The features of evaluation technical experts’ competence in the field of metrology

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Abstract. In the paper the improved method was proposed for evaluation of technical experts’ competence in metrology. Comparative analysis of the proposed method which is laid the basis for the software algorithm "Competence TE 1.0" and Borda Count method is applied to the electric power measurements was done for group technical experts. Experimental evaluation of accuracy proposed approach and traditional Borda Count method of voting is done in the field of electricity measurement.

1. Introduction
Expert evaluations are carried out in different areas of life in modern society for solutions of specific problems, taking into account the views of the technical experts (TE). Their essence consists in averaging the opinions of TE on the issues to be considered in various ways. Obtaining reliable estimates should be based on the opinion of qualified TE having special skills or knowledge in a particular field of activity. To do this is necessary correctly carry out the selection of TE who is involved in research and scientific and technical expertise of specific issues [1-4].

For the selection of TE, it is advisable to develop certain criteria for assessing the level of competence of TE. Accounting for the competence of TE should increase the reliability of the TE evaluation.

The most common TE methods include the ranking method, the direct estimation method, the pair comparison method [5-6]. Also widely used methods based on voting theory, such as the simple majority rule, the Borda Count method of voting (BCM), the Kemeny rule [7-9].

In order to objectively evaluation of the quality of independent work in the field of metrology is developed special software "Competence TE 1.0", designed to assess the competence of TE. In the framework of the software "Competence TE 1.0" founded an improved method, that takes into account the uncertainty of the data (UD), analysis of data consistency with the use Kendall coefficient of concordance (KCC) and analysis of consistency data using Pearson correlation coefficient (PCC).

The actual task is the development of software for both the processing of the results of the group expert evaluation itself and for the processing of objective data on TE involved in such an assessment. To implement these tasks, it is necessary to develop special software tools based on various algorithms.

2. Proposed improved method
Appropriate criteria are set for scoring expertise of TE and industry specific calculated to implement the improved method UD [10]: the average score \( \tau_i \) for each \( i \)-th TE from \( M \) TE for all criteria UD \( N \);
the relative average \( \bar{r}_i \) for each \( i \)-th TE from \( M \) TE; the normalized average \( \bar{n}_i \) for each \( i \)-th TE from \( M \) TE; the overall average \( \bar{X} \) for all \( M \) TE for all evaluation criteria is calculated according to the formula:

\[
\bar{X} = \frac{1}{M} \sum_{i=1}^{M} \bar{x}_i ;
\]

(1)

the relative overall average \( \bar{r}_r \) for all \( M \) TE is calculated according to:

\[
\bar{r}_r = \frac{\sum_{i=1}^{M} \bar{r}_i}{M} = 1 ;
\]

(2)

the average normalized score \( \bar{n}_x \) for all \( M \) TE is calculated according to:

\[
\bar{n}_x = \frac{\sum_{i=1}^{M} \bar{n}_i}{M}.
\]

(3)

Later parameters characterizing the consistency of the data of the TE are calculated: KCC taking into account the associated ranks. The received values of KCC are analyzed and concluded on the degree of consistency according to the data. If it is necessary, examines the score of correction values for certain criteria UD.

The resulting value of PCC \( \chi^2 \) for the level of confidence 0.05 is compared with a critical value \( \chi^2 > \chi^2_{1(0.05; M-1)} \). In case if the resulting criterion value less tabulated critical value, than are needed consideration of score correction values for specific criteria (Figure 1). TE are ranked in descending the order \( \bar{x}_m \).

Selection of TE is based on the Pareto principle with display results of UD on a special chart (Pareto diagram).

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**Figure 1.** Algorithm of the uncertainty of the data method.
3. The results of evaluation of technical expert competence

3.1 Processing data by Borda Count method

One of the main problems when processing TE information is choosing the best alternative (or candidate). One of the way to determine the winner and rank objects by the degree of manifestation of a certain feature are to assign points to each candidate based on its rank on each ballot. Finding a consensus relationship is a task of voting, in which the set $E$ is a set of candidates, and $\lambda$ is the set of voters. By methods of the theory of voting, based on the constructed rankings, one can find the only consensus relation, i.e. take such a decision, which will be approved by all participants in the process [10-11].

