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DECISION-MAKING: CRITERION METHOD OF MULTI-LEVEL SYSTEM RESEARCH

Purpose. Expansion of applications of the Analytical Procedure Method (APM) to multi-level decision making systems in a variety of socioeconomic fields. The development of methods that are based both on calculations and on argument-based expert opinions, which allows one to make qualitative grounded decisions in different socioeconomic fields, is an important issue.

Methodology. The method of paired comparison, the method of analytical procedure structuring of a series of alternatives and criteria (the Analytical Procedure Method).

Findings. Studies were carried out that have confirmed the legitimacy of using the Analytical Procedure Method in application to multi-level decision making systems, which allow for increased criteria detail that leads to a higher quality choice of alternatives. The problem is solved in general for an arbitrary number of levels. The method allows one to obtain the global priorities for all of the elements of a multi-level decision making system.

Originality. The method of analytical procedure is extended from two-level on the multilevel systems of decision making. Unlike the Analytic Hierarchy Process approach, here, the global priorities of the criteria are defined in a manner that is consistent with all of the elements of the multi-level system, which expands the scope of problems in which this approach can be used. When the number of alternatives (criteria) changes in the APM approach (elements of overhead and most bottom levels of the system), the initial global priorities of the alternatives (criteria) both maintain relative signs during comparisons and preserve the initial relations.

Practical value. The global priorities of the alternatives are important information to those who are making a decision. For this reason, the relations between the resulting number of them (after an increase or decrease in their amount) must remain the same during the decision making process. The offered method can be used for making decision in the different spheres of human activity.

Keywords: *decision making methods, Analytical Procedure Method, multi-level systems*

Introduction. Decision-making is a vital component of any field of human activity where a choice must be made regarding which path to take. This increases the value of making correct, motivated decisions – ones that are based both on calculations and on the arguments/opinions of specialists. Currently, the key role in decision making theory is played by multi-criterion choice problems. It is generally assumed that by taking into account multiple criteria, one is able to approximate the real situation more carefully. Decision making resolves itself into using the available criteria to select a correct option out of many. In this process, it is important to determine the amount of criteria and options. At the same time, the weights assigned to the criteria and options should have the same meaning as the values of measurable physical quantities. A wide array of decision-making methods is used: the games theory, the ELECTRE method group; the Podinovsky method; the method of calculation of compromise curves; the Joffrion-Dyer-Feinberg method; the Zeitsman-Vallenius procedure; the Shtoyer method; the STEM method (STEpMethod); methods that use points and curves in visualization; methods of random searching; evolutionary methods; the Analytic Hierarchy Process (AHP), the Analytical Procedure Method (APM), the Criterion Stochastic Method (CSM), and others (Ramsey F.P., von Neumann John, Morgenstern Oskar, Friedman Milton, Savage L. J., Dempster A. P., De Groot Morris, Shafer Glenn, Myerson Roger B., Simon H. A., Kaneman D., Slovik P., Tversky A., W. Edwards Deming, Podinovskiy V. V., Nogin V. D., Saati T. L., Anich I., Larichev O. I., Lotov A. V., Pospelova I. I., Gorbunov V. M., Kuznichenko V. M., Lapshin V. I.).

Each of these has advantages and disadvantages. The improvement of existing decision-making methods, as well as the development of new approaches, is undoubtedly important.

The most widespread and commonly used method of the choice of an optimal solution based on multiple criteria in the absence of an objective measurement scale is the AHP (Saati T. L. [1]). The AHP theory has been widely used in many areas of economics and in the planning and management of complex socioeconomic development processes.

The AHP is in use to this day. Velasquez M., Hester P. T. [2] compared eleven multi-criterion methods. They noted AHP's simplicity and its effectiveness when applied to many socioeconomic problems. The application of multi-criterion decision making systems to the choice of projects that use agricultural waste to generate energy and to develop alternative energy solutions was analysed by Brudermann T., Mitterhuber C. and

Posch A. [3]. The risks inherent to innovational projects in coop farms were studied by Luo J. L. and Hu Z. H. [4]. In order to define the elements of the hierarchy structure, 106 coop farms that used innovative technologies were analysed. Specific examples were used to determine the risks of innovational projects.

