Expert assessments in an innovative environment of the optimization of the information security process in the digital educational environment

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Abstract. The article provides a comparative analysis of the practical use of expert assessments in an innovative environment of the optimization of the information security process in the digital educational environment of internal affairs agencies, namely, the correspondence of the interviewed experts’ assessments and of the research data. To process expert opinions on the threat probability, during comparative analysis we will use expert assessment methods. These methods are mainly intended for solving unstructured problems when the representation in mathematical form is difficult or impossible. Data provided by the experts is processed by a given mathematical method. Within the framework of this publication, we determine the most dangerous attack vectors by use of expert assessment methods. In order to determine the risk of information security threats implementation and, as a consequence, the occurrence of a damage in the information systems of internal affairs agencies, we will consider the possibility to determine the probability of the usage of given attack vectors by the experts. When resolving this issue, the definition of IS should be supplemented with the word “technological” in connection with the importance of large distributed technological systems supporting the operation of internal affairs agencies information technological systems.

1. Introduction
The main stages of the application of expert assessment methods [1-3]: goal setting; selection of experts; examination procedure development; data collection and analysis; data processing; results evaluation.

Direct assessment method. A direct assessment allows us to make the correspondence between the study object and the numerical value. This value is proportional to the importance of the study object for the final result. As a rule, the expert selects the corresponding value from the interval [0; 1], which corresponds, for example, to the probability measurement. Equally possible events receive the same numerical values. Such a scale is measurable on the premise of a high degree of knowledge about the features of the study object and a high degree of expert readiness. In some cases, it is advisable to change the scale to 5, 10 or 100 points, but the accuracy of such a measurement is significantly reduced.
Expert assessment does not always have to be expressed in numerical value. The individual object features can be expressed in different scales, but the numeric expression seems difficult, like in the case of the range of color images.

The method of pairwise comparisons. The application of the method of pairwise comparisons supposes the presence of a matrix of pairwise comparisons:

\[
A = (a_{ij})_{n \times n} = \begin{pmatrix}
    a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\
    a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \\
\end{pmatrix}
\]

Any element of the indicated above matrix expresses a number greater than zero, representing how many times the weight of the \( A_i \) object is greater than the weight of the \( A_j \) object.

In accordance with this method based on expert assessments, as a result of \( \frac{n(n-1)}{2} \) pairwise comparisons of objects, that part of the matrix of pairwise comparisons \( A = (a_{ij})_{n \times n} \) is formed, which is located, for example, above the main diagonal. Matrix elements below the main diagonal are calculated using the reverse symmetry property.

We find the maximum eigenvalue \( \lambda_{\text{max}} \) of the matrix of pairwise comparisons \( A \) and then we solve a homogeneous system of linear equations \( (A - \lambda_{\text{max}} I)w = 0 \) with respect to the vector \( w \), equivalent to \( Aw = \lambda_{\text{max}} w \).

The obtained vector \( w \) has positive constituents and is a calculable weight vector.

As a result of applying this method, as a rule, the strict inequality \( \lambda_{\text{max}} > n \) is fulfilled and the constituents \( \omega_1, \omega_2, \ldots, \omega_n \) of the weight vector “are not in agreement” with the data contained in the matrix of pairwise comparisons \( A = (a_{ij})_{n \times n} \) in the sense that the equality \( a_{ij} = \omega_i / \omega_j \) is most often violated.

Group assessment method. The data obtained as a result of a survey of experts also contain various preferences of expert opinions and the rationale for these preferences. The content of various data, both informative assessments and numerical data, necessitates the use of qualitative and quantitative methods of processing the results of group expert assessment.

During a survey of experts, a group of experts assesses the required number of objects with respect to the given number of parameters. It is reasonable to introduce a coefficient of competence of experts. Under this paradigm, it is calculated from the data obtained as the results of assessment of the object under study. The main idea of this method is the assumption that the competence of an expert is evaluated in accordance with the consistency of his assessments with the group assessment of objects.

