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MULTICRITERIA GRAPHICAL-ANALYTICAL EVALUATION OF THE FINANCIAL STATE OF CONSTRUCTION ENTERPRISES

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Abstract. Complex evaluation of the effectiveness of financial activities of construction enterprises may be made by multicriteria methods. As a result of calculations, the priority order of the considered objects can be established. A more thorough analysis reveals that the above methods do not take into consideration the effect of the components of a particular evaluation method on the result obtained. This can be achieved only if multicriteria evaluation is based on graphical-analytical approach. In this case, the reasons why some of the compared alternatives get lower ranks than others can be clearly demonstrated and some effective measures can be provided for improving the situation.

Keywords: construction enterprises, financial criteria, multicriteria evaluation, graphical-analytical interpretation of the results.

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1. Introduction

In recent years, lots of criteria describing the commercial-economic activities of enterprises from various perspectives (Financial analysis of enterprises 1999) have been used. The main criteria belong to three major groups, including 1) solvency and financial risk; 2) turnover; 3) profitability (Lithuanian statistical yearbook 1999). The criteria of Group 1 describe the ability of an enterprise to return short-term credits. The criteria belonging to Group 2 show how actively the available capital is used, while the criteria of Group 3 describe profitability of enterprise performance. Besides, the criteria describing the structure of property, enterprise growth, risk, supplies, etc. are considered. In general, the criteria of Group 1 reflect the level of using enterprise financial, material and labour resources, while the criteria of Group 3 show

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the results of economic-commercial activities, i.e. the effectiveness of enterprise performance. Considering the criteria of Group 1, we can see that they describe various aspects of enterprise performance. Moreover, they are oppositely directed and have different significances. Therefore, the question arises how to assess enterprise performance effectiveness under these conditions. Usually, efforts are made to combine particular criteria, describing various aspects of a complex phenomenon, into a single generalized criterion.

Currently used multicriteria evaluation methods (Hwang, Yoon 1981; Figueira *et al.* 2005; Zavadskas *et al.* 2006; Zavadskas, Antuchevičienė 2007) yield different results due to their specific character. In many cases, the estimated values of the criteria of various methods are actually the same for the particular objects compared; however, the priority is given to a 'better' value.

One of the more effective ways for presenting the results of multicriteria evaluation is their graphical (geometrical) interpretation. A few investigations based on this approach confirm its effectiveness (Ginevičius, Podvezko 2000). The main advantage of this approach is that it can clearly show the components' effect on the method used in multicriteria evaluation of the ultimate result. In this way, the reasons for lower ranks obtained by some alternatives being compared, as well as some measures to be taken to improve the situation, can be determined. Therefore, this paper aims to suggest some clear and simple methods of interpreting the results of multicriteria evaluation based on graphical-analytical approach.

2. The specific character of multicriteria evaluation methods

Quantitative multicriteria evaluation methods differ in their intrinsic logic (concept), type of data normalization as well as the way of combining the data and the criteria weights into the criterion of method evaluation, variation range of the criteria values and the influence of the initial data, i.e. the criteria values and weights in the evaluation result (Ginevičius 2006; Ginevičius, Podvezko 2008a, 2008b; Podvezko 2006; Turskis *et al.* 2006; Ustinovichius *et al.* 2007; Viteikienė, Zavadskas 2007).

The results obtained by different evaluation methods, i.e. the ranks, established for the compared objects, may differ to some extent. However, the estimated values of the criteria of the methods are often similar for particular objects, but the priority is given to a formally 'better' value.

The user (e.g. the head of an enterprise), making a decision based on the estimates obtained by using multicriteria evaluation methods, compares the results of ranking, analysing the reasons for some alternatives being among the leaders and others lagging behind. To plan the future activities, he/she should know the influence of particular criteria and their weights (significances) on the results of multicriteria evaluation.