The integration of business and the application of informational systems are increasing each year. Organizations strive to connect their business goals into a unified systemic architecture, which allows for the efficient use of resources. When choosing specific hardware and software components of the IT-infrastructure, it is crucial that they be as close as possible to the specifications of the tasks at hand. For this reason, when developing the architecture of the enterprise, it is important to pay special attention to the choice of its projection methodology. Votnitseva V. O., Sakhipova M. S., Deryabin A. I. [5] applied the AHP to the choice of projection methodologies of the systemic architecture of an enterprise, since they considered the AHP to be effective and reliable. A ranking and choice of the best investment projects in the agricultural sector, in which the importance of criterion definition was noted, was carried out by Din G. Y., Yunusova A. B. [6, 7]. The estimations of agro-industrial projects were conducted upon criteria to financial, social and risk degrees. It was shown that a technological risk and risk of price of products abatement are more important for making decision than account of risk at the increase in investments volumes. Din G. Y. [8], in a review of scientific articles, confirms the widespread use of the AHP in different socioeconomic fields. From 1994 to 2014, the number of Russian-language scientific publications that used the AHP was about 15 % of the corresponding number of English-language publications, with their growth being exponential. It has also been noted that the key to the future development of the AHP lies in its application in conjunction with alternative multi-criterion choice methods used for solving complex problems (socioeconomic, regional-sectoral, and others).

Objectives of the article. The goal of the present article is the expansion of the applications of the Analytical Procedure Method (APM) to multi-level decision making systems in a variety of socioeconomic fields. Multi-level systems increase the level of detail of the criteria, which allows for a higher-quality decision making process.

Originality of the research. One of the main downsides to the AHP method lies in the fact that when the number of alternatives (criteria) is changed, it is possible that the global weights of the priorities of the alternatives (criteria) will also change. In any event, their ratios will change, which makes the distribution of finances among different types of work difficult when multiple contractors (alternatives) are used to achieve the goal (Larichev O. I.). This is related to the fact that the matrix of eigenvectors of the matrices of criteria paired comparison relative to the goal is, usually, not in agreement with the matrices of the lower levels of the hierarchy structure.

In order to alleviate this downside, the method of analytical procedure structuring of a series of alternatives and criteria was proposed (APM – Analytical Procedure Method), as was the criterion method for the analytical stochastic support procedure for the decision making process (CSM – Criterion Stochastic Method) by Kuznichenko V. M., Lapshyn, V. I. [9]. These two-level system methods (criteria-alternatives), during the increase (decrease) in alternatives (criteria) both maintain relative signs during comparisons and preserve the initial relations. A comparison of these methods with the AHP was carried out by Kostenko E., Kuznichenko V., Lapshyn V. [10].

Presentation of the main research. Let us consider a multi-level decision making system, which is composed of *s* levels. The uppermost (zeroth) level has the criteria $K_j (j=\overline{1,n})$. The subsequent $s-1$ lower levels can be called “sub-criteria”, with the final level *s* being the alternatives. Let us say that each of the sub-criterion levels contains P_l^i elements ($i=\overline{1,s-2}$, $l=\overline{1,m_i}$, where m_i are integers), while the level of alternatives *s* has A_f $(f=\overline{1,m_{s-1}})$. We note that Saati T. L. [1] also used different level definitions: forces, actors, goals and scenarios.

The main task of decision making methods is the determination of global priorities for the alternatives. At the same time, it is important to find the global priorities for the elements of all the levels.

In order to determine the global priorities for the elements of all the levels, we will start by finding their value for the first and second levels, using the APM. For this purpose it is enough to compare all subcriteria in relation to all criteria and all criteria in relation to one subcriterion. We will construct paired comparison matrices of the subcriteria of the second level of the system (first level of subcriteria) relative to the criteria. In our comparisons, we will use the nine-point scale of Saati T. L. [1]. The paired comparison matrix of the sub-criteria of the first level $P_l^{(1)}$ $(l=\overline{1,m_1})$ relative to the criterion $K_j (j=\overline{1,n})$ is presented in its general form in Table 1.

Here, x_{lj}^i is the weight of the *i* ($i = 1$) level of the sub-criterion $P_l^{(1)}$ $(l=\overline{1,m_1})$ relative to the criterion K_j.

In addition to these matrices, we also need the paired comparison matrix of the criteria $K_j (j=\overline{1,n})$ relative to the sub-criterion $P_l^{(1)}$ (Table 2).

