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MINIMAX RANKING METHOD FOR PRIORITIZATION PROBLEMS IN PROJECT PORTFOLIO MANAGEMENT AND BUSINESS ANALYSIS

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In the conditions of the Digital Economy, rapid turbulent changes in the environment, it becomes vitally important to constantly adjust the priority of previously planned activities, individual tasks and requirements for project solutions, and, first of all, in the field of IT, projects in portfolios, etc. This happens under conditions of increase in the volume of qualitative data, the processing of which at the initial stages of their appearance requires the use of expert methods. However, existing expert methods have been developed to work with small amounts of data. Therefore, the increased interest in the field of portfolio management and business analysis in the development of new universal methods to prioritize big meaningful data is quite justified. The minimax ranking method described in the work is based on taking into account the psychological features of the human brain perception of information about positive and negative emotions, the presence of a sensitivity threshold in identifying differences between two objects, stimuli, etc. Application of the method allows solving the problems of prioritizing projects of large strategic portfolios of companies. The use of the information obtained in this case makes it possible to conduct a business analysis to identify differences in the level of prioritization between groups of projects within the portfolio, both from the standpoint of their holistic perception, and by the totality of the given prioritization parameters.

INTRODUCTION

The modern world is developing in the Digital Economy trend. This is largely due to the effective work with rapidly increasing amounts of data (Big Data). At the same time, meaningful ("smart") data (Smart Big Data, SBD) and a decrease in the amount of "garbage" data and transaction costs, as well as an increase in the transparency and visibility of the processes of generating and processing data, are gaining more and more value [1]. This applies to all aspects of the life of socio-economic systems (SES) of different scales from an individual, through a team, an enterprise to the commonwealth of states and world civilization as a whole.

The main consumer of SBD are projects for the SES creation or innovative development, which at the design stage use technologies to develop a digital twin [2]. This significantly expands the possibility of multivariate generation and accelerated design, not only for the creation of new products that surpass the world's best analogues, but also to develop and research various SES business models.

The key element of the digital twin development technology is the multilevel matrix (MDT) of requirements, targets and resource constraints (time, financial, technological, production, environmental, etc.) [1]. The matrix aims to ensure harmonization (rational "balancing") within the given criteria of a large number of target indicators both at the same level and at different levels of the SES description and different stages of their life cycles. The results of harmonization depend on the selected set of criteria and the option of their priority. These conditions determine the holistic vision of the functioning of the future SES, which is advisable to consider within the framework of the service model of the project [3]. The service model allows not only to "imagine" the future materialized product of the digital twin as functioning, but also to prioritize the criteria, requirements, indicators that indicate the achievement of exactly the values expected by the consumer, which are the base for the considered version of the project and determine the SES's system model parameters. When implementing such projects, operational management of requirements and changes, continuous cascading and decomposition of targets and constraints in the MDT matrix are in use. Thus, indicators are constantly being re-prioritized. In almost all areas of activity, such as economics, psychology, sociology, pedagogy, medicine, biology, etc., it is not always possible to collect quantitative data. Therefore, one has to resort to expert assessment, which operates experts' and business analysts' subjective opinions. At the same time, at those cases methods of pairwise comparison, without direct assessment and ranking, are applicable. The ranking method meets the requirements of a systematic approach, a holistic vision of all indicators (criteria) in the process of their prioritization. Nevertheless, a significant disadvantage of ranking is the impossibility to apply it in case of a large set of objects (more than 15-20). Increasing objects in a square increases the number of connections between them [4]. Removal of this limitation is possible if to use the minimax ranking method, first described in [5] and successfully used for over 20 years in the scientific school VARIORUM [6, 7, etc.].

1. THE ESSENCE OF THE MINIMAX RANKING METHOD

The term ranking has a different context depending on the area and purpose of use. However, in all cases, the essence of ranking they consider as an operation of data distribution from one extreme value of indicators in a group to another extreme indicator - the distribution of individual units of the population in ascending or descending order of the studied feature [8]. In addition, ranking involves the arrangement of the SES elements by rank, by signs of significance and/or scale; establishing the order of location, place of persons, problems, goals and objectives, depending on their importance, weight.

