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RANKING THE IMPORTANCE OF MULTI-CRITERIA EVALUATION INDICATORS BASED ON THEIR TRANSITIVITY

Romualdas Ginevicius
Bialystok University of Technology,
Bialystok, Poland
E-mail: r.ginevicius@pb.edu.pl
ORCID 0000-0003-2067-4398

Joanicjusz Nazarko
Bialystok University of Technology,
Bialystok, Poland
E-mail: j.nazarko@pb.edu.pl
ORCID 0000-0002-0236-2334

Dainora Gedvilaite
Vilniaus Kolegija/Higher Education Institution
Vilnius, Lithuania
E-mail: d.gedvilaite@ekf.viko.lt
ORCID 0000-0001-5813-0607

Vladislavas Petraskevicius
Vilnius Gediminas Technical University,
Vilnius, Lithuania
E-mail: vladislavas.petraskevicius@vilniustech.lt
ORCID 0000-0002-6131-1318

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ABSTRACT. In recent decades, multi-criteria methods have been increasingly used for the quantitative assessment of the development of socioeconomic systems. Their essence lies in weighted indicators, i.e., combining the values multiplied by the weights into one summarizing index. However, determining the significance of indicators is important in such approaches. It can be done in one or two stages. In the first case, the significance is assessed immediately, in the second case, the importance ranks of the indicators are determined before the assessment. Today, most people are satisfied with the first method, i.e., determining significance without knowing the importance ranks. This makes sense when the number of indicators is small. Socio-economic phenomena are, by their nature, complex and multifaceted, so in practice they manifest in many aspects. Therefore, their condition can be adequately assessed only with a large number of indicators. The significance of the indicators of such systems is assessed by comparing the importance of paired indicators. However, in the presence of a large number of indicators, there are constantly recurring problems - excessive volumes of expert evaluations and, as a result, a decrease in the adequacy of the evaluation. Transitive analysis of index importance (TAII) is the proposed methodology that allows to significantly increase the number of evaluated indicators while reducing the volume of expert evaluations and increasing their adequacy. This can be achieved by integrating their transitivity as a property into the ranking procedure of determining the importance of indicators. In this way, the volume of expert evaluations can be reduced by 40%. The suitability of the proposed methodology has been verified using real problems.

Keywords: multi-criteria methods, indicator importance ranking, significance determination, transitivity of indicators.

Introduction

We live in a world of systems, from family, institutions where we work, the country we live into entire regions and humanity as a whole. By their very nature, they are all socioeconomic systems (SES), i.e., social systems into which various kinds of material, technological, informational, and other resources are integrated. The mission of socioeconomic systems stems from the operational purpose of SES – the pursuit of results that embody the vision. This implies a constant need and necessity for improvement. The situation is complicated by the fact that this development cannot happen by itself, since SES are open systems. This means that socioeconomic systems are constantly interacting with the outside, which influences the possibilities of SES development. External environmental conditions are not always favorable for the development of SES, so the SES must be able to adapt to them. Only with good adaptation can we expect long-term targeted development towards the goal. Directional development can be achieved if it can be managed, however, to answer the question of whether the development is directional, it is necessary to quantify the state of the SES at the desired moment in time, which allows for a comparison of development costs to the results achieved.

Socio-economic systems are complex and complex by their nature. This means that in reality they are manifested in a large number of the most diverse aspects that reflect its components as a system. To quantify the state of SES, these aspects need to be formalized, i.e., turn into criteria and indicators. The use of expert evaluation in SES problems became typical for different levels – population, entrepreneurial, macroeconomic issues (Bilan et al., 2023; Tamimi & Orbán, 2022; Tauraitė & Aleksandravičienė, 2023; Zhidebekkyzy et al., 2023). Depending on the nature of the mentioned aspects, they can be expressed in different dimensions, be of unequal importance about the phenomenon under consideration, change in opposite directions, etc. For several decades, multi-criteria methods have been successfully applied to combine such indicators into one summarizing measure reflecting the state of SES. Based on them, the state of not only social but also technical-technological phenomena are assessed (Oželienė, 2019; Volkov, 2018; Gedvilaitė, 2019; Podvezko V.; Podviezko, A., 2014; Keshavarz Ghorabaee et al., 2016; Yazdani et al., 2019; Zavadskas, Turskis, 2011; Turskis et al., 2016; Ginevičius et al., 2021; Podvezko, Sivilevičius, 2013).

The philosophy of multi-criteria evaluation is reflected by the SAW (Simple Additive Weighting) method (Hwang, Yoon, 1981). Its essence, like other methods, is the weighted values of indicators, i.e., multiplied by their weights, combining them into one summarizing quantity. Three issues to be resolved follow from this: first, the transformation of the values of indicators expressed in different dimensions into comparable ones; second, determining the importance of the indicators and third, combining the product of the transformed values and weights of the indicators into an index.