Table 1

Paired comparison matrix of the sub-criteria $P_l^{(1)}$ relative to the criterion K_j

K_j	$P_1^{(1)}$	$P_2^{(1)}$	…	$P_{m_1}^{(1)}$
$P_1^{(1)}$	$\frac{x_{1j}^{(1)}}{x_{1j}^{(1)}}$	$\frac{x_{1j}^{(1)}}{x_{2j}^{(1)}}$	…	$\frac{x_{1j}^{(1)}}{x_{m_1j}^{(1)}}$
$P_2^{(1)}$	$\frac{x_{2j}^{(1)}}{x_{1j}^{(1)}}$	$\frac{x_{2j}^{(1)}}{x_{2j}^{(1)}}$	…	$\frac{x_{2j}^{(1)}}{x_{m_1j}^{(1)}}$
…	…	…	…	…
$P_{m_1}^{(1)}$	$\frac{x_{m_1j}^{(1)}}{x_{1j}^{(1)}}$	$\frac{x_{m_1j}^{(1)}}{x_{2j}^{(1)}}$	…	$\frac{x_{m_1j}^{(1)}}{x_{m_1j}^{(1)}}$

Table 2

Paired comparison matrix of the criteria K_j relative to the sub-criterion $P^{(1)}_l$

$P^{(1)}_1$	K_1	K_2	…	K_n
K_1	$\frac{x^{(1)}_{11}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{11}}{x^{(1)}_{1n}}$
K_2	$\frac{x^{(1)}_{12}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{12}}{x^{(1)}_{1n}}$
…	…	…	…	…
K_n	$\frac{x^{(1)}_{1n}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{1n}}{x^{(1)}_{1n}}$

The data in Tables 1 and 2 allows us to build a unified criterion table of the first level, which will at first not contain elements in every cell. The free cells are filled in later in accordance with the properties of ideal inverse-symmetrical matrices. A completely filled unified criterion matrix is presented in Table 3.

Table 3, in turns, allows us to construct a normalized criterion table of the first level (Table 4), which defines the global priorities of the criteria $W(K_j) = X(K_j)/D$ and of the first level of sub-criteria $W(P^{(1)}_l) = X(P^{(1)}_l)\big/D$ $(l=\overline{1,m_1})$. Here, D is the sum of all the weights of the elements of the criterion table.

The rows are filled in the following way. We find the sum of all the elements in each row of Table 3. The sum of the elements in a given row is divided by the sum of the elements in all the rows. The normalized values are a vector-column for each sub-criterion $P^{(1)}_l$. We trans-

Table 3

Unified criterion table of the first level

		$P^{(1)}_1$				$P^{(1)}_2$				…	$P^{(1)}_{m_1}$			
		$x^{(1)}_{11}$	$x^{(1)}_{12}$	…	$x^{(1)}_{1n}$	$x^{(1)}_{21}$	$x^{(1)}_{22}$	…	$x^{(1)}_{2n}$	…	$x^{(1)}_{m_1 1}$	$x^{(1)}_{m_1 2}$	…	$x^{(1)}_{m_1 n}$
$P^{(1)}_1$	$x^{(1)}_{11}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{11}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{11}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{11}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{11}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{11}}{x^{(1)}_{m_1 n}}$
	$x^{(1)}_{12}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{12}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{12}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{12}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{12}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{12}}{x^{(1)}_{m_1 n}}$
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	$x^{(1)}_{1n}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{1n}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{1n}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{1n}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{1n}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{1n}}{x^{(1)}_{m_1 1}}$
$P^{(1)}_2$	$x^{(1)}_{21}$	$\frac{x^{(1)}_{21}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{21}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{21}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{21}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{21}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{21}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{21}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{21}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{21}}{x^{(1)}_{m_1 n}}$
	$x^{(1)}_{22}$	$\frac{x^{(1)}_{22}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{22}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{22}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{22}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{22}}{x^{(1)}_{22}}$	…		…	$\frac{x^{(1)}_{22}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{22}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{22}}{x^{(1)}_{m_1 n}}$
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	$x^{(1)}_{2n}$	$\frac{x^{(1)}_{2n}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{2n}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{2n}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{2n}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{2n}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{2n}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{2n}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{2n}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{2n}}{x^{(1)}_{m_1 n}}$
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
$P^{(1)}_{m_1}$	$x^{(1)}_{m_1 1}$	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{m_1 1}}{x^{(1)}_{m_1 n}}$
	$x^{(1)}_{m_1 2}$	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{m_1 2}}{x^{(1)}_{m_1 n}}$
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	$x^{(1)}_{m_1 n}$	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{11}}$	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{12}}$	…	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{1n}}$	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{21}}$	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{22}}$	…	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{2n}}$	…	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{m_1 1}}$	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{m_1 2}}$	…	$\frac{x^{(1)}_{m_1 n}}{x^{(1)}_{m_1 n}}$