One of them the BCM also gives a ranking of the candidates. The method is that each TE is assigned a number of points depending on its place in the ranking: 0 points for the last position, 1 point for the penultimate position, etc. to $n - 1$ points for the first position. Points of each TE are summed across all rankings, and its position in ranking of consensus is determined by the received sum. If the total sum of the ranks are denoted as $S_i$, for every alternative $a_i$, then the best alternative is that which for $S_{i1} \geq S_{i2} \geq S_{i3} \geq \ldots S_{in}$.

For calculation points was used $(n \times n)$ electoral matrix $S = [s_{ij}]$, where:

$$s_{ij} = \sum_{k=1}^{m} b_{ij}^k, \quad i, j = 1, \ldots, n \quad (4)$$

$b_{ij} = 1$ if $E_i \succ E_j$; $b_{ij} = 0.5$ if $E_i \sim E_j$; $b_{ij} = 0$, if $E_i \preceq E_j$.

The sum of points earned for each TE on the ranking BCM in Table 1, is the sum of the corresponding line items of electoral matrix (Figure 2).

1. Compilation of the list of $M$ TE, estimate characteristics whose are analyzed
2. Building a preference profile from $M$ rankings
3. Assignment of ranks (scores) to alternative evaluated TE

- $E_i \succ E_j$, $b_{ij} = 1$
- $E_i \sim E_j$, $b_{ij} = 0.5$
- $E_i \preceq E_j$, $b_{ij} = 0$

4. Determination of the sum of ranks (scores) assigned to TE
5. Determination of the final consensus ratio
6. Calculations for establishing consistency of data based on TE calculations of KCC
7. Conclusion on the degree of consistency of data based on the calculated values of KCC
8. Calculations for establishing consistency of data based on TE calculations of PCC

- $\chi^2 > \chi^2_{(0.05, M-1)}$
- $\chi^2 > \chi^2_{(0.05, M-1)}$

9. TE are ranked in descending order and presenting it on a special chart
10. Identify reliable and unreliable TE

Figure 2. Algorithm of Borda Count method.
Apply BCM for evaluation TE competence. For example, the BCM was used to assess the problem of TE competence.

Preference profile is based on questionnaires developed for the 26 TE:

\[ \lambda_4: E_24 > E_1 - E_2 - E_3 - E_4 - E_5 - E_6 - E_7 - E_8 - E_9 - E_{10} - E_{11} - E_{12} - E_{13} - E_{14} - E_{15} - E_{16} - E_{17} - E_{18} - E_{19} - E_{20} - E_{21} - E_{22} - E_{23} - E_{25} - E_{26}; \]

\[ \lambda_2: E_3 - E_7 - E_9 - E_{10} - E_{11} - E_{12} - E_{13} - E_{14} - E_{15} - E_{20} > E_6 - E_{15} - E_{22} - E_{16}; \]

\[ \lambda_3: E_3 - E_7 - E_9 - E_{10} - E_{11} - E_{12} - E_{13} - E_{17} - E_{18} - E_{21} - E_{15} - E_{19} - E_{24} - E_8 - E_{14} - E_{16} - E_{22} - E_{26} > E_{23} > E_1 - E_2 > E_{25} > E_4 - E_5 - E_{20}; \]

\[ \lambda_4: E_3 - E_7 - E_9 - E_{10} - E_{11} - E_{12} - E_{13} - E_{14} - E_{15} - E_{17} - E_{18} - E_{21} - E_{22} - E_{23} > E_{15} - E_{19} - E_{24} - E_8 - E_{14} - E_{16} - E_{22} - E_{26} > E_{23} > E_1 - E_2 > E_{25} > E_4 - E_5 - E_{20}; \]

\[ \lambda_5: E_{20} > E_{24} > E_2 - E_4 - E_9 - E_{10} - E_{12} - E_{15} - E_{18} - E_{21} - E_{22} - E_{23} > E_8 - E_1 - E_3 - E_6 - E_{13} - E_{14} - E_{17} - E_{19} > E_8 - E_7 - E_{11} - E_5 - E_{16} - E_{26}. \]

**Table 1.** Competence coefficients for technical experts by using two methods.

| Technical expert, \( E_i \) | \( E_1 \) | \( E_2 \) | \( E_3 \) | \