Determining the significance of indicators in this set of tasks is the most complicated. The analysis of literature sources shows that it can be done in three ways – subjective, objective and mixed (Fan et al., 1977; Ustinovičius, 2001; Hwang, Yoon, 1981; Podvezko V., Podviezko, A., 2014). All of them have their advantages and disadvantages. In the first case, the significance of indicators is determined based on the subjective evaluations of experts, in the second case, based on the structure of the data array. In the third case, to get a more accurate result, it is suggested to combine them.

The adequacy of determining the significance of multi-criteria evaluation indicators largely depends on their number (Rakauskienė, 2013; Brodny & Tutak, 2023). Based on today's existing methodologies, experts can evaluate only a limited number of them due to limited opportunities to mentally compare the importance of all other indicators of the system. The situation is further complicated by the fact that, as their number grows, the complexity of expert assessment increases in a geometric progression. It is believed that this number is up to 12 indicators (Oželienė, 2019). This implies the need to look for ways to increase the number of simultaneously assessed indicators without reducing the adequacy of the assessment. Analysis shows that this can be done based on their pairwise comparison (Saaty, 1980). Such a comparison has another advantage – it becomes possible to determine the importance of indicators taking into account their interaction with all other indicators of the system. In this situation, if there are enough indicators, it is appropriate to evaluate their importance in two stages. In the first, the importance ranks of the indicators are determined, in the second, the importance of the indicators is based on these ranks. This approach makes sense because the expert will not give more weight to an indicator with a lower importance rank. In this way, the expert evaluation procedure will become simpler, and the compatibility of experts' opinions will be significantly increased.

In this situation, it is necessary to have a methodology that would solve three problems: first, it would allow a significant increase in the number of evaluated indicators; secondly, it would allow to reduce the volume of expert evaluations; third, would increase the consistency of these assessments. The first problem can be solved by applying a pairwise comparison of the importance of the indicators, and the second – is based on the fact that the indicators of SES status, as elements of the system, are interrelated. This means that the importance rank of the indicator under consideration can be determined based on its interaction with all other indicators. The third problem can be solved based on the transitivity property of indicators (Cherchye et al., 2018; Devi, Mangang, 2020; Yang, Dimitrov, 2021; Fishburn, 1979; Carpentiere et al., 2022; Muñoz, 2022; Khurana, Nielsen, 2022).

The article aims to propose a methodology for ranking the importance of indicators of SES status, which would allow to significant expand the number of evaluated indicators while at the same time reducing the costs of expert evaluations and increasing the compatibility of the evaluation.

1. Literature review

Literary sources examine the ranking of the importance of indicators of the phenomenon under consideration and the determination of significance as components of one whole (Podvezko, 2008; Podvezko V., Podviezko, A., 2014; Oželienė, 2019; Volkov, 2018; Rakauskienė, 2013; Podviezko, 2013). This procedure is often used in related tasks resolving, like further taxonomic analysis with defining the distance from the best value (Oliinyk et al., 2022), holistic evaluation of the certain problem combining expert estimates and sociological survey findings (Kézai & Konczos Szombathelyi, 2021). Ranking is a procedure in which the most important indicator is given the highest rank, usually 1, and the others in descending order of their importance to the phenomenon under consideration. In this case, the least important indicator gets rank m (m is the number of evaluated indicators). The importance of contracting is that it significantly facilitates the determination of the significance of indicators and increases the adequacy of the assessment (Podvezko, 2008; Rakauskienė, 2013). The importance of this procedure is very clearly confirmed by the methodology of the concordance of expert assessments, which is based on the calculation of Kendall's concordance coefficient W. It provides that indicator values are first converted into ranks. This is the basis of further calculations (Kendall, 1955; Beshelev, Gurvich, 1974).

Ranking the importance of indicators is especially important when direct assessment of their significance is applied, i.e., when it is determined in parts or percentages of the unit, in compliance with the condition that $\sum_{i=1}^{m} \omega_i = 1$either $\sum_{i=1}^{m} \omega_i = 1\,00$ (ω_i – the significance of the i-th indicator, m – the number of indicators) (Ginevičius, Podvezko, 2004). In this case, the weight of the i-th indicator ω_i will coincide with the average of all expert assessments $\bar{c}_i$:

$$\bar{c}_i = \frac{\sum_{k=1}^{r} c_{ik}}{k},$$

here $\bar{c}_i$– the average of all experts' assessment of the i-th indicator; c_{ik} – evaluation of the importance of the i-th indicator of the k-th expert indicator ($k = \overline{1,r}$); r is the number of experts.

