR-F and usual TOPSIS-F with vector normalization (1 – 3 pair of methods in Table 8). Consequently, VIKOR-F and COPRAS-F are eliminated from calculations in turn. Consistency between TOPSIS-F and COPRAS-F as well as TOPSIS-F and VIKOR-F is measured. The same consistency of results is observed in the both cases, i .e. the best ranked alternatives and all ranks matches 67 percent and 50 percent in a smaller sample respectively. The scattering of results is larger when an experimental sample is analyzed. On the other hand, the latter results are more reliable due to a large number of data in the sample. It is found that TOPSIS-F and COPRAS-F contain more consistency comparing with TOPSIS-F and VIKOR-F when an experimental sample is analyzed. Accordingly, based on the above research, the conclusion can be made that the priority should be given to COPRAS-F and TOPSIS-F methods instead of VIKOR-F method in a case when the methods produce different ranking results when solving a problem of rational redevelopment of buildings.

5. Conclusions

A case study of Lithuania was presented and multiple criteria analysis of redevelopment decisions of derelict rural buildings was performed.

Four decision making methods, i.e. TOPSIS-F based on vector as well as TOPSIS-F based on linear normalization of initial criteria values, COPRAS-F and VIKOR-F, were applied for ranking of redevelopment alternatives. It was ascertained that priority order of alternatives was not always the same when applying particular methods.

Spearmen's rank correlation coefficients were calculated to measure objective congruence (incongruence) of ranks of derelict buildings' management alternatives.

The above rank correlation coefficients were calculated with a particular level of credibility. We can state that the real values of Spearman's rank correlation coefficients are within the limits of confidence intervals.

Accordingly, it was found out that every correlation coefficient was statistically significant with the probability of 95 percent.

We assessed that Spearmen's rank correlation coefficients between the COPRAS-F and the TOPSIS-F methods can be considered identical within the particular probability (95 percent). While Spearmen's rank correlation coefficients between the COPRAS-F and the VIKOR-F methods considered identical within the probability of 99 percent. Accordingly, multiple criteria evaluation results can be considered to be congruous within the same probability.

When applying the developed criteria of consistency (inconsistency) of results, it was proved that the final decision should be adopted by giving the priority to the results of COPRAS-F and TOPSIS-F based on vector normalization, if the ranking results of the analyzed methods differ. 74 percent of the best ranked alternatives by using the above methods and 64 percent of all ranks matched in a particular experimental sample.

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