Nowadays the term with the root "minimax" is widely used to denote different rules, criteria, approaches, concepts, etc. For most specialists from different branches of knowledge, it is associated with the L.J. Savage criterion of regret [9], which in decision theory is known as the minimax criterion (minimax risk criterion) [10]. The minimax principle of optimal choice of parameters (minimization of the maximum deviation) is widely used to solve extreme problems [11]. There is a whole class of minimax estimation methods (methods of guaranteed or robust (stable) estimation), which are used to solve problems related to unique measuring systems, for which it is not possible to accurately determine the parameters of measurement error distributions [12]. In managerial accounting and financial management, there is a minimax method to differentiate production costs into variable and constant [13]. It is known to use the minimax method to solve the problem of hypervector ranking of systems [14]. Its idea is to choose instead of r particular criteria one that minimizes the scalar value of the vector component. In this case, the system with the maximum value of this criterion on the set of admissible systems serves as the optimal one.

All of mentioned methods we classify as "hard", quantitative mathematized methods that operate on a set of numerical data. However, applied managerial problems are characterized by the use of qualitative parameters, fuzzy criteria or data. In addition, the main load when ranking falls on the "soft" component of the system - personalities. Let us consider in more depth some of the psychological features of the personality, which are still not explicated in the minimax ranking method [5]. Until now, they have been used mainly intuitively, based on the practice of applying the method.

The first feature is related to such a concept as "sensitivity threshold". According to the Oxford Explanatory Dictionary of Psychology, a differential (or difference) threshold is "a statistically determined point in the magnitude of the difference between the energy levels of two stimuli that is sufficient to detect that the two stimuli are actually different" [10]. Therefore, the farther energetically stimuli are from each other, the more noticeable the difference between them.

The second feature concerns the perception of positive and negative emotions. From childhood, they inspire us by belief that a person should be "white and fluffy" (in terms of [15]). Therefore, a person reacts more emotionally to negative situations and focuses his/her attention on them. It was found that the average number of negative emotions (equal to 7) significantly exceeds the number of positive ones (equal to 2). Negative emotions last longer than positive ones [15]. Nevertheless, if a person stays in the zone of stable negative choice for a long time, this will lead to an increase in negative emotions. Therefore, it is necessary to switch to a positive direction, positive emotions [16]. A self-confident person directly expresses his/her positive and negative feelings [17, p. 250]. Positive and negative assessments reflect compliance with the internal norms of what the person assesses [17, p. 268]. At the same time, as established at the Ohio University, the brain remembers negative information better than positive. According to Clifford Nass, professor of communications at Stanford University, "Positive and negative information is processed in different brain hemispheres. Negative emotions usually involve more reflection and analysis, and this information is processed more thoroughly than positive" [18]. According to Rogers' principle, experiences that are perceived as preserving or developing a person are evaluated positively, and those that contradict preservation or development are negatively evaluated [17, p. 392].

This gives a base to assume that, when ranking, less significant indicators, which in relation to more significant ones have a more negative connotation, will be found (differed, selected) faster than more significant ones. We have fixed this fact in the experimental verification of the applicability of the minimax method. However, to fix it in the form of a scientific statement, additional research is required.

Let we consider the implementation procedure for the minimax method proposed in [5]. Initial indicators, objects, tasks, etc. (hereinafter objects) are placed in an arbitrary form in the ranking zone (the cloud in fig. 1a), under which there are sequentially located cells in a number equal to the number of ranking objects. In this case, the leftmost cell is for the least important object, and the rightmost one for the most important object.

The decision-maker (DM) who carries out the ranking, based on the target setting of the ranking and the holistic subjective perception of each object, chooses the one that, in his/her opinion, is the least significant in the specific conditions set (in this case, for example, the object is a square). Then this object is moved to the leftmost cell (fig. 1b). From the objects remaining in the ranking zone, the decision maker selects the most significant object for the conditions under consideration, and transfers it to the rightmost cell (for example, a rhombus, fig. 1c). After these procedures, the first minimax ranking cycle is completed. Objects remained in the ranking zone, between which the energy levels of stimuli, that determine their difference, decreased.

The second cycle begins by choosing the least significant object (for example, the circle in fig. 1d) from the remaining ones in the ranking zone, and then the most significant one (for example, the inverted triangle in fig. 1e). Then such cycles are repeated until the objects are completely transferred from the ranking area to the cell area. With an odd number of ranking objects, the latter automatically takes place in the center cell. Thus, a ranked series of objects is obtained (fig. 1f). Let we note that the lowest rank 1 is assigned to the least significant object, and the highest rank is assigned to the most significant one.