Practical applications of this method have shown that it is easy to understand and it gives a sufficiently accurate result of evaluating the weights of indicators if the experts' opinions are aligned. It makes sense to apply it when the number of evaluated indicators is small, i.e. does not exceed 10–12 (Ginevičius, 2009; Oželienė, 2019). The indirect determination of their importance can be attributed to methods of determining level indicators similar to direct ones (Podvezko, 2008). In this case, first of all, a rating scale is chosen, for example, 10, 20, 50, 100 points. Experts determine the significance of each individual indicator without considering the significance of other indicators. Next, the average of all assessments for each indicator is calculated $\bar{c}_i$. Its weight ω_i is $\bar{c}_i$ the normalized value of the averages.

When the number of indicators is large enough, both direct and indirect methods are insufficient. In search of a way out of how to increase the number of indicators without reducing the adequacy of the assessment, pairwise comparison methods were proposed (Zavadskas, 1987; (Zavadskas, Kaklauskas, 1996; Beshelev, Gurvich, 1974; Saaty, 1980). In both cases, the indicators are compared in pairs, determining which of them is more important In the first case, the result of the comparison is a square matrix $\mathbf{P} = \|p_{ij}\|$. Its elements p_{ij} get a score of 1 if it is more important than the other element of the pair and 0 if it is less important. Analysis of the application of this method shows that it is complex and difficult to implement in practice (Podvezko, 2008). A method based on the comparison of the most important indicator with all other remaining indicators is also proposed. Its meaning is that it facilitates expert assessment and eliminates the logical contradictions of comparison (Ginevičius, 2006). So far, this method has not gained wider application yet.

The most popular and widely applied method is the method of pairwise comparison of T. Saaty indicators (Saaty, 1980). The following essential aspects of it can be presented. First, the importance of indicators is compared in pairs without considering the effect of other pairs of indicators. This makes it possible to add new indicators to the pairwise comparison matrix as needed, or to disable existing indicators while leaving the previous evaluations intact. Secondly, qualitative indicators can be compared with each other. Thirdly, expert assessment of the importance of indicators is integrated into the methodology. This helps to avoid additional calculations. On the other hand, this method also has its drawbacks. First, it is difficult for experts to correctly fill in the pairwise comparison matrix, especially when the number of evaluated indicators is large. Second, the interpretation of the obtained results is difficult. Third, the concept of an ideal expert is unclear. If the experts give the same assessment to the indicators, according to the methodology, the value of the compatibility indicator should be close to zero. Meanwhile, it is large enough and increases disproportionately as the number of indicators grows. All this raise doubts about the adequacy of the assessment (Podvezko, 2008; Tutygin, Korobov, 2010).

The analysis of literature sources reveals the shortcomings of determining the significance of both indicators, especially their importance ranks. The main ones are: all of them are characterized by the fact that the weights of the indicators can be determined adequately only with a small number of them. In addition, both importance ranks and significance are determined without assessing the mutual interaction of indicators as elements of one and the same system. Thirdly, the pairwise comparison of the importance of indicators in order to increase the number of evaluated indicators is not accurate due to the fact that the expert evaluation is carried out in one stage, i.e., without first determining their importance ranks. This affects the adequacy of the assessment, increases the incompatibility of expert opinions and the costs of the assessment. All these shortcomings mean that both the ranking of the importance of the indicators and the methods of determining the significance need to be improved. This article addresses the first issue.

2. Methodological approach

The basis for determining the importance of the indicators reflecting the phenomenon under consideration (NR), taking into account their mutual interaction, is the comparison of the importance of one of the freely chosen indicators that make up the system, which we will call the base indicator, with the importance of all other indicators of the system. If the effect of indicator “A” on the considered phenomenon is stronger than the effect of indicator “B”, then this indicator receives the input “+”, and vice versa, if this effect is weaker – the estimate “–”.

It is important to emphasize that the result of the assessment of the importance of one pair of indicators does not influence the result of the assessment of the importance of another pair of indicators, i.e., all pairwise comparisons of significance are performed independently of each other. Only two evaluation options (“+” or “–”) result from the goal of the evaluation – to determine which of the two compared indicators is more important in relation to NR. Both of these assessments have the same potential to be more or less important. The task here is not to determine how much one indicator is more important than the other – it is simply stating the fact.

Experts perform a mutual comparison of the importance of indicators in a matrix (hereinafter referred to as the Matrix). First of all, its first line is filled (Table 1).