Comparison and evaluation of the estimates yielded by various quantitative multicriteria methods (Ginevičius, Podvezko 2007b, 2008a), their integration into a unified estimate, as well as simultaneous analysis of the effect of the components, i.e. the particular criteria on the calculation results, could be possible if the criteria of the methods, as well as variation range of their values, methods of normalization and transformation of the initial data (Ginevičius 2008) were the same for all methods. This problem is very complicated, but it can be solved.

Now, when the solution is still in the future, graphical (geometrical) interpretation can hardly be of practical interest for all quantitative multicriteria evaluation methods used in the work. For example, the simplest methods based on the sum of ranks (SR) and geometrical mean (GM) (Ginevičius, Podvezko 2004, 2006, 2007a; Ginevičius *et al.* 2006; Ginevičius *et al.* 2008) do not take into consideration the criteria weights. This largely reduces the scope of their practical application and, therefore, the benefits of graphical interpretation.

The method TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is based on non-standard, so-called vector normalization (Opricovic, Tzeng 2004; Ginevičius, Podvezko 2007b, 2008a). However, the criterion C_j^* of TOPSIS, assessing the available alternatives, may take the value 0, if the alternative is the worst according to all criteria, and the value 1, if it is the best according to these criteria. Moreover, the values of the components of the criterion C_j^* may take 'the extreme values' 0 and 1 for particular alternatives, which actually make their graphical interpretation impossible. The same applies to the method VIKOR (Opricovic, Tzeng 2004; Ginevičius *et al.* 2006), which, on the one hand, uses a specific type of normalization, while its criterion Q_j and the criterion values may also take 'the extreme values' 0 and 1 for particular alternatives. On the other hand, in using this method, the best alternatives are assigned the minimum value Q_j. This makes it different from other methods, as well as reducing a possibility of its graphical interpretation.

Of all the methods used by the authors, the method SAW (Simple Additive Weighting) (Hwang, Yoon 1981), which is widely used in practice, and a similar method COPRAS (Kaklauskas *et al.* 2006; Zavadskas, Kaklauskas 2007) meet the requirements of graphical (geometrical) interpretation.

The method SAW may use 'classical' normalization (Ginevičius, Podvezko 2007b). The values of the criterion S_j of the method range from 0 to 1 (not taking the ultimate values) for all the alternatives considered, while the sum of the criterion values is equal to unity ($\sum_{j=1}^{n} S_j = 1$), allowing for graphical (geometrical) interpretation of the method.

3. The approaches suggested for graphical interpretation of multicriteria methods

It is well-known that quantitative multiple criteria evaluation methods allow us to select the best alternative, to arrange the available alternatives in the order of preference and, finally, to take the most rational decision. However, a decision-maker is interested to know why some alternatives become the leaders, while others are the outsiders, and to determine the influence of particular criteria and their weights (significances) on the resulting estimates. This can be achieved by using graphical-analytical multicriteria evaluation methods. The use of the approaches suggested is demonstrated by a case study based on construction practice.

In assessing the financial position of a construction enterprise, two basic matrices are used: a matrix of statistical data (or expert estimates) $R = \| r_{ij} \| \left(i = \overline{1,m};\ j = \overline{1,n} \right)$ of the i-th criteria for the j-th enterprise and a vector of the criteria weights $\omega = \| \omega_i \|$. The data of 5 criteria of 4 enterprises are given in Table 1.

Table 1. Values of the criteria describing the financial state of construction enterprises

No.	Criterion	Criterion direction	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	max	1.09	1.1	1.03	1.01
2	Critical liquidity	max	0.79	0.7	0.96	1.03
3	Overall liquidity	max	1.56	0.4	0.4	2.2
4	Mobility	max	0.7	2.6	2.18	2.3
5	Debts (%)	min	64.28	70	69	49

We can see that none of the enterprises have the highest values of all the criteria. Enterprise 1 is in the leading position once, enterprise 2 – twice, enterprise 3 – once and enterprise 4 – three times.

To determine the priority order and to calculate the weights of the criteria, a method of pairwise comparison (Saaty 1980, 2005; Su *et al.* 2006; Podvezko 2007) developed by T. Saaty was used. The vector of the calculated weights' values of the criteria is as follows: $\omega = (0.32, 0.26, 0.21, 0.10, 0.11)$.