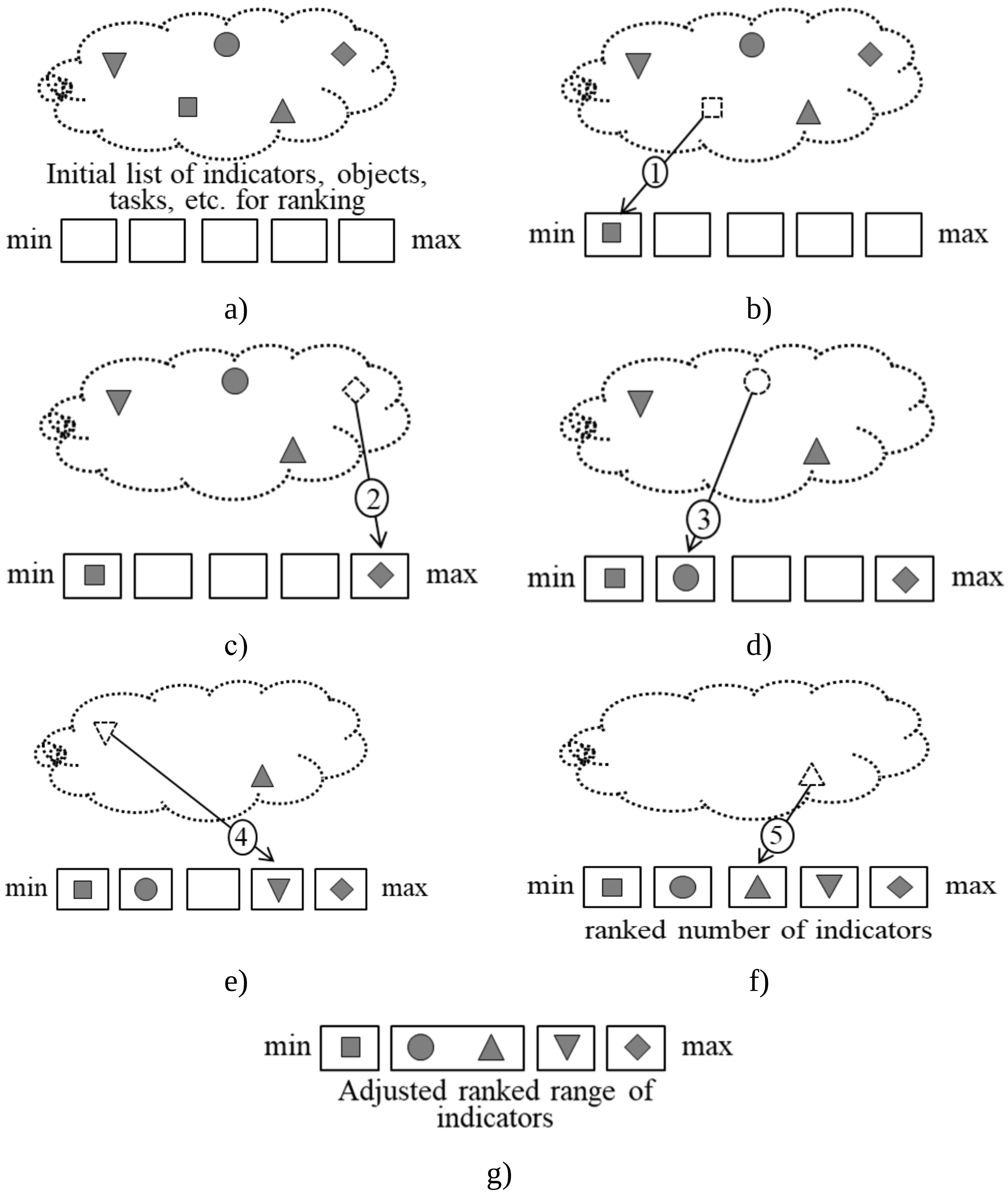

Fig. 1. Implementation stages of the minimax ranking method

A holistic assessment of the sequence of ranked objects makes it possible to identify such objects, the sensitivity threshold between which does not allow distinguishing them. In this case, these objects are combined into one cluster, which is assigned one average rank. In this way, the final adjusted ranked row of objects is determined (fig. 1g).

Despite the ambiguous attitude to such a ranking on the part of the adherents of the "tough" approach, it is a known fact that "... employees of enterprises and organizations can always give very accurate assessments of the climate of their institutions ..." [19]. Moreover, such an assessment is inherently holistic, does not use individual characteristics of objects when comparing them.