Table 4

Normalized criterion table of the first level

	K_1	K_2	K_3	...	K_n	Sum $W(P_l^{(1)})$
$P_1^{(1)}$	$x_{11}^{(1)}/D$	$x_{12}^{(1)}/D$	$x_{13}^{(1)}/D$	...	$x_{1n}^{(1)}/D$	$X(P_1^{(1)})/D$
$P_2^{(1)}$	$x_{21}^{(1)}/D$	$x_{22}^{(1)}/D$	$x_{23}^{(1)}/D$	...	$x_{2n}^{(1)}/D$	$X(P_2^{(1)})/D$
$P_3^{(1)}$	$x_{31}^{(1)}/D$	$x_{32}^{(1)}/D$	$x_{33}^{(1)}/D$	...	$x_{3n}^{(1)}/D$	$X(P_3^{(1)})/D$
...	...	...	...	...	...	...
$P_{m_1}^{(1)}$	$x_{m_1 1}^{(1)}/D$	$x_{m_1 2}^{(1)}/D$	$x_{m_1 3}^{(1)}/D$	...	$x_{m_1 n}^{(1)}/D$	$X(P_{m_1}^{(1)})/D$
Sum $W(K_j)$	$X(K_1)/D$	$X(K_2)/D$	$X(K_3)/D$	...	$X(K_n)/D$	1

pose these vectors and insert them into Table 4 line by line for each sub-criterion $P_l^{(1)}$.

The sums of the elements in last columns and rows define the global priorities of the criteria and sub-criteria.

In order to define the global priorities of the second level of sub-criteria, we must construct the paired comparison matrices of the second level sub-criteria $P_l^{(2)}$ $(l=\overline{1,m_2})$ relative to the sub-criteria $P_l^{(1)}$ $(l=\overline{1,m_1})$, that is driven to Table 5.

Table 5

Paired comparison matrices of the second level sub-criteria $P_l^{(2)}$ relative to the sub-criteria $P_l^{(1)}$

$P_l^{(1)}$	$P_1^{(2)}$	$P_2^{(2)}$	...	$P_{m_2}^{(2)}$	$V(P_l^{(1)})$
$P_1^{(2)}$	$\frac{x_{1l}^{(2)}}{x_{1l}^{(2)}}$	$\frac{x_{1l}^{(2)}}{x_{2l}^{(2)}}$	...	$\frac{x_{1l}^{(2)}}{x_{m_2 l}^{(2)}}$	$V(P_1^{(2)})$
$P_2^{(2)}$	$\frac{x_{2l}^{(2)}}{x_{1l}^{(1)}}$	$\frac{x_{2l}^{(2)}}{x_{2l}^{(2)}}$	...	$\frac{x_{2l}^{(2)}}{x_{m_2 l}^{(2)}}$	$V(P_2^{(2)})$
...	...	...	...	...	
$P_{m_2}^{(2)}$	$\frac{x_{m_2 l}^{(2)}}{x_{1l}^{(2)}}$	$\frac{x_{m_2 l}^{(2)}}{x_{2l}^{(2)}}$	...	$\frac{x_{m_2 l}^{(2)}}{x_{m_2 l}^{(2)}}$	$V(P_{m_2}^{(2)})$

The rightmost column of Table 5 contains the eigenvectors (the sum of the elements in a given row is divided by the sum of the elements in all the rows) of these matrices.