Qualitative multicriteria evaluation methods are based on integrating normalized (non-dimensional) values $\tilde{r}_{ij}$ of the criteria and their weights ω_i into a particular formula (the criterion of a method). The methods considered differ in the criteria used and normalization technique of the initial data. The main principle of multicriteria evaluation methods can be demonstrated by Simple Additive Weighting (SAW) approach, which is best suited for showing graphically the influence of its components on the final evaluation result.

The criterion S_j of SAW is calculated by the formula (Hwang, Yoon 1981):

$$S_j = \sum_{i=1}^{m} \omega_i \tilde{r}_{ij}, \tag{1}$$

allowing the classical normalization to be used:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}. \tag{2}$$

The values normalized by formula (2), which were taken from Table 1, are given in Table 2.

Table 2. Normalized values of the criteria

No.	Criterion	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	0.2577	0.2600	0.2435	0.2288
2	Critical liquidity	0.2270	0.2011	0.2759	0.2960
3	Overall liquidity	0.3421	0.0877	0.0877	0.4825
4	Mobility	0.0900	0.3342	0.2802	0.2956
5	Debts (%)	0.2403	0.2207	0.2238	0.3152

The components of the criterion S_j of the method, i.e. the products of $\tilde{r}_{ij}\omega_i$, are given in Table 3.

Table 3. Normalized weighted values of the criteria

No.	Criterion	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	0.082304	0.083200	0.077920	0.073216
2	Critical liquidity	0.059020	0.052286	0.071734	0.076960
3	Overall liquidity	0.071841	0.018417	0.018417	0.101325
4	Mobility	0.009000	0.033420	0.028020	0.029560
5	Debts (%)	0.026433	0.024277	0.024618	0.034672
	Total (the values of S_j):	0.24860	0.2116	0.2207	0.3157

Based on the data presented in Table 3, it is hardly possible to determine the influence of the components of the method on the resulting estimate. We offer some graphical methods to simplify the process of evaluation.

Case 1. The square of the j-th circle is equal to the value S_j of the criterion and refers to the j-th enterprise:

$$S_j = \pi R_j^2 ,$$

where R_j is the radius of the j-the circle. Then,

$$R_j = \sqrt{\frac{S_j}{\pi}} . \quad (3)$$

The calculated values of the circle radii are $R_1 = 0.280$, $R_2 = 0.260$, $R_3 = 0.265$, $R_4 = 0.317$. If the smallest (the 2nd) radius value is assumed to be equal to one (unity), then the values of the radii will be as follows: $R_1 = 1.08$, $R_2 = 1$, $R_3 = 1.02$ and $R_4 = 1.22$.

The central angle (in degrees) corresponds to the summand $\tilde{r}_{ij}\omega_i$ of the criterion S_j, relating to the j-th enterprise:

$$\psi_{ij} = \frac{360°\omega_i \tilde{r}_{ij}}{S_j} .$$

The calculated values of the central angles are given in Table 4.

Table 4. The values of the central angles of sectors

No.	Criterion	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	119°	142°	127°	83°
2	Critical liquidity	85°	89°	117°	88°
3	Overall liquidity	104°	31°	30°	116°
4	Mobility	13°	57°	46°	34°
5	Debts (%)	39°	41°	40°	39°

The first case is represented graphically in Fig. 1. The relative estimates are simplified compared to the calculation results provided in the table, however, they are still not clearly evident, being comparable with standard diagrams.

