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Original Article

Experience of determining the priority of complex process or system (on the example of physical education and sport)

OLKHOVYI OLEH[1], CHERNOZUB ANDRII[2], DANYLCHENKO SVITLANA[3], KORCHAGIN MUKOLA[4], ROMANCHUK SERHII[5], ODEROV ARTUR[6], KLYMOVYCH VOLODYMYR[7], ZHEMBROVSKYI SERHII[8]
[1,2,3,]Black Sea Petro Mohyla National University, Department of olympic and professional sports, Mykolaiv, UKRAINE
[4]Military Institute of Armored Forces of National Technical University "Polytechnic Institute" Department of Physical Education, Special Physical Training and Sport, Kharkiv, UKRAINE
[5,6,7,]National Academy of the Army, Department of Physical education, special physical training and sports, Lviv, UKRAINE
[8]National Defense University of Ukraine named after Ivan Chernyakhosky, UKRAINE

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Abstract
The most used in today's methods of expert assessments (questionnaires, surveys, brainstorming) have a number of underestimations, the main of which is that the consistency and logic of expert statements are not determined. To solve this problem field, a computer program has been created for collecting, saving, quantitative comparison and operational processing of the results obtained through a collective expert evaluation. The article describes the mathematical algorithm of this program. As a base of the program, due to the combination of elements of the Delphi expert survey and the method of modern theory of hierarchical systems T. Saati, the procedure of synthesis of priorities is taken, which is calculated on the basis of subjective expert estimation. The priority or weighting factor is determined on the basis of the individual judgment pair comparison principle of the expert on the priority (the degree of advantage, weight) of one component of a particular process over another. In this work, the method of simple iteration is used. The created program establishes the judgments coherence and logic degree of each of the experts. That is, by way of the estimation pair comparison of the individual expert it is not permissible to violate the coherence and logic of his estimations. A dual comparison excludes the possibility of "blind" use of an uncoordinated and illogical evaluation, requires its refinement or ignores the use of such an assessment. With the help of convenient and easy to use author's computer program, scientists were able to quickly obtain quantitative units of weighting factors of the studied components of a particular process. This allows to display all the results of an interdependent collective, logical and coordinated individual expert estimation.
Key words: expert evaluation, weight coefficient, pair comparison, synthesis of priorities, consistency of judgments.

Introduction

The present of various scientific fields, in the formation of "... adequate and optimal ..." models of the functioning of processes (systems, phenomena) in fact, in absolute majority, can not do without the use of expert judgment (thoughts, judgments, statements) of specialists of practical, methodological and theoretical components of the investigated aspects. And the results of the expert evaluation, as shown by the analysis of a number of scientific papers, are determined by the researchers due to the trivial establishment of the arithmetic mean for each of the studied components (indicators, components, questions), with subsequent allocation of preferences and taking into account those who scored more or the maximum average arithmetic value (Kozina Zh., et al., 2020; Romanchuk S., et al., 2020).

So, from a logical point of view, such an approach can be called the most rational. However, is this solution in the sense of defining a sufficiently objective weight criterion and quantitative (numerical) ordering of the priority of a component of a particular process on the basis of the results of expert evaluations thus obtained, is completely complete, complete and scientific? With such an approach to elaborating the results of an expert assessment, those components that have received the minimum arithmetic mean value are not taken into account or rejected as not significant (Brown D.J., Fletcher D., 2017).

According to the results of the analysis of literary sources of the late 20th and early 21st centuries, a generalized definition for the term "expert estimation method" is formulated - forecasting and evaluating the results of certain follow-up actions based on expert forecasts (Andreichikov A.V., Andreichikova O.N., 2004; Sergienko L.P., 2010).

Corresponding Author: OLKHOVYI OLEH, E-mail: olkhovoleg@gmail.com

The well-known modern methods of expert assessments are divided into individual ones, which take into account independently formulated expert opinions without the influence of other experts (detached evaluation, interviews, surveys, proposals, questionnaires, etc.) (Mistulova T. E., 2004) and collective, where the only common the opinion of a group of experts (Delphi, commission, brainstorming, discussion talks, conference of proposals and ideas, etc.) (Zheleznyak Y. D., 2002; Krusevich T.Y., 2019).

Taking into account and taking into account the most used methods of expert assessments (commission, marginal assessment, Delphi) (Olkhovy O.M., 2015; Romanenko V.A., 2005; Romanenko V.A., 2002; Saaty Thomas L.,1992), based on questionnaires, surveys and brainstorming, the results of which are processed using mathematical statistics, we believe that these methods have a number of underestimations, namely:

- expert assessment is not protected from external influence, bias and inconsistency;
- majority opinion is not necessarily correct, adequate and optimal, and creative (perhaps more correct and effective) solutions are rejected (because they are in the minority);
- the propensity of experts to compromise, subjectivism and stereotyped thinking and the desire to fall into the majority,
- processing results takes a lot of time.

The purpose of the formation of an optimal method for conducting and prompt display of the results of an interdependent collective, logical and coordinated individual expert assessment within the group to determine the priority (weight) of the components of a particular process in physical education and sports.