2. APPLICATION OF THE MINIMAX METHOD IN PORTFOLIO MANAGEMENT (SYSTEM-HOLISTIC APPROACH)

Let's move on to considering the application of the minimax method in the context of portfolio management. Terminologically, in practice, the term "prioritization" is often used when it is necessary to form a balanced set of enterprise projects in accordance with its strategy and/or financial indicators, investment periods (short-term, medium, long-term), risk and profitability forecasts, and other organizational and technical aspects. Additionally, they try to take into account the economic indicators of individual projects, their net present value, payback period, internal rate of return, etc. Most often, it is the form that the task of prioritizing in a project portfolio is posed [20]. Here we note that all these indicators are predictive values, i.e. refer to NON-factors [21]. However, in conditions of instability and high turbulence of the economic, social, political, mental and physical components of the environment, it is advisable to use the approach to form a project portfolio, which is based on the concept of strategic unity - the correct location of objects related to each other [22]. Correct location presupposes alignment with each other of the three main components of any company effectiveness: the portfolio of projects (i.e., its future "currency") - with its goals; individual projects in the portfolio - among themselves; portfolios and goals - with an overall business context that is constantly changing. And the main tool that is used for the correct location is the information border - these are new business contexts that arise from multilateral communication and encompass connections, information flows and relationships in a dynamic network environment [22]. There are many information boundaries in an organization. The main boundaries outline short-term, long-term goals, as well as goals by circumstance, which form the seven zones of intent and the outer zone where projects that are not related to any group of goals go (fig. 2).

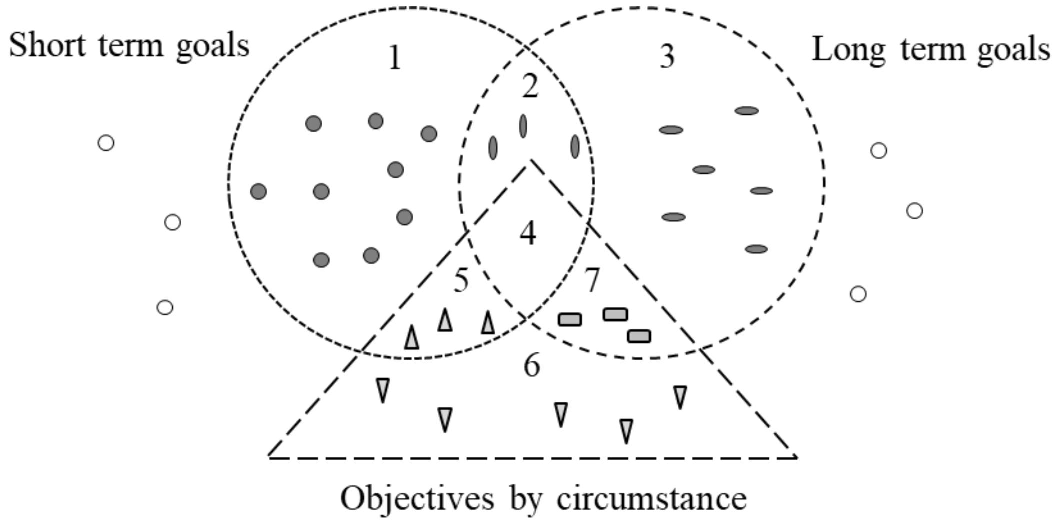

Fig. 2. Organizational intent chart and location of portfolio projects there

Zones 1,3,6 – projects to achive a single goal;

Zones 2,4,5,7 – projects to achive two and more goals

Once the organization's projects have been positioned on the intent chart, the task appears to prioritize them in terms of sequence of execution. To make it, it is most expedient to use the minimax method. When implementing the method, one should not take into account information boundaries, as well as to consider all zones of intentions as one ranking zone.

For the tasks to manage the implementation of portfolio projects, after prioritizing them, it is important to understand the existence or absence of a statistical difference between the zones of the intent chart at the same time. For this, it is advisable to use the Kruskal-Wallis H-criterion [23]. It allows one to establish that the level of the feature changes when transiting from zone to zone, but does not indicate the direction of these changes. For this, we formulate statistical hypotheses:

H0: There are only random differences in priority between the intent zone projects.

H1: There are non-random differences in priority between the intent zone projects.

Table 1 shows an example of the results of the minimax method application for 29 projects that fell into the zones of the chart of intentions (fig. 2).