We will multiply the eigenvectors $V(P_l^{(1)})$ by the corresponding components of the global priority vector $W(P_l^{(1)}) = X(P_l^{(1)})/D$ $(l=\overline{1,m_1})$, and will write the results in the columns of the second-level criterion table (Table 6). The sums of the cells in the columns and rows of Table 6 define the global priorities of the sub-criteria of the first and second levels respectively. The global priorities of the first level sub-criteria remain unchanged, as already are obtained.

We then carry out, step by step, procedures for the remaining sub-criteria and alternatives that are analogous to those that allowed us to obtain the global priorities of the second level sub-criteria. The final $s-1$ criterion table (Table 7) has the following form.

The rightmost column defines the global priorities of the alternatives, while the bottom row defines the sub-criteria priorities of the final level (the second-to-last level of the system).

Conclusion. We have showed how to obtain the global priorities for all the elements of a multi-level decision making system. The global priorities of the alternatives are important information to those that are making the decision. Unlike the AHP, the global priorities of the

Table 6

Normalized criterion table of the second level

	$P_1^{(1)}$	$P_2^{(1)}$	$P_3^{(1)}$	...	$P_{m_1}^{(1)}$	Sum $W(P_l^{(2)})$
$P_1^{(2)}$	$x_{11}^{(2)}/D$	$x_{12}^{(2)}/D$	$x_{13}^{(2)}/D$	...	$x_{1m_1}^{(2)}/D$	$X(P_1^{(2)})/D$
$P_2^{(2)}$	$x_{21}^{(2)}/D$	$x_{22}^{(2)}/D$	$x_{23}^{(2)}/D$	...	$x_{2m_1}^{(2)}/D$	$X(P_2^{(2)})/D$
$P_3^{(2)}$	$x_{31}^{(2)}/D$	$x_{32}^{(2)}/D$	$x_{33}^{(2)}/D$	...	$x_{3m_1}^{(2)}/D$	$X(P_3^{(2)})/D$
...	...	...	...	...	...	...
$P_{m_2}^{(2)}$	$x_{m_2 1}^{(2)}/D$	$x_{m_2 2}^{(2)}/D$	$x_{m_2 3}^{(2)}/D$	...	$x_{m_2 m_1}^{(2)}/D$	$X(P_{m_2}^{(2)})/D$
Sum $W(P_l^{(1)})$	$X(P_1^{(1)})/D$	$X(P_2^{(1)})/D$	$X(P_3^{(1)})/D$	...	$X(P_{m_1}^{(1)})/D$	1

Table 7

Normalized s – 1 criterion table

	$P_1^{(s-1)}$	$P_2^{(s-1)}$	$P_3^{(s-1)}$	…	$P_{m_{s-1}}^{(s-1)}$	$\mathrm{Sum}W(A_f)$
A_1	$x_{11}^{(s)}/D$	$x_{12}^{(s)}/D$	$x_{13}^{(s)}/D$	…	$x_{1m_{s-1}}^{(s)}/D$	$X(A_1)/D$
A_2	$x_{21}^{(s)}/D$	$x_{22}^{(s)}/D$	$x_{23}^{(s)}/D$	…	$x_{2m_{s-1}}^{(s)}/D$	$X(A_2)/D$
A_3	$x_{31}^{(s)}/D$	$x_{32}^{(s)}/D$	$x_{33}^{(s)}/D$	…	$x_{3m_{s-1}}^{(s)}/D$	$X(A_3)/D$
…	…	…	…	…	…	…
A_{m_s}	$x_{m_s1}^{(s)}/D$	$x_{m_s2}^{(s)}/D$	$x_{m_s3}^{(s)}/D$	…	$x_{m_sm_{s-1}}^{(s)}/D$	$X(A_{m_s})/D$
$\mathrm{Sum}W(P_l^{(s-1)})$	$X(P_1^{(s-1)})/D$	$X(P_2^{(s-1)})/D$	$X(P_3^{(s-1)})/D$	…	$X(P_{m_{s-1}}^{(s-1)})/D$	1

criteria are defined in a matter that is consistent with all of the elements of the multi-level system, and not from paired comparison criteria relative to the common goal. In other words, the system of subjective expert opinions has been shortened by one level. When the number of alternatives (criteria) change in the APM approach, the initial global priorities of the alternatives (criteria) both maintain relative signs during comparisons and preserve the initial relations. Application of the multilevel systems (criteria, subcriteria, alternatives) extends working out in detail of criteria for more quality choice of alternatives at a decision-making. The offered method can be used for making decision in the different spheres of human activity. In economy it can be reliably used for the choice of objects for investing in industrial and agricultural industries [3, 4, 6, 7], at the choice of ways of enterprises modernisation [5], and others, wherein AHP can bring to the illogical conclusions at the change in amount of the examined objects. Example of the multilevel systems of making decision is: at investments in industrial enterprises for a criterion of investments recoupment due to realization of products subcriteria there can be a recoupment term, income, market of products, for a criterion of the developed infrastructure – accordance to the project, necessity of modernisation and so forth.