Methods

To solve the above-mentioned problem field as the prototype, we selected the closest technical solution, which is based on the method of analysis of the hierarchy of (T.Saati Mitichin V.G., 2012; Saati T.L., 2008; Peker A.T., et al., 2020), which contains the procedure of synthesis of priorities, which is calculated on the basis of sub ' expert judgments (number of judgments - dozens or hundreds), and the priority or weighting factor is determined on the basis of paired comparisons of the degree of advantage of one component over another. At the same time, a measure of degree of coherence and logic of judgments of each expert must be established. That is, a pair comparison of each of the judgments of an individual expert will not allow a violation in the coherence and logic of his judgments. A pair comparison excludes the possibility of "blind" use of an uncoordinated and illogical evaluation and requires its re-development or, in the absence of such an opportunity, ignores its use.

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Results

To your attention is an example of the application of T. Saati's algorithm to the problem of expert determination of weight coefficients of the studied components of a certain process in physical education and sports, which we used to create a way to conduct and promptly display the results of an interdependent collective, logical and consistent individual expert evaluation within the group.

The work is, in general, practical and therefore does not contain subtle mathematical aspects of the fundamental theory of hierarchical systems.

Consequently, we denote a certain group of investigated constituents (R) as

$$r_1, r_2, r_3, r_4, \ldots, r_N , \tag{1}$$

where N - number of investigated components. For example, it may be components such as

$$r1 = \{first\}; r2 = \{second\}; r3 = \{third\}; r4 = \{fourth\}, etc. \tag{2}$$

On the basis of existing components, the total expression of a given process is presented in the form

$$R = \sum_{i=1}^{N} \gamma_i r_i , \tag{3}$$

where γ_i weight component of the component, which characterizes the priority of the relevant investigated components when evaluating its level. The value γ_i, $i = \overline{i, N}$ determined by expert judgment.

To solve the problem of ordering the group of investigated components (2), the priority for the survey involves experts who must form an expert matrix of priority (square matrix of pair comparisons) A (Olkhovy

O.M., 2015) of a quantitative measure of the degree of priority of components of a certain process in physical education and sport (2).

This matrix is square with a size N × N with positive elements and with inverse symmetry:

$$A = \{ a_{ij} \}, \quad i, j = \overline{1, N}, \tag{4}$$

$$a_{ij} = \begin{cases} p_{ij}, \text{якщо } p_{ij} \geq 1 \\ \dfrac{1}{p_{ji}}, \text{якщо } p_{ji} \geq 1 \end{cases} \tag{5}$$

where: N - number of investigated components;
p_{ij} – the priority of the investigated component r_i over r_j in a nine-point (from 1 to 9) scale (a_{ij} shows how the investigated factor ri is more (more significant) than the investigated parameter r_j).

The experts determine the priority of the studied components we propose to conduct a nine-point scale of evaluation. The physical meaning of whole ballroom values p is taken from the work of T. Saati (Romanenko V.A., 2000; Maleka E.N., 2017). To determine the investigated components (2), an expert matrix of priority has been formed:

$$A = \begin{pmatrix} 1 & 2 & 1/3 & 1/7 \\ 1/2 & 1 & 1/2 & 1/3 \\ 3 & 2 & 1 & 1/2 \\ 7 & 3 & 2 & 1 \end{pmatrix} \tag{6}$$

If the matrix of pairwise comparisons is formed by A = $\{a_{ij}\}$, the task of determining the weight or quantity of the degree of weight (priority) of each of the N components of a certain process in physical education and sports, according to the method of analysis of hierarchical systems T. Saati (Saati T.L., 2008), is reduced to the problem of the expansion of the matrix A into eigenvalues and eigenvectors:

$$AH = \lambda N \tag{7}$$

$$\det (A - \lambda I) = 0 \tag{8}$$

$$I = (I_{ij}), , \quad I_{ij} = \begin{cases} 1, i = j \\ 0, i \neq j \end{cases}$$

where: λ - the actual value of the matrix A, which is the solution of the characteristic algorithmic equation (8); And I - a unit matrix; H - own vector corresponding to its own value λ,, or normalized vector of component priorities of components of a certain process in physical education and sports.

To calculate the priority vector, we used the following method, which ensures high accuracy (no worse than 5%):

Multiply the elements in each row of matrix of pair comparisons:

$$W_i = \prod_{j=1}^{N} a_{ij}, \tag{9}$$

where N is the order of the matrix.

The root of the N-th degree is calculated from each W_i.. The vector V=$\{V_i\}$ is a non-standardized vector of priority:

$$V_i = \sqrt[N]{W_i} \quad i=1,\ldots, N. \tag{10}$$

The normalized vector of priority H is obtained by standardizing the elements of the vector V:

$$H_i = \frac{V_i}{\sum_{i=1}^{N} V_i} \ ; i=1, \ldots, N. \tag{11}$$

The resulting vector, H=$\{H_i\}$, is a normed vector of priorities, or an own vector of a judgment matrix.