Table 1. Comparison matrix of the importance of one expert’s indicators

Indicators	1	2	3	...	*i*	*i* + 1	...	*n* – 1	*n*
1 (basic)		–	–	...	+	+	...	–	–
2	+		–	...	+	+	...	+	+
3	+	+		...	+	+	...	+	+
⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮
i	–	–	–	...		+	...	–	+
i + 1	–	–	–	...	–		...	+	–
⋮	⋮	⋮	⋮	...	⋮	⋮		⋮	⋮
n – 1	–	–	–	...	+	–	...		+
n	–	–	–	...	–	+	...	–	

Source: *own compilation*

Table 1 shows that, firstly, the importance of the base indicator is lower compared to the second, third, $n - 1$ and n indicators, but higher compared to i and $i + 1$ indicators. The remaining indicators received the same importance estimates – “+” or “–” in relation to the base indicator.

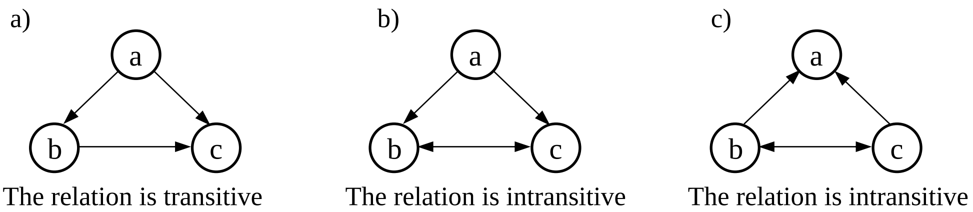
The first pairs of indicators in the group are transitive, i.e. i.e. they are characterized by the property of transitivity. Transitivity is a method of mathematical induction (Cherchye et al., 2018; Devi, Mangang, 2020; Yang, Dimitrov, 2021; Fishburn, 1979; Carpentiere et al., 2022; Muñoz, 2022; Khurana, Nielsen, 2022). Its essence is as follows. Let's say we have a set X of elements (X, Y, Z). If the pair of its elements (Z, Y) satisfies the relation (ZRY), and the pair of elements (Y, Z) satisfies the relation (YRZ), then the relation R is transitive if the relation

(XRZ) also holds for the pair (X, Z) (for each X, Y, Z from the set X). Typical cases of relation R are as follows:

a) if a > b, ob > c, then a > c;

b) if a ||b and b ||c, then a ||c, i.e. lines are parallel.

Graphically, the transitivity of quantities can be represented as follows (Graph 1).



Graph 1. Cases of transitive and intransitive relation of magnitudes
Source: *own compilation*

The property of transitivity is characteristic of all indicators of the state of development of SES. They interact as elements of the same system (Bertalanffy, 1973; Ginevičius, 2009). From the first line of Table 1, it can be seen that transitivity is characteristic of the following pairs of indicators: 2 – *i*; 2 – (*i* + 1); 2 – (*n* – 1); 2 – *n*; 3 – *i*; 3 – (*i* + 1); 3 – (*n* – 1) and 3 – *n*, i.e. for those whose members obtained opposite estimates. The following pairs of indicators are non-transitive: 2 – 3; *i* – (*i* + 1); *i* – (*n* – 1); *i* – *n*; (*i* + 1 – (*n* – 1); *i* + 1 – *n* and (*n* – 1 – *n*), i.e. those whose members obtained the same estimates. In principle, the relationships between pairs of these indicators are also transitive, but we cannot use this feature of them due to their equal importance in relation to the base indicator. On the other hand, it can be done by experts, i.e. they can determine the nature of the relationship between the importance of these pairs of indicators. In this way, the full scope of expert assessments is revealed. This would be the filling of the first lines of the Matrix, as well as the corresponding cells of the indicators that received equal estimates (they are highlighted in the Matrix).

Due to the transitivity of the indicators, the scope of expert evaluations is reduced. Table 1 shows that this decrease reaches almost 40 percent. It largely depends on the structure of the first row of the Matrix – the more varied it is, the bigger it is. This volume depends on the number of indicators – as it grows, it increases.

Due to the evaluation of the interaction of one pair of indicators independently of all other pairs of indicators, the problem of expert assessment of their importance is solved in a completely different way. Whether the opinions are aligned will be shown by the number of equal evaluations of the pair. They will be matched if the total number of equal evaluations exceeds the total number of evaluations with the opposite sign by at least one unit.

The importance ranking of indicators is determined based on the interaction of each indicator with all other indicators in the summary matrix. It is obtained by summing up the estimates given by all experts. If, for example, there were such ten experts, then the summary estimate of the considered indicator system (table 1) will look like this (table 2).