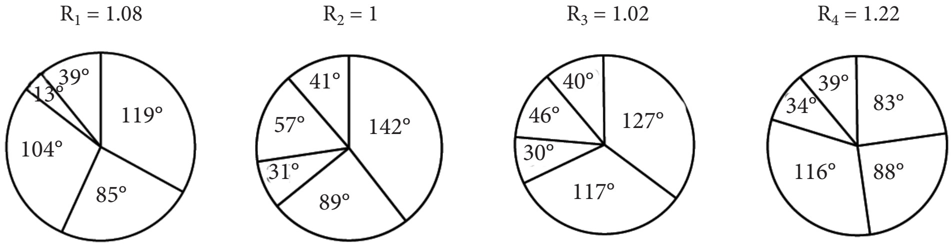

Fig. 1. A graphical view of case 1

Case 2. The central angles of all sectors are the same, being equal to $\psi_{ij} = \frac{360°}{m} = \frac{360°}{5} = 72°$. The square of the i-th sector is equal to the summand $\tilde{r}_{ij}\omega_i$ of the criterion S_j, relating to the j-th enterprise: $S_{ij} = \tilde{r}_{ij}\omega_i$. On the other hand, the square is equal to $S_{j(i)} = \frac{1}{2}R^2_{j(i)}\psi_i$. Then, the radius of the i-th sector is equal to $R_{j(i)} = \sqrt{\frac{2S_{j(i)}}{\psi_i}} = \sqrt{\frac{2\omega_i\tilde{r}_{ij}}{\psi_i}}$, i.e. the radius is proportional to the value of $\sqrt{2\omega_i\tilde{r}_{ij}}$. These values are given in Table 5.

Table 5. The values of the radii of the sectors

No.	Criterion	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	0.406	0.408	0.395	0.383
2	Critical liquidity	0.344	0.323	0.379	0.392
3	Overall liquidity	0.379	0.192	0.192	0.450
4	Mobility	0.134	0.259	0.237	0.243
5	Debts (%)	0.230	0.220	0.222	0.263

The second case is graphically represented in Fig. 2. Thus, the influence of the components on the leadership of the fourth enterprise and lagging behind the second enterprise has become clearly evident.

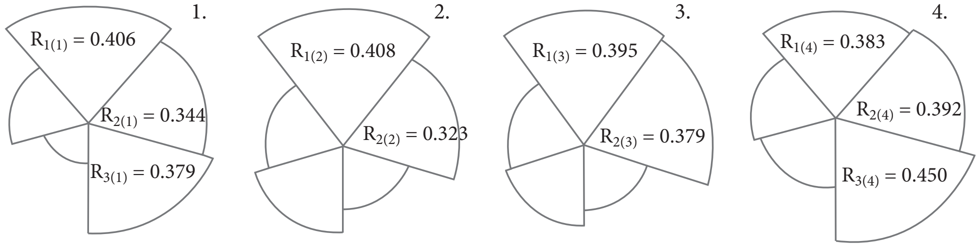

Fig. 2. A graphical view of case 2

Case 3. Similar to case 2, the central angles of all sectors are the same and equal to $\psi_i = \frac{360°}{m} = \frac{360°}{5} = 72°$. In this case, the radius of the i-th sector is equal to the summand $\tilde{r}_{ij}\omega_i$ of the criterion S_j, relating to the j-th enterprise: $R_{j(i)} = \tilde{r}_{ij}\omega_i$. However, the square of the sector is equal to $\frac{1}{2}R^2_{j(i)}\psi_i = \frac{1}{2}\left(\omega_i\tilde{r}_{ij}\right)^2\psi_i$. The values of the radii, i.e. the products of $\tilde{r}_{ij}\omega_i$, are given in Table 3.

The squares of the sectors are proportional to the value of $\left(\omega_i\tilde{r}_{ij}\right)^2$. These values are given in Table 6 and may be assumed as a criterion of evaluation:

$$S^2_j = \sum_{i=1}^{m}\left(\omega_i\tilde{r}_{ij}\right)^2.$$

A possibility to use square normalization in calculations based on multicriteria evaluation methods was discussed in the works of F. Peldschus and E. K. Zavadskas (Zavadskas *et al.* 2003; Zavadskas, Kaklauskas 2007). The criterion S^2_j realizes this concept. It may be applied, when the influence of some insignificant criteria should be reduced.

