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Practical Aspects of Obtaining a Consolidated Opinion of Experts in the Calculation of the Weights of Action (Objects) in the Field of Nanobiomedicine

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Abstract: This study focuses on the method of determining the weights required to form an integrated assessment of any of the alternative courses of action (objects) in the decision-making process. Some features of the analytic hierarchy process are reviewed and the results of simulations that determine the limits of its applicability in solving practical problems are presented. The necessity of attracting a pool of experts in the case of a small amount used for comparison criteria is justified. Detailed methods can serve as a tool for evaluation of the consolidated group during the examination. Some of the methods are further modified by the researchers in order to adapt them to the problems of expertise in biomedical nano-technologies.

Key words: Analytic hierarchy process, evaluation criteria, relative importance of criteria, decision-making, adjustment of judgments, group expertise, mathematical methods of processing expert data, nano-biomedical technologies

INTRODUCTION

Organisation of effective activity in any economic sector implies the presence of control procedures. Any action or object can be estimated in several aspects often different in their nature and key characteristics. However, to allow comparison of several objects, each of which is characterised by a set of different criteria, there is a need to form a single integrated assessment which will subsequently be used to compare and select one or more objects of the set in question and their priority in terms of predetermined goals. Each valued object or effect is specific and therefore their evaluation requires the development of specific criteria. After determining the meaning of the criteria and their value measures, their significance in this particular situation must be taken into account in other words, their weight must be determined. The correct definition of the weight criterion is necessary to form a correct integral evaluation.

Often problems related to the formation do not arise at the stage of formalising the criteria but at the stage of their ratio determination. Formalisation of criteria values can be done by one person who knows the method of formalisation while to obtain a more or less objective assessment of the weights we need to refer to a considerable number of experts. Typically, this process involves experts specialists who are competent in a particular narrow area. This study presents a method of determining the weights required to form an integrated assessment of any of the alternative courses of action (objects) in the decision-making process as well as the approach to selection and evaluation of experts called in to evaluate alternatives.

MATERIALS AND METHODS

An expert (lat. expertus experienced) is a licensed specialist in any field of knowledge who is able to give a reasoned assessment of a particular phenomenon (Zhmurov, 2012). Also, experts are defined as specialists in a particular area who were called in to investigate, counsel, make judgments, draw conclusions, advance proposals and undertake examinations.

In order to improve the reliability of the study a group of experts is usually called in. Selecting a group of highly qualified independent experts who do not have a hidden interest in a particular outcome of the study is also a challenge. Experts are competent in their field of work and related disciplines and do not always have sufficient information on methods for the assessment and approach to the assessment criteria. This aspect also must be considered. Therefore, in order to obtain reliable estimates of the weights for comparision, the methodology of assessment must be unambiguous, clear and easy to use.

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One such method is the method of analysis of hierarchies by Saaty (1993). According to this method, all of the identified criteria are matched by the expert using the matrix of pairwise comparisons. The grading scale that the author proposes is a simple scale from 1-9, the values of which correspond to the importance of the actions or objects with regard to each other. The more the superiority of one object to another, the higher the mark is. For example, a value of 1, reflects the fact that the two actions (projects) make the same contribution to the achievement of objectives.

Value 5 is attributed, if the experience and judgment give strong preference to one action (object) regarding another and the value 9 is evidence in favor of choosing one action (object) to another in the highest degree. This scale is a tool for determining the importance of a particular action (object) in relation to the objectives of the study when it is necessary to make a decision. Table 1 shows the symbols for variables for anormal matrix.

Experts are required to make paired comparisons of actions (objects) i and j. The matrix is filled with pairwise comparisons based on the data. The estimates of experts are put at the top of the matrix (above the diagonal) because if action i is attributed one of the highest values of scale compared with the action j, the actionjis attributed an inverse value when compared to i.

A consistency index (hereinafter CI) of the matrix of pairwise comparisons is introduced in order to determine if the logical connection between the assessment of the actions (objects) by experts.