Further use of the APM approach is linked to the development and application of numerical modelling methods.

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Ухвалення рішень: критеріальний метод дослідження багаторівневих систем

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Мета. Розширення застосування методу аналітичної процедури на багаторівневі системи для ухвалення рішень у різних соціально-економічних сферах. Розробка методів, що базуються як на розрахунках, так і на аргументованих судженнях фахівців, які дозволяють приймати якісні, обгрунтовані рішення в різних соціально-економічних сферах, є актуальним завданням.

Методика. Метод парних порівнянь, метод аналітичної процедури структурування безлічі альтернатив і критеріїв.

Результати. Проведені дослідження обґрунтували застосування методу аналітичної процедури на багаторівневі системи для ухвалення рішень, що розширюють деталізацію критеріїв для якіснішого вибору альтернатив. Завдання вирішене в загальному випадку для довільної кількості рівнів. Метод дозволяє визначати глобальні пріоритети для всіх елементів багаторівневої системи ухвалення рішень.

Наукова новизна. Метод аналітичної процедури розширено із дворівневих на багаторівневі системи прийняття рішень. На відміну від методу аналізу ієрархій, розроблений метод визначає глобальні пріоритети критеріїв самоузгодженої з усіма елементами багаторівневої системи і розширює, таким чином, завдання для його застосування. За зміни кількості альтернатив (критеріїв) при обчисленнях цим методом первинні глобальні пріоритети альтернатив (критеріїв) не лише не змінюють знаки їх порівняння, але й зберігають їх співвідношення.

Практична значимість. Глобальні пріоритети альтернатив є важливою інформацією для особи, що приймає рішення. Тому співвідношення між результуючим числом із них (після збільшення або зменшення їх кількості) у процесі прийняття рішень повинні зберігатися незмінними. Запропонований метод може бути використаний для ухвалення рішень у різних сферах людської діяльності.

Ключові слова: *методи ухвалення рішень, метод аналітичної процедури, багаторівневі системи*

Принятие решений: критериальный метод исследования многоуровневых систем

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Цель. Расширение применения метода аналитической процедуры на многоуровневые системы для принятия решений в различных социально-экономических сферах. Разработка методов, которые базируются как на расчетах, так и на аргументированных суждениях специалистов, позволяющих принимать качественные, обоснованные решения в различных социально-экономических сферах, является актуальной задачей.

Методика. Метод парных сравнений, метод аналитической процедуры структурирования множества альтернатив и критериев.

Результаты. Проведенные исследования обосновали применение метода аналитической процедуры на многоуровневые системы для принятия решений, которые расширяют детализацию критериев для более качественного выбора альтернатив. Задача решена в общем случае для произвольного количества уровней. Метод позволяет определять глобальные приоритеты для всех элементов многоуровневой системы принятия решений.

Научная новизна. Метод аналитической процедуры расширен с двухуровневых на многоуровневые системы принятия решений. В отличие от метода анализа иерархий, разработанный метод определяет глобальные приоритеты критериев самосогласованно со всеми элементами многоуровневой системы и расширяет, таким образом, задачи для его применения. При изменении количества альтернатив (критериев) при вычислениях этим методом первоначальные глобальные приоритеты альтернатив (критериев) не только не изменяют знаки их сравнения, но и сохраняют их соотношения.

Практическая значимость. Глобальные приоритеты альтернатив являются важной информацией для лица, принимающего решение. Поэтому соотношения между результирующим числом из них (после увеличения или уменьшения их количества) в процессе принятия решений должны сохраняться неизменными. Предложенный метод может быть использован для принятия решений в различных сферах человеческой деятельности.

Ключевые слова: *методы принятия решений, метод аналитической процедуры, многоуровневые системы*

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