Table 6. The values of the squares of the sectors $\left(\omega_i\tilde{r}_{ij}\right)^2$

No.	Criterion	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4
1	Prompt liquidity	0.006774	0.006922	0.006072	0.005361
2	Critical liquidity	0.003483	0.002734	0.005146	0.005923
3	Overall liquidity	0.005161	0.000335	0.000339	0.010267
4	Mobility	0.000081	0.001117	0.000785	0.000874
5	Debts (%)	0.000699	0.000589	0.000060	0.001202
	Total (the values of S^2_j):	0.016198	0.011697	0.012402	0.023627

The third case is graphically represented in Fig. 3. This method most clearly demonstrates the influence of the components on the leadership of a particular group of enterprises and lagging behind of some other enterprises.

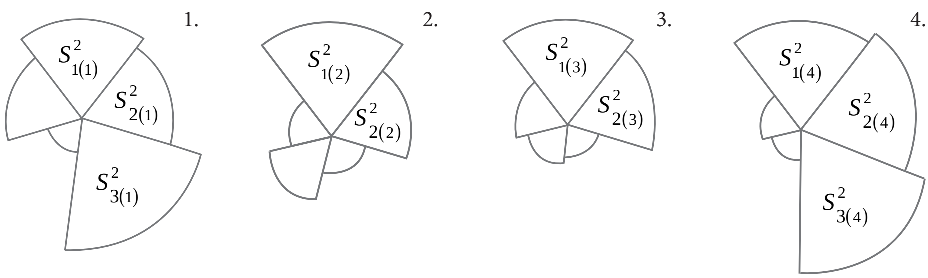

Fig. 3. A graphical view of case 3

Relative estimates of the financial status of four construction enterprises based on the application of various multicriteria evaluation methods are given in Table 7.

Table 7. Relative estimates of the financial status of four construction enterprises

Method	VS		GV		SAW		COPRAS		TOPSIS		S_j^2	
Enterprise 1	12	2	0.223	2	0.249	2	0.253	2	0.52	2	0.0162	2
Enterprise 2	14	4	0.212	4	0.212	4	0.227	4	0.29	4	0.0117	4
Enterprise 3	13	3	0.222	3	0.221	3	0.234	3	0.30	3	0.0124	3
Enterprise 4	11	1	0.254	1	0.316	1	0.286	1	0.71	1	0.0236	1

4. Conclusions

The criteria describing the effectiveness of the financial activities of enterprises reflect various aspects of the considered phenomenon, as well as being oppositely directed and having different weights. In this environment, it is difficult to find a general expression to assess them. In this case, the application of multicriteria evaluation methods gives sufficiently good results. However, these methods are either too simplified or too complicated (Ginevičius, Podvezko 2007b). A different approach to solving this problem is possible, when multicriteria evaluation is based on graphical-analytical interpretation. The main advantage of this approach to complex evaluation of complicated phenomena is that it allows us to determine the influence of the components of the method used on the general evaluation result. This, in turn, makes it possible to identify the reasons why some of the alternatives compared are assigned lower ranks and to provide for some measures to be taken to improve the situation.

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STATYBOS ĮMONIŲ FINANSINĖS VEIKLOS GRAFINIS ANALITINIS DAUGIAKRITERINIS VERTINIMAS

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Santrauka

Statybos įmonių finansinės veiklos efektyvumą kompleksiškai galima įvertinti taikant daugiakriterinius metodus. Tokių skaičiavimų rezultatas – prioritetinė nagrinėjamų objektų eilė. Išsamesnė analizė rodo, kad šie metodai neišryškina sudėtinių vertinimo būdo komponentų įtakos bendram vertinimo rezultatui. Ši galimybė atsiveria tada, kai daugiakriterinis vertinimas remiasi grafine ir analitine interpretacija. Tokiu atveju galima akivaizdžiau nustatyti lyginamų variantų žemesnio reitingo priežastis ir numatyti veiksmingesnę padėties gerinimo priemonę.

Reikšminiai žodžiai: statybos įmonės, finansiniai rodikliai, daugiakriterinis vertinimas, grafinė ir analitinė rezultatų interpretacija.

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