2. Materials and methods
Let the Global study of information leaks in 2018 be the object of analysis of the expert assessment methods applicability, namely, the data on information leak breakdown by the attack vectors are presented in table 1 [5].

| Year | Theft / loss of equipment | Mobile devices | Removable media | Network | e-Mail | Paper-based media | IM (text, voice, video) |
|------|--------------------------|----------------|-----------------|---------|-------|------------------|------------------------|
| 2017 | 3.3                      | 0.7            | 2.2             | 69.9    | 13.3  | 8.2              | 2.4                    |
| 2018 | 2.5                      | 0.5            | 2.2             | 72.2    | 8     | 11               | 3.6                    |
Based on the data provided by INFOWOTCH company, we will designate each of the attack vectors as an object of expert assessment, for ease of calculations, we assign to each of the channels the letter value $O_1, ..., O_7$ respectively.

Further, to apply the expert assessment methods, it is necessary to carry out an expert survey, where practicing employees of IT departments, as well as information security specialists with higher technical education, acted as experts. Based on the above described assessment methodology for direct and group assessment methods, after interviewing 10 experts we obtain the following values of normalized estimates (table 2).

| Expert/Object | O1  | O2  | O3  | O4  | O5  | O6  | O7  |
|---------------|-----|-----|-----|-----|-----|-----|-----|
| Expert 1      | 0.16| 0.22| 0.15| 0.22| 0.16| 0.05| 0.04|
| Expert 2      | 0.05| 0.2  | 0.1  | 0.25| 0.2  | 0.1  | 0.1  |
| Expert 3      | 0.14| 0.15| 0.1  | 0.4  | 0.15| 0.01| 0.05|
| Expert 4      | 0.1 | 0.25| 0.1  | 0.25| 0.15| 0.05| 0.1  |
| Expert 5      | 0.2 | 0.05| 0.1  | 0.3  | 0.05| 0.15| 0.15|
| Expert 6      | 0.1 | 0.15| 0.1  | 0.5  | 0.05| 0.05| 0.05|
| Expert 7      | 0.29| 0.2  | 0.17 | 0.15| 0.09| 0.06| 0.04|
| Expert 8      | 0  | 0.4 | 0    | 0.4  | 0    | 0    | 0.2  |
| Expert 9      | 0.1 | 0.2 | 0.1  | 0.3  | 0.2  | 0.1  | 0    |
| Expert 10     | 0.1 | 0.25| 0.2  | 0.3  | 0.05| 0.1  | 0    |

We apply the direct assessment method, for which we average the obtained normalized estimates according to formula (2):

$$\bar{x} = \sum_{i=1}^{n} x_i$$

The vector of the general normalized estimate has the following form:

$$(0.043; 0.072; 0.039; 0.108; 0.038; 0.023; 0.025).$$

Based on the table 1 we apply the above described group assessment algorithm, having set the calculation accuracy $\varepsilon = 0.001$, we carry out the calculation of the first-approximation average estimates of the objects.

The first-approximation average estimates will be equal to:

$$x^1 = (0.127; 0.213; 0.104; 0.304; 0.109; 0.060; 0.083).$$

Normalizing coefficient is $\chi^2 = 1.87$.

The first-approximation coefficients of competence will take the values (table 3).

| $k^1_1$ | $k^1_2$ | $k^1_3$ | $k^1_4$ | $k^1_5$ | $k^1_6$ | $k^1_7$ | $k^1_8$ | $k^1_9$ | $k^1_{10}$ |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|
| 0.0927  | 0.0916  | 0.11    | 0.0962  | 0.0879  | 0.012   | 0.0852  | 0.012   | 0.1     | 0.099     |

Calculating the second-approximation group assessments, we obtain:

$$x^2 = (0.121; 0.217; 0.100; 0.314; 0.106; 0.057; 0.084).$$

Then we verify the sign of the iteration process end and obtain a value of less than 0.01, which complies with the required calculation accuracy.