The characteristic algorithmic equation (8) has N roots, which are arranged in descending order (a variation series is formed):

$$\lambda_1 > \lambda_2 > \lambda_3 > \lambda_4 > \ldots > \lambda_N, \tag{12}$$

$$\lambda_1 = \max \lambda_i, \quad i = \overline{1, N} \tag{13}$$

We denote our own vector of the matrix (6) corresponding to the maximal eigenvalue λ_{max} as H_{max} :

$$H_{max} = \begin{pmatrix} H_1 \\ H_2 \\ H_3 \\ H_4 \\ . \\ H_N \end{pmatrix}. \qquad (14)$$

Then the weight vector of the priority of the components of a particular process or phenomenon is presented in the form of such a decision (Saaty Thomas L., 1992):

$$W = qH, \quad q = \frac{1}{\sum_{i=1}^{N} H_i}, \quad \sum_{n=1}^{N} \gamma_i = 1. \qquad (15)$$

$$\gamma_i \geq 0$$

As shown in [13] $\lambda_{max} > N$, the degree of coherence and logic of judgments accepted by the expert (expert evaluations) is estimated here by the index of coherence (ІУ):

$$ІУ = \frac{\lambda_{max} - N}{N - 1} \qquad (16)$$

The smaller the value of the ІУ, the greater the degree of confidence in the decision (15). The numerical degree of confidence can be a difference:

$$G = 1 - ІУ = 1 - \frac{\lambda_{max} - N}{N - 1}. \qquad (17)$$

Along with the index of consistency, we use the coherence relation (ВУ):

$$ВУ = \frac{ІУ}{M(ІУ)}, \qquad (18)$$

where M (ІУ) is the average value of the index of coherence of the randomly generated matrix of pair comparisons, which is based on experimental data (Table 1) obtained by T. Saati (Oderov A., et al., 2017; Olkhovy O. M., 2012).

Table 1

Average value of the matrix index of pair comparisons

Matrix size N	3	4	5	6	7	8	9	10
Random coherence M(ІУ)	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Valid value is used ВУ $\leq$ 0,10. If for the matrix of paired comparisons the ratio of coherence ВУ>0,10, this indicates an existing violation of the logic of the judgments assumed by the expert, when filling the matrix. Such expert data is not usable and should be reviewed.

We note that for determining the maximum eigenvalue and the maximal eigenvector H_{max} of the expert matrix of priority (6) there are sufficiently fast and accurate numerical iterative methods. In this work, we used a simple iteration method (Klymovych V., et al., 2019)

As an example, for an expert matrix of priority (6), we obtained the following solution:

$$\lambda_{max} = 4{,}0206, \quad G = 0{,}0069\ (99{,}31\%), \qquad (19)$$

$$\gamma_1 = 0{,}464; \quad \gamma_2 = 0{,}2499; \quad \gamma_3 = 0{,}2499; \quad \gamma_4 = 0{,}0464.$$

Discussion

Thus, among the components of a certain process in physical education and sports (2), according to the expert matrix of priority (6, 19), the highest priority is r_4 (0.438), less priority – r_3 (0.265), even less priority – r_1 (0.184) and least priority – r_2 (0.113). The consistency index (16) is ą 0.0069 and the consistency ratio (18) – 0.0076. That is, the degree of confidence in the decision of an individual expert in the proposed example (17, 19) - 99.31%.

In cases N = 2, 3, 4 we can obtain a similar solution of the spectral problem for an expert matrix of priority, since algebraic equations of degree not higher than fifth are solved in quadratures. In cases where N > 5 is spectral, the problem for an expert matrix of priority is solved by numerical iterative methods (Doherty C. et al., 2020); Klymovych V. et al, 2016).

In the subsequent work, we created an automated information system (computer program) for operational collection, preservation, quantitative comparison and processing of the results obtained with the help of a collective expert evaluation. The basis of this program is the principle of paired comparisons of the expert judgment of the expert on the priority (the measure of the measure), which is based on the combination of the elements of the expert survey (taking into account the positive aspects of the Delphi method) and the method of modern theory of hierarchical systems T. Saati (Saati T.L., 2008; Saaty Thomas L., 1992; Kolovelonis A., Goudas M., 2019).) advantages, weight) of one component of a particular process over another. The program is executed using the Delphi 5.0 software package running on the Windows operating system. The created automated information system is convenient and easy to use (Klymovych V., et al., 2019; Klymovych V., et al., 2020).

Conclusion.

Based on the results of the study, a technical result was obtained, which consists in the creation of a computer program (automated information system), through which the researchers have the opportunity to quickly obtain quantitative units of the weighting factors of the studied components of a particular process, not only in physical education and sports, but and in other scientific fields. This will allow you to display all the results of an interdependent collective, logical and coordinated individual expert assessment within the group.

The prospect of further research is to refine the acquired method of carrying out and promptly display the results of an interdependent collective, logical and coordinated individual expert assessment within the group to determine the priority (weight) of the components of a particular process.

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