Table 1

Ranks of projects in the organization's intent diagram

Project No. in the zone	**Projects ranks**					
	zone 1	**zone 2**	**zone 3**	**zone 5**	**zone 6**	**zone 7**
1	7	4	28	2	14	1
2	9	27	10	6	16	3
3	12	29	11	8	19	5
4	13	-	15	-	20	-
5	17	-	18	-	23	-
6	21	-	22	-	-	-
7	24	-	-	-	-	-
8	25	-	-	-	-	-
9	26	-	-	-	-	-

Having implemented the algorithm for calculating the Kruskal-Wallis H-criterion and choosing the tabular values for the significance levels p=0.01 and 0.05, let we construct the "significance" axis (fig. 3).

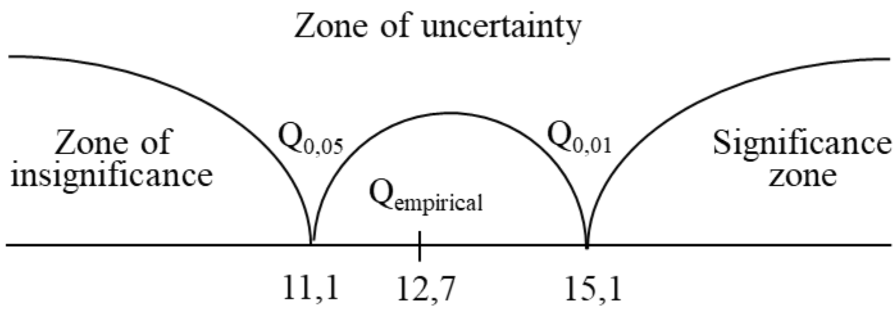

Fig. 3. "Significance axis" for the Kruskal-Wallis H-test

As one can see, the empirical value of the criterion, equal to 12.7, fell into the zone of uncertainty. Therefore, it is expedient to reject the hypothesis about the randomness of the difference in the level of priority of projects (H0), but it is impossible to accept the hypothesis about the non-randomness of the difference (H1).

In this case, it is advisable to carry out additional calculations to determine the pairwise difference between the zones. To do this, let we use the Mann-Whitney U-test, which allows to identify the differences between small samples [23]. The essence of the above formulated statistical hypotheses will not change, we will only apply them for a specific pair of zones of the intention chart. Table 2 shows the results of a pairwise analysis of the results of calculating the Mann-Whitney U-test.

As one can see, for five pairs of zones, a hypothesis about the existence of a difference between the level of projects prioritization in these zones (H1) is not rejected. This information is especially important when deciding on the reallocation of resources, when implementing the portfolio, between projects that are behind the schedule and directing them (if necessary) to successfully completing projects in another zone of these pairs.

Table 2

Accepted hypotheses based on the Mann-Whitney U-test in pairwise comparison of the degree of projects prioritization in different zones of the intention chart

Projects No. in the zone	**9**	**3**	**6**	**3**	**5**	**3**
Zone №	1	2	3	5	6	7
1	-	H0	H0	H1	H0	H1
2	H0	-	H0	H0	H0	H0
3	H0	H0	-	H0	H0	H1
5	H1	H0	H0	-	H1	H0
6	H0	H0	H0	H1	-	H1
7	H1	H0	H1	H0	H1	-

In this case, the prioritization of zones will be preserved, which is determined when forming a project portfolio.

3. APPLICATION OF THE MINIMAX METHOD TO PRIORITIZE PROJECTS UNDER THE GIVEN SET OF CONSIDERATION ASPECTS (SYSTEM-ELEMENT APPROACH)

In the business analyst professional standard BABOK, prioritization is considered as a process of determining the relative importance of an object (information, tasks, requirements, etc.) based on a preliminary assessment of its value, risks, implementation complexity or other clear criteria [24]. Therefore, the task arises to consider these clear criteria when determining the relative importance of an object. Additionally, the business analyst has to take into account various stakeholders' views about the object. Most of the clear criteria deal with qualitative values. According to Antonio Nieto-Rodriguez, author of the book "Purpose as a project. How to successfully solve any problems using a project approach" [25], in order to prioritize strategic initiatives and projects, it is advisable for teams to take into account five aspects: the organization's goal, importance in the time aspect, compliance with the strategy and resource availability, the presence of a competent project implementation team and efficiency, which determined by productivity and value formation [12]. As one can see, all aspects are qualitative. Let's consider step by step the application of the minimax method to solve this type of business-task.