The method of pairwise comparisons is applicable for a wide range of problems [4] and belongs to the group of numerous methods of pairwise comparisons, for which it is necessary to carry out the
reassessment [5] of the objects under consideration, since the method of expert interview differs fundamentally from the similar ones from the group of expert assessment methods [6–8]. The obtained pairwise comparison matrix A has the form:

\[
A = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 6 \\
5 & 5 & 9 & 9 & 5 & \\
5 & 1 & 3 & 1 & 1 & 1 \\
5 & 3 & 1 & 1 & 1 & 1 \\
9 & 7 & 9 & 1 & 9 & 9 \\
5 & 2 & 5 & 1 & 1 & 6 \\
6 & 4 & 3 & 1 & 1 & 1 \\
1 & 3 & 3 & 1 & 1 & 1 \\
9 & 9 & 5 & 5 & 1 \\
\end{bmatrix}
\]

To calculate estimates by the method of pairwise comparisons, we use Mathcad, the calculation process with explanations is shown in figure (1):

\[
v := \text{eigenvec}(A) \quad \text{– to determine the eigenvectors of the matrix } A
\]

\[
n := \text{eigenval}(A) \quad \text{– to determine the eigenvalues of the matrix } A
\]

\[
v = \begin{bmatrix}
0.154 & 0.536 & 0.0536 & -0.255 & -0.012 & -8.656i 	imes 10^{-3} & -0.033 \\
0.149 & -0.27 - 0.3i & -0.27 + 0.3i & 0.018 & -9.1 	imes 10^{-3} + 9.4i 	imes 10^{-3} & -9.1 	imes 10^{-3} - 9.4i 	imes 10^{-3} & -0.127 \\
0.109 & -0.112 - 0.38i & -0.112 + 0.38i & 0.449 & -0.022 + 0.016i & -0.022 + 0.016i & 0.085 \\
0.893 & -0.057 - 0.15i & -0.057 + 0.15i & 0.564 & 0.987 & 0.987 & 0.979 \\
0.328 & 0.198 - 0.072i & 0.198 + 0.072i & -0.255 & -0.031 + 0.152i & -0.031 - 0.152i & -0.12 \\
0.165 & -0.047 + 0.44i & -0.047 - 0.44i & 0.346 & -0.014 - 3.341i 	imes 10^{-3} & -0.014 + 3.341i 	imes 10^{-3} & -0.026 \\
0.104 & -0.251 + 0.24i & -0.251 - 0.24i & -0.48 & 2.72 	imes 10^{-3} - 5.5i 	imes 10^{-3} & 2.72 	imes 10^{-3} + 5.5i 	imes 10^{-3} & 0.041 \\
\end{bmatrix}
\]

\[
\sum v^{(0)} = 1.902
\]

\[
\sum \rho l = 1
\]

**Figure 1.** The process of estimates calculation using the method of pairwise comparisons.

3. Results and discussion

To compare the obtained results, it is necessary to determine a certain coefficient of conformity of the initial data for 2018 and the data obtained by expert assessment methods. For determination we use the Euclidean metric as the most popular distance function between two data sets. The calculation is made using the formula (3):
\[ d(p, q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \ldots + (p_n - q_n)^2} = \sqrt{\sum_{k=1}^{n} (p_k - q_k)^2} \]  \tag{3}

where \( p, q \) are the initial data and the data obtained by expert assessment method, respectively. The obtained results are shown in Table 4:

| Method \ Object | \( O_1 \) | \( O_2 \) | \( O_3 \) | \( O_4 \) | \( O_5 \) | \( O_6 \) | Metric value |
|----------------|--------|--------|--------|--------|--------|--------|-------------|
| Direct assessment method | 0.124  | 0.207  | 0.112  | 0.307  | 0.11   | 0.067  | 0.073       | 0.52346     |
| Group assessment method | 0.121  | 0.217  | 0.1007 | 0.314  | 0.106  | 0.057  | 0.0843      | 0.482323    |
| Method of pairwise comparisons | 0.081  | 0.078  | 0.057  | 0.469  | 0.172  | 0.08   | 0.055       | 0.288832    |
| Initial data | 0.025  | 0.005  | 0.022  | 0.722  | 0.08   | 0.11   | 0.036       | 1.00        |

By way of illustration of the obtained results, we plot a chart describing the information leaks breakdown by the channels in figure 2.

![Figure 2. Information leaks breakdown by the channels.](image)

4. Conclusion

Based on the data obtained, it can be concluded that the expert assessment methods are applicable within the framework of handling the problem of optimizing the information security process in the IAA IS, moreover, the calculation of Euclidean metric demonstrated that the method of pairwise comparisons is the most optimal and reliable.

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