The maximum eigenvalue of the matrix must be calculated to find its index of consistency. The consistency index is calculated by Eq. 1:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

Where:

λ_{max} = Maximum eigen value

n = Shape of the matrix

If the first effect (object) is preferred more than the second action (object) k times and it is m times more preferable than the third one and the first is k×m times preferrable regarding the third, such a matrix is considered coherent and its consistency index is zero (Eq. 2):

Table 1: Description of variables in a normal matrix

Matrix	1	2	3
1	α_{11}	α_{12}	α_{13}
2	α_{21}	α_{22}	α_{23}
3	α_{31}	α_{32}	α_{33}

$$\begin{vmatrix} 1 & a_{12} & a_{12} \cdot a_{23} \\ \frac{1}{a_{12}} & 1 & a_{23} \\ \frac{1}{a_{12} \cdot a_{23}} & \frac{1}{a_{23}} & 1 \end{vmatrix} \quad (2)$$

Typically, the matrix formed on the basis of data obtained by experts is not perfectly consistent. To evaluate the consistency of the matrix, conformity relation (hereinafter CR) is introduced. It shows the relationship of CI of the investigated matrix to the average index (hereinafter AI), calculated for inversely symmetric random matrices of similar dimension. Table 2 shows the AI of matrices formed using a scale from 1-9, applied for paired comparisons of actions (objects). The formed experts matrix is considered conventionally compatible if the value of CR is less than or equal to 0.10.

In cases where the CR is superior to the value of 0.10, it is recommended to make adjustments to the matrix of pairwise comparisons. The review can be done by the following algorithm:

1. Locating line i:

$$\max_i \sum_{j=1}^{n} \left| a_{ij} - \frac{w_i}{w_j} \right| \quad (3)$$

2. Replacing all a_{ij} with w_i/w_j
3. Recalculation of priority vector and the consistency index
4. Repetition of the preceding paragraphs, if necessary

This technique allows one to reliably determine the coefficients of priority (importance) of considered actions (objects) in the case of a good level of conformityamong expert estimates.

However, in practice, matrices based on a survey of experts are not always well coordinated. This is due to the

Table 2: The average index for random matrices

Matrices	Average
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

fact that in the comparison of each pair of objects experts focused on identifying the most accurate correlation of objects being analysed at the moment. They do not think about the connection with those objects that have been evaluated before or will be subject to analysis in the future.

Given the high probability of poorly coordinated matrices, it is reasonable to evaluate the 'cost' of experts' mistakes (Kryanev *et al.*, 2013). For this purpose, deviations of pairwise comparisons matrices from completely consistent ones were modelled; these deviations are measured in different numbers of steps (Pedrycz and Mingli Song). To calculate the consistency of the matrix, different from the ideal, the following actions were performed:

- 1-step increase of one value
- 1-step decrease of one value
- 1-step increase of two values
- 1-step decrease of two values
- 1-step increase of three values
- 1-step decrease of three values
- 1-step increase of one and 1-step decrease another value
- 1-step increase in two values and 1-step decrease of another value
- 1-step increase of one and 1-step decrease of two other values
- 2-step increase of one vaule
- 2-step decrease of one value

The following example is performed on a three dimension matrix (Eq. 4):

$$\begin{vmatrix} 1 & \frac{1}{2} & 1 \\ 2 & 1 & 2 \\ 1 & \frac{1}{2} & 1 \end{vmatrix} \quad (4)$$

As in the case of any coherent matrix, the eigenvalue coincides with the dimension and equals 3 and consequently CI = 0 and CR = 0%.

Based on this matrix, all possible matrices that differ from it by one step on the scale from 1-9 were formed. One example of such modification is presented in Eq. 5:

$$\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & \frac{1}{2} & 1 \end{vmatrix} \quad (5)$$

A 1-step increase as well as a 1-step decrease for one of the values gave a maximum CR value, equal to 4.6% (Table 3).