It is proposed to consider holistically each of *N* aspects, which should be taken into account in solving the task, for that purpose to apply the minimax method described in section 1. The procedure begins with determining for each object a finally adjusted ranked series from the position of the considered aspect of the weight coefficient. For this, the method proposed in [5] is used. This involves setting the weighting coefficient k_{min} from the perspective of the aspect under consideration for an object with a minimum rank. It is recommended to choose the value of this coefficient approximately equal to 0,2/n, where *n* is the number of objects in the adjusted ranked row. In this case, the maximum value of k_{min} should not exceed 1/n.

Then the number of ranking levels in the adjusted ranked series is calculated using the formula

$$m = n - \sum_{i=1}^{k}(L_i - 1), \tag{1}$$

where k – the number of ranks that have two or more objects, L_i – the number of objects at the *i*-th level of ranking.

With this in the mind, the step between adjacent values of the weight coefficients in the adjusted ranked series is calculated. Under the condition of a uniform increase in the weight coefficient between the ranks, the calculation formula has the following form

$$\Delta = \frac{1 - n \cdot K_{min}}{\sum_{i=1}^{m-1}(m - i) \cdot L_i}. \tag{2}$$

Then, for each rank of the adjusted ranked series, the weighting coefficient K_p is determined by the formula

$$K_p = K_{min} + (m - p) \cdot \Delta \,. \tag{3}$$

The correctness of the calculation of the weight coefficients within the framework of the aspect under consideration is checked by summing them

$$\sum_{j=1}^{n} K_j = 1 \,. \tag{4}$$

The described procedure is repeated for each aspect separately. As a result, for each object, one obtains a set of weight coefficients for each aspect

$$(K_j^1,\ K_j^2,\ \ldots K_j^z,\ \ldots,\ K_j^N). \tag{5}$$

Finally, the integral weight coefficient of the *j*-th object in the set task is equal to

$$K_j^p = \frac{\sum_{z=1}^{N} K_j^z}{N}. \tag{6}$$

The described procedure is implemented in the MMRON software product. fig. 4 shows the program interface after the implementation of the procedure for combining adjacent objects into one group, which, according to the decision maker, have the same weight. In total, in the example under consideration, 55 objects were used, which were distributed between 42 levels.

Fig. 4. The result of combining adjacent objects with the same weight

The result of the program is the calculation of the weight factors for each aspect of the task and the integral weight factor for each object.

CONCLUSIONS

The results of the research give a base to draw some particular conclusions.

1. In modern conditions of rapid, turbulent changes in all life aspects, the number of states in socio-economic systems of various scales is increasing, which require prompt changes in priorities for previously planned projects, tasks, requirements, indicators, etc. (hereinafter referred to as objects). At the same time, the number of qualitative indicators of various origins is sharply increasing, which is practically impossible to obtain in a clearly defined quantitative form. Therefore, the methods of expert assessment and ranking, which are based on the subjective perception of experts and business analysts, are becoming very popular. However, existing methods cannot be effectively used when working with a large set of objects.

2. The conceptual basis of the approaches to prioritize objects considered in the research from the standpoint of the system-integral and system-element approaches is a variant of the minimax ranking method, the foundations of which were developed at the beginning of the 21st century. The method bases on the psychological features of a person's work with knowledge that have been preserved

or arise from positive and negative emotions, as well as the existence of a threshold of sensitivity in the perception of the difference between two stimuli, objects.

3. The method involves cyclical execution of procedures to select objects from a given set according to the "least significant - most significant" scheme, followed by their removal from the set and placing them on two opposite sides of a sequentially located set of cells equal to the number of objects in the population. The procedure is performed until the objects are completely transferred to the cells and the subsequent merging of the cells, between which the expert does not feel the difference in their importance.

4. For the rational reallocation of resources between "lagging" and successful projects, it is necessary to have information about the existence or absence of a difference degree in the level of prioritization between groups of projects that are in different zones of the organization's intentions. For this, it is proposed to use the Kruskal-Wallis H-test and the Mann-Whitney U-test. The first makes it possible to get an answer as for the existence of a difference in the level of prioritization between all groups simultaneously, and the second - between a specific pair of groups.

5. Based on the minimax ranking method, an approach has been developed to prioritize objects in several assessment aspects. The approach involves the calculation of weights for each aspect of ranking projects with the subsequent calculation of the integral priority as the arithmetic mean of the weight coefficients for all aspects.

6. Computer implementation of the considered methods and approaches greatly simplifies and significantly reduces the work time for teams, experts and business analysts when solving tasks of prioritization in portfolio management and business analysis when working with big data arrays.

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