Table 2. Summary matrix of the expert assessment of the importance of indicators (numbers are hypothetical)

Indicators	1		2		3		...		*i*		*i* + 1		...		*n* – 1		*n*	
	+	–	+	–	+	–	...	...	+	–	+	–	...	...	+	–	+	–
1			3	7	4	6	...	...	2	8	6	4	...	...	4	6	6	4
2	4	6			3	7	...	...	5	5	4	6	...	...	8	2	4	6
3	5	5	6	4			...	...	7	3	7	3	...	...	8	2	7	3
⋮	⋮	⋮	⋮	⋮	⋮	⋮			⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	2	8	5	7	4	4	...	...			5	5	...	...	6	4	6	4
i + 1	3	7	5	5	6	4	...	...	6	4			...	...	7	3	5	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮			⋮	⋮	⋮	⋮
n – 1	4	6	6	4	5	5	...	...	4	6	6	4	...	...			5	5
n	7	3	7	3	6	4	...		5	5	6	4	...	...	4	6		

Source: *own compilation*

Based on Table 2, a summary matrix of the importance of indicators is formed (Table 3).

Table 3. Summary matrix of indicator importance ranks

Indicators	1	2	3	...	*i*	*i* +1	...	*n* – 1	*n*	Cumulative number of “+” estimates	Total number of estimates “–”	estimates with a “+” and “–” sign	Rank of importance of indicators
1		–	–	...	–	+	...	+	–	2	4	–2	4
2	+		–	...	–	+	...	+	+	4	2	+2	3
3	+	+		...	+	+	...	+	+	6	0	+6	1
⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	+	+	–	...		+	...	+	+	5	1	+4	2
i + 1	–	–	–	–	–		...	+	–	1	5	– 4	6 – 2
⋮	⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮	⋮
n – 1	–	–	–	...	–	–	...		+	1	5	– 4	6 – 7
n	+	–	–	...	–	+	...	–		2	4	– 2	4 – 5

Source: *own compilation*

Table 3 shows that the nature of the interaction between a pair of indicators is shown by the number of summary estimates with the same sign. For example, for the pair of indicators 1 – *i* the number of summative estimates for *i* with the sign “+” is 2, and with the estimate “–” – 8. In this case, the interaction is evaluated with the estimate “–”. The importance rank of the indicators is determined by summing the estimates of all their pairs with the sign “+” and with the sign “–” and determining their difference (Table 3).

If two indicators have the same difference in summary estimates, they share the importance ranks among themselves.

The proposed TAII methodology for determining the importance ranks of indicators is illustrated by a specific example – determining the importance ranks of the country’s economic development indicators.

3. Conducting research and results

The factors of the country's economic development were selected based on literature sources (Šimelytė, 2014; Alguacil et al., 2011; Zaman, Vasile, 2012; Arbeláez, Ruiz, 2013). Table 4 shows the indicators reflecting these factors.

Table 4. Indicators of the country's economic development

Row No.	Indicator name	Unit
1	The level of economic development of the country	GDP per capita
2	Investments	thousand euros per inhabitant
3	Innovations	Number of patents per capita
4	The size of the labor market	million able-bodied people of the country
5	Labor market (quality)	Scores
6	State tax policy	Scores
7	Unemployment	percent from the working population

Source: *own compilation*

Based on the outlined methodology, first of all, the base indicator was chosen, with which the experts compared the importance of all other indicators of the system for the country's economic development – the level of the country's economic development (Table 4). It is chosen intuitively, i.e. trying not to be the most important or the least important, i.e. about in the middle. It is not of great importance – only that the volume of expert evaluations partly depends on it.

Based on the methodology, experts first of all fill in the first line of the Matrix (Table 1), and also indicate the nature of mutual interaction of those pairs of indicators, the importance of which received equal estimates. Table 5 shows an example of the Matrix completed by one of the eight selected experts.

Table 5. Matrix of expert assessment of the importance of the country's economic development indicators

Indicators	Indicators						
	1	2	3	4	5	6	7
1		–	–	–	–	+	+
2	+		+	–	+	+	+
3	+	–		–	+	+	+
4	+	+	+		+	+	+
5	+	–	–	–		+	+
6	–	–	–	–	–		–
7	–	–	–	–	–	+	

Source: *own compilation*

With the answers of all experts, the compatibility of their opinions was checked and a summary matrix of the importance of the indicators was compiled (Table 6).

Table 6. Summary matrix of the importance of the country's economic development indicators

Indicator no.	Indicator name	Indicator no.													
		1		2		3		4		5		6		7	
		+	–	+	–	+	–	+	–	+	–	+	–	+	–
1.	The level of economic development of the country			2	6	3	5	3	5	4	4	5	3	3	5
2.	Investments	5	3			6	2	5	3	7	1	6	2	5	3
3.	Innovations	3	5	3	5			5	3	3	5	5	3	6	2
4.	The size of the labor market	6	2	5	3	8	0			7	1	5	3	6	2
5.	Labor market (quality)	3	5	4	4	2	6	5	3			3	5	5	3
6.	State tax policy	1	7	2	6	3	5	2	6	5	3			3	5
7.	Unemployment	3	5	3	5	4	4	2	6	5	3	2	6		

Source: *own compilation*

Based on Table 6, a summary matrix of the importance ranks of the country's economic development indicators is formed (Table 7).