A 1-step increase or decrease of two values gave the maximum CR of 11.7% which is considered excessive when assessing the consistency ofthe judgment matrix (Eq. 6 and Table 4):

$$\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 3 \\ 1 & \frac{1}{3} & 1 \end{vmatrix} \quad (6)$$

A unidirectional change of values relative to the original fully coherent matrix results in a decrease of the limits of the CR (11.7% for the third-order matrices). While a 1-step increase of one value and a 1-step decrease of another value affect the limitary CR even stronger (Eq. 7 and Table 5):

$$\begin{vmatrix} 1 & 1 & \frac{1}{2} \\ 1 & 1 & 2 \\ 1 & \frac{1}{2} & 1 \end{vmatrix} \quad (7)$$

Further, simulations showed that the presence of a larger number of deviations from the ideal values in a coherent matrix result in a further increase in operating limit which is formed in the calculation of all possible deviations.

Also, based on the analysis results, we can conclude that the larger the dimension of the matrix, the less influence has any consistency error in an expert's judgment. Thus, for the matrix of four, a 1-step deviation of one value regarding a perfectly coherent matrix, the maximum CR will be only 2.2%.

Table 3: The calculations for the modified matrix with a 1-step deviation

Matrices	X	w	M×w	L×w	L_{max}	CI	CR
1	1.000	0.327	1.000	3.054	3.054	0.027	4.6%
2	1.260	0.413	1.260	3.054	-	-	-
3	0.794	0.260	0.794	3.054	-	-	-

Table 4: Calculations for the modified matrix with a 1-step deviation of two values

Matrices	X	w	M×w	L×w	L_{max}	IC	CR
1	1.000	0.319	1.000	3.136	3.136	0.068	11.7%
2	1.442	0.460	1.442	3.136	-	-	-
3	0.693	0.221	0.693	3.136	-	-	-

Table 5: Calculations for the modified matrix with a 1-step deviation of two values (opposite changes)

Matrices	X	w	M×w	L×w	L_{max}	CI	CR
1	0.794	0.260	0.836	3.217	3.217	0.109	18.7%
2	1.260	0.413	1.327	3.217	-	-	-
3	1.000	0.327	1.054	3.217	-	-	-

RESULTS AND DISCUSSION

The resulting value of individual errors made by experts at small dimension of the matrix is an additional argument to be taken into account. In the research process, this fact should be considered and its impact should be reduced. Obviously, the uncertainty or incorrect relations of expert ratio leads to inconsistency and hence to the unreliability of the estimation as a whole. In this regard, it is necessary to find a way to reduce the influence of the human factor misperception or misinterpretation on the final result. Among the actions that reduce the impact of such an error, there are two approaches. The first approach is based on increasing the number of criteria for comparison so that the wrong expert comprehension of one or two criteria for comparison would be compensated by other evaluation criteria of the group in question. If for some reason this is impossible, the error can be corrected by the expertise of a team of specialists (a pool of experts).

However, in practice it is impossible to find several specialists with equal credibility of the opinion. For this reason, it is necessary to develop the methodology for assessing the reliability (correctness and competence) of the opinions of experts.

In practice, there are several approaches for the averaging of estimates obtained by experts which can be divided into two groups: mathematical approaches and qualitative approaches. Such, a division is conditional because the application of 'qualitative' methods also uses mathematical apparatus.

Mathematical approaches include the use of a variety of ways to calculate the average value. The average value can be calculated using the formula of degree average (geometric mean, arithmetic mean, mean square, harmonic mean, the average cubic, etc.) or structural average (mode, median) (Vasnev, 2001).

A more sophisticated approach is to calculate the average value based on the Bayesian scheme. This method is based on the proximity of views of individual experts to the computed expectation based on the aggregate estimates. The result of the application of the method is the weight of expert, formed in such a way that the expert whose opinion was closer to the average for the aggregate has more weight. This method is considered more effective for a large number of experts involved in the examination as it is based on the hypothesis that an increase in the number of experts brings the computed expectation of their estimates closer to the true value which more accurately reflects the analysed properties of objects. Thus, to obtain a more accurate assessment of the consolidated assessment, the 'distance' of the expert evaluation regarding the true evaluation is taken into account by assigning different weights to the experts.