Table 7. Summary matrix of importance ranks of economic development indicators of the country

Indicators	1	2	3	4	5	6	7	Cumulative number of "+" estimates	Total number of estimates "–"	estimates with a "+" and "–" sign	Rank of importance of indicators
1		–	–	–	+	+	–	2	4	–2	4–5
2	+		+	+	+	+	+	6	0	+6	1
3	+	–		+	+	+	+	4	1	+4	2
4	+	–	–		+	+	+	4	2	+2	3
5	–	–	–	–		–	–	0	6	–6	7
6	–	–	–	–	+		–	1	5	–4	6
7	+	–	–	–	–	+		2	4	–2	4–5

Source: *own compilation*

From Table 7, we can see that the experts gave the most important ranks to investments. This is followed by innovation, the size of the country's labor market, the level of economic development of the country, unemployment, state tax policy and the quality of the labor market.

The ranks in Table 7 assess the interaction of each indicator with all other indicators in their system, thus adequately reflecting the phenomenon under consideration.

Conclusion

Multi-criteria assessment of the state of development of socioeconomic systems is gains wider application. The philosophy of multi-criteria methods is reflected by the SAW method – the sum of the values of the weighted indicators. Weighted indicators are their transformed (comparable) values multiplied by their weights (importance). Determining the weights of the indicators remains an unsolved problem. Two methods are known – direct and pairwise comparison. In the first case, experts determine the weight of the indicators either in parts of the unit or in percentages, subject to the condition that the sum of all weights must be equal to one. This method, due to the limited possibilities of adequate assessment by experts, is applied when the number of indicators is small. Meanwhile, socioeconomic systems are complex phenomena, so their condition can be adequately assessed only on the basis of a sufficiently large number of indicators. In this case, the first method of determining their importance is not suitable. While searching for baseline indicators, the importance is assessed using pairwise comparison methods. T. Saaty's AHP method is the most well-known and widely used. In all cases, the assessment of the importance of indicators is carried out in one stage, i.e. the importance ranks of the indicators are not determined beforehand. This affects the compatibility of expert assessments, reduces the adequacy of the reflection of the situation under consideration. It is no coincidence that literature sources claim that the assessment of the importance of indicators should take place in two stages. The first would determine the importance ranks of the indicators, and the second would determine their importance based on these ranks. This would prevent the expert from giving more weight to an indicator with a lower rank. This method of determining the importance of indicators is especially meaningful when the number of evaluated indicators is large.

The fundamental problem of determining the importance of indicators is expert evaluation, which is faced with a contradictory situation. The adequacy of the reflection of the phenomenon under consideration increases as the number of indicators increases. On the other hand, it increases the scope of expert assessments and reduces the adequacy of the assessment of the importance of indicators. In this situation, the proposed methodology of transitive index importance analysis (TAII) can be used, which would allow solving all these problems - as the number of indicators increases, the scale of expert assessments would not increase and their adequacy would not decrease. The proposed methodology allows to solve all this. It is based on two essential things - a pairwise comparison of the importance of indicators and the transitivity properties of indicators as interrelated elements of one and the same system. Its practical application showed that the number of evaluated indicators can be increased due to the fact that the importance of one pair of indicators is determined independently of the interaction of other pairs of indicators; the volume of expert evaluations decreases by about 40 percent due to the transitivity of indicators; thanks to the analytical method of determining the nature of the interaction of some indicators, the adequacy of expert assessments increases. In addition, the importance rank of each indicator results from its interaction with all other indicators in the system.

The suitability of the proposed methodology was confirmed by the determination of the importance ranks of the countries' economic development indicators.

References

Alguacil, M.; Cuadros, A.; Orts, V. (2011). Inward FDI and growth: the role of macroeconomic and institutional environment. *Journal of Policy Modeling, 33* (3), 481-496. doi:https://doi.org/10.1016/j.jpolmod.2010.12.004

Arbeláez, H.; Ruiz, I. (2013). Macroeconomic antecedents to US investment in Latin America. *Journal of Business Research, 66* (3), 439-447. doi:https://doi.org/10.1016/j.jbusres.2012.04.011

Bertalanffy, L. (1973). *General System Theory: Foundations, Development, Applications.* New York, NY, USA: George Braziller.

Bilan, Y., Mishchuk, H., & Samoliuk, N. (2023). Digital Skills of Civil Servants: Assessing Readiness for Successful Interaction in e-society. *Acta Polytechnica Hungarica, 20*(3), 155-174. *DOI: 10.12700/APH.20.3.2023.3.10*

Brodny, J., & Tutak, M. (2023). The level of implementing sustainable development goal "Industry, innovation and infrastructure" of Agenda 2030 in the European Union countries: Application of MCDM methods. *Oeconomia Copernicana, 14*(1), 47–102. https://doi.org/10.24136/oc.2023.002

Carpentiere, D., Giarlotta, A., & Watson, S. (2022). The interplay between transitivity and completeness: Generalized NaP-preferences. *Journal of Mathematical Psychology, 108*(1), 102667. doi:https://doi.org/10.1016/j.jmp.2022.102667

Cherchye, L.; Demuynck, LT; De Rock, B. (2018). Transitivity of preferences: When does it matter? *Theoretical Economics, 13* (3), 1043-1076. doi:https://doi.org/10.3982/TE2733

Devi, TT; Mangang, KB (2020). On Equicontinuity, Transitivity and Distality of Iterated Function Systems. *Journal of Dynamical Systems and Geometric Theories, 18* (2), 223-239. doi:https://doi.org/10.1080/1726037X.2020.1847766

Fan, Z.; Ma, J.; Tian, P. (1977). A Subjective and Objective Integrated Approach for The Determination of Attribute Weights. *Materials of 4th Conference of the Interna tional Society for Decision Support Systems.*

Fishburne, P. (1979). Transitivity. *The Review of Economic Studies, 46* (1), 163-173. doi:https://doi.org/10.2307/2297179

Gedvilaitė, D. (2019). *The assessment of sustainable development of a country's regions. Doctoral dissertation.* Vilnius: Technika. Retrieved from http://dspace.vgtu.lt/bitstream/1/3797/1/Gedvilaite%20 dissertation%2005%2016nn.pdf

Ghorabaee, MK; Amiri, M.; Zavadskas, EK; Turskis, Z.; Antucheviciene, J. (2017). A new multi-criteria model for supplier evaluation and order allocation with environmental considerations. *Computers & Industrial Engineering, 112* , 156-174. doi:doi.org/10.1016/j.cie.2017.08.017

Ginevičius, R. (2006). Determining the weights of multi-criteria evaluation indicators based on their mutual interaction. *Business: Theory and Practice, 7* (1), 3-13.

Ginevičius, R. (2009). Some problems of quantitative evaluation of the state of social-economic systems. *Business: Theory and Practice, 10* (2), 69–83. doi:https://doi.org/10.3846/1648-0627.2009.10.69-83

Ginevičius, R., & Podvezko, V. (2004). Assessing the accuracy of expert methods. *Engineering Economics, 5* (40), 7-12.

Ginevičius, R., Szczepańska-Woszczyna, K., Szarucki, M., & Stasiukynas, A. (2021). Assessing Alternatives to the Development of Administrative-Economic Units Applying the FARE-M Method. *Administratie si Management Public, 36* , 6-24. doi:10.24818/amp/2021.36-01

Ginevicius, R., Trish, R., Remeikiene, R., & Gaspareniene, L. (2021). Complex Evaluation of the Negative Variations in the Development of Lithuanian Municipalities. *Transformations In Business & Economics, 20* (2A (53A)), 635-653.

Grybaite, V. (2023). *Evaluation of factors having an impact on the development of the sharing economy: doctoral dissertation.* Vilnius: Technika.

Hwang, C.-L.; Yoon, K. (1981). *Multiple attribute decision making: methods and applications: a state-of-the-art survey.* New-York: Springer-Verlag.

Kendall, MG (1955). *Rank correlation methods.* New York: Hofner Publishing House.

Keshavarz Ghorabaee, M., Zavadskas, EK, Olfat, L. and Turskis, Z. (2015). Multicriteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica, 26* (3), 435-451. doi:10.15388/Informatica.2015.57

Keshavarz Ghorabaee, M.; Zavadskas, EK; Turskis, Z.; Antucheviciene, J. (2016). A New Combinative Distance-based Assessment (CODAS) Method for Multi-Criteria Decision-making. *Economic computation and economic cybernetics studies and research / Academy of Economic Studies, 50* (3), 25-44.

Kézai, K.P., & Konczos Szombathelyi, M. (2021). Factors effecting female startuppers in Hungary. *Economics and Sociology, 14*(4), 186-203. doi:10.14254/2071-789X.2021/14-4/11

Khurana, D.; Nielsen, PP (2022). Transitivity of Perspective. *Algebra and Representation Theory, 25* , 281-287. doi:https://doi.org/10.1007/s10468-020-10020-y

Muñoz, D. (2022). Sources of transitivity. *Economics & Philosophy*, 1-22. doi:10.1017/S0266267122000074

Oliinyk, O., Mishchuk, H., Bilan, Y., & Skare, M. (2022). Integrated assessment of the attractiveness of the EU for intellectual immigrants: A taxonomy-based approach. *Technological Forecasting and Social Change, 182*, 121805. https://doi.org/10.1016/j.techfore.2022.121805

Oželienė, D. (2019). *Modeling the factors of a company's sustainable development. Doctoral dissertation.* Vilnius: Technika.