The results of a survey of experts are the estimated weights of analysed criteria obtained through pairwise comparisons. As a result, for each of the n criteria obtained from the m specialists there is a m×n number of evaluations that can be displayed in a matrix (Eq. 8):

$$V = \begin{vmatrix} v_1^{(l)} & \cdots & v_n^{(l)} \\ \cdots & v_j^{(i)} & \cdots \\ v_1^{(m)} & \cdots & v_n^{(m)} \end{vmatrix} \quad (8)$$

where, $v_j^{(i)}$ is the weight ofjcriterion according to specialist i. After getting all sets of objects' estimates from m experts, the average estimates can be calculated for each jth object by calculating the expectation. The result is a vector describing a set of statistical expectations for estimates for each of the n objects:

$$\overrightarrow{v^{(A)}} = \frac{1}{m}\sum_{i=1}^{m}\overrightarrow{v^{(i)}} = \left(\frac{1}{m}\sum_{i=1}^{m}v_1^{(i)}, ..., \frac{1}{m}\sum_{i=1}^{m}v_n^{(i)}\right) = \left(\overline{v_1^{(A)}}, ..., \overline{v_n^{(A)}}\right) \quad (9)$$

where, $\overline{v_j^{(A)}}$ average estimation of the j object. Estimates obtained by calculating the expectation estimate of the average quantities are denoted by the superscript (A). After the calculations are done, experts who were more 'accurate' and whose opinion was closer to a true assessment areidentified. To define the weights of the experts it is necessary to calculate deviationsfor each of the estimated objects from the average grade of the same objects for each ith expert. It does not take into account the direction of the deviation (positive or negative) of the assessment. As a result, variance estimate of parameters from the 'true' value of the project is calculated for each expert:

$$\sigma^{(i)2} = \frac{1}{n-1}\sum_{j=1}^{n}\left(v_j^{(i)} - \overline{v_j^{(A)}}\right)^2 \quad (10)$$

Further, the sum of the reciprocals of the variances of the deviations of all the experts is calculated according to the method:

$$\sum_{i=1}^{m}\frac{1}{\sigma^{(i)2}} \quad (11)$$

and the weight of each of them:

$$w^{(i)} = \frac{1/\sigma^{(i)2}}{\sum_{i=1}^{m}1/\sigma^{(i)2}} \quad (12)$$

Wherein:

$$\sum_{i=1}^{m}w^{(i)} = 1 \quad (13)$$

Thus, the weight of expert evaluations will be formed as the result, allowing theformation of a consolidated assessment of the object.

A qualitative approach to the formation of a consolidated opinion implies taking into account the personal and professional features of an expert. This approach also implies taking into account the specifics of the study area.

One of the methods of qualitative approach is producing a summary estimate of the profile by assigning qualifying factors to experts. A qualifying factor is usually a complicated indicator having several components. The uniqueness of each situation needing an expert assessment states the impossibility of creating a universal approach to the assessment of specialists in different fields. High quality examination can be achieved only if the selection of experts is based on their merits in a particular professional field.

It is important to keep in mind that each component of the profile factor is formed differently. Of course, when forming a pool of experts it is necessary to carry out their primary selection which should be based on formalised qualitative or quantitative indicators of candidate experts. A certain minimum of requirements, mismatch to which would mean an end to further consideration of the candidate as an expert should be applied. For example, the minimum requirements are:

- The presence of higher education with the corresponding profile
- The presence of practical work experience for example, at least 5 years
- If a certain minimum requirement is met, the candidate expert should be analysed in terms of his or her professional competence
- To understand the principle of this method, we will consider an example in the field of nano-biomedicine (Tikhomirov and Sidorenko, 2012). Thus, the following groups of indicators can be formulated for those engaged in practical work in this area in hospitals
- Indicators of activity in the scientific work
- Indicators of practical experience in this specialist field of nano
- Biomedical technologies
- Indicators of knowledge of modern technologies

Each area has a number of features and when forming the weight values indicated by the profile parameters in the integral ratio of the expert's qualification in the field of medicine, it is necessary to take into account the specifics of the area. Experts in the area of nano-biotechnology for example can be divided into two conditional groups. The first group includes practitioners, the second group includes scientists with specialised medical training, conducting research in one of the areas of biotechnology. With this division of group features, it is necessary to implement various schemes for forming profile qualifying factors for each group.