Podvezko V.; Podviezko, A. (2014). Criteria significance estimation methods. *Lithuanian mathematics collection, 55* , 111–116.

Podvezko, V. (2008). Comprehensive evaluation of complex quantities. *Business: Theory and Practice, 9* (3), 160-168.

Podvezko, V.; Sivilevičius, H. (2013). The use of AHP and rank correlation methods for determining the significance of the interaction between the elements of a transport system having a strong influence on traffic safety. *Transport, 28* (4), 389–403. doi:10.3846/16484142.2013.866980

Podviezko, A. (2013). *Evaluation of financial stability of commercial banks.* Vilnius: Technika.

Rakauskiene, G. (2013). *The increase of validity of National Competitiveness' Promotion Decisions. Doctoral dissertation.* Vilnius: Technology.

Saaty, TL (1980). *The Analytic Hierarchy Process.* New York: McGraw-Hill.

Šimelytė, A. (2014). *Forming Foreign Direct Investment Policy in The Baltic States. Doctoral dissertation [Foreign direct investment policy formation in the Baltic countries: doctoral dissertation].* Vilnius: Technika. Retrieved from http://dspace1.vgtu.lt/handle/1/1721

Tamimi, O., & Orbán, I. (2022). Financial engineering and its impact on audit efficiency in the opinion of experts. *Journal of International Studies, 15*(2), 50-62. doi:10.14254/2071-8330.2022/15-2/4

Tauraitė, V., & Aleksandravičienė, A. (2023). Characteristics of the economic phenomenon of happiness and related aspects among the self-employed population in Lithuania. *Economics and Sociology, 16*(2), 229-247. doi:10.14254/2071-789X.2023/16-2/14

Trish, RM, Sichinava, A., Bartoš, V., Stasiukynas, A., & Schieg, M. (2023). Comparative assessment of economic development in the countries of the European Union. *Journal of Business Economics and Management, 24* (1), 20-36. doi: https://doi.org/10.3846/jbe

Turskis, Z., Daniūnas, A., Zavadskas, EK, & Medzvieckas, J. (2016). Multicriteria Evaluation of Building Foundation Alternatives. *Computer-Aided Civil and Infrastructure Engineering, 31* (9), 717-729. doi:https://doi.org/10.1111/mice.12202

Tutygin, A., & Korobov, V. (2010). Advantages and disadvantages of the analytical hierarchy process. *Economics [Экономика]* , 108-115.

Ustinovich, L. (2001). Determining integrated weights of attributes. *Building [Construction], 7* (4), 321-326. doi:https://doi.org/10.1080/13921525.2001.10531743

Volkov, A. (2018). *Assessment of the impact of the common agricultural policy direct payments system on agricultural sustainability. Doctoral dissertation.* Vilnius: Technika.

Yang, Y., & Dimitrov, D. (2021). Weak transitivity and agenda control for extended stepladder tournaments. *Economic Theory Bulletin, 9* , 27-37. doi:https://doi.org/10.1007/s40505-020-00190-9

Yazdani, M., Zarate, P., Zavadskas, EK, & Turskis, Z. (2019). A combined compromise solution (CoCoSo) method for multi-criteria decision-making problems. *Management Decision, 57* (9), 2501-2519. doi:https://doi.org/10.1108/MD-05-2017-0458

Zaman, G., &Vasile, V. (2012). Macroeconomic Impact of FDI in Romania. *Procedia Economics and Finance, 3* , 3-11. doi:https://doi.org/10.1016/S2212-5671(12)00113-X

Zavadskas, EK; Kaklauskas, A. (1996). *System-technical assessment of buildings.* Vilnius: Technika.

Zavadskas, EK, & Turskis, Z. (2011). Multiple criteria decision making (MCDM) methods in economics: an overview. *Technological and Economic Development of Economy, 17* (2), 397-427. doi:https://doi.org/10.3846/20294913.2011.593291

Zavadskas, EK (1987). Comprehensive assessment and selection of resource saving solutions. Vilnius: Science.

Zhidebekkyzy, A., Moldabekova, A., Amangeldiyeva, B., & Šanova, P. (2023). Transition to a circular economy: Exploring stakeholder perspectives in Kazakhstan. *Journal of International Studies, 16*(3), 144-158. doi:10.14254/2071- 8330.2023/16-3/8