For those specialists that are engaged in practical work in hospitals, the following scheme forming profile qualifying factor is suggested (Fig. 1).

The qualifying factor is formed from the objective numerical characteristics of an expert. Each component of the profile factor itself may have features of formation.

The maximum value that the component of the 'Degree' can have is 0.05 it corresponds to the level of a doctorate in medicine; 'PhD' gives an increase of 0.025. Lack of degree indicates zero value of this component.

The title of professor adds 0.05 to the qualification ratio and the title of associate professor adds 0.025. It is worth noting that the presence of academic rank and scientific degree are separate components. This is due to the fact that in medicine an academic title is not due to a degree as it requires extensive practical experience.

Hirsch index (H-index) can also be a significant criterion in the evaluation of an expert. It shows the distribution of citations of works:

- 3≤H-index<8 adds 0.025
- 8≤H-index<12 adds 0.05
- 12≤H-index<18 adds 0.075
- 18≤H-indexadds 0.1

Practical experience in the profile field for the expert refers to one of the three main components of the qualifying factor the presence of such an experience for >5 years is a mandatory requirement for experts. So in this case, there is no option to select 'no experience'. Maximum value of this coefficient can be obtained by a specialist with >15 years experience in the field of biomedical technologies. Other indicators of the value of the experience can have the value of 0.05 or 0.1 or 0.2.

The analysis of the index of experience in the field of nano-biotechnology can prevent the possibility of the

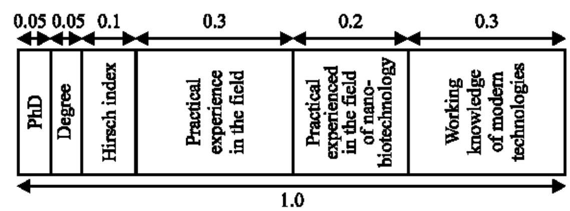

Fig. 1: Composition of the profile qualification index for expert practitioners

absence of such experience. Today, nano-technology is not widely enough used in Russia for this measure to be necessarily binding. However, the presence of such experience is highly desirable andan expert with a high index of experience of work with nano-biotechnology receives an additional competitive advantage.

For the expert evaluating of new technologies, the knowledge of modern technologies in his or her core area is necessary. To assess the degree of working knowledge of technologies, three levels are suggested:

- Theoretical knowledge
- One-time practical experience
- Regular use

The maximum score provided for the working knowledge of one technology is 0.1. For the coefficient of 0.3 in this category the expert must specify the three technologies of which he or she has expert knowledge.

The proposed components of the qualification factor are only an example. Selection and evaluation of components depend on the purpose of the examination, the requirements for its results and management approaches within the organisation conducting the examination.

In practice, often the organisation (team of specialists) has an employee (member of the group) who unconditionally has the highest priority and whose opinion is fundamental (the main expert). In such cases, one can resort to the assessment of the significance of expert opinions based on the opinions of this decisive person. This person can also express his or her opinion by filling the matrix of pairwise comparisons. Further, processing can be performed based on the analytic hierarchy process. In this case, the main expert is guided by the achievements of each expert, their academic title, experience, number of publications in the subject area and others. The weight of the experts in this case is characterised by their relative expertise and qualification in the given group.

CONCLUSION

The conclusion is that today there are several methods that can be used as a tool to provide a summary of expert evaluation. Some of the methods are further modified by the researchers in their adaptation to the field of biomedical nano-technology. In the practical application of these methods, the subject area must be carefully analysed and the appropriateness of a particular method in each unique situation must be determined. Errors associated with the opinion that any problem can be solved with the help of available tools should be avoided. The applied methods will be effective only if they are adapted to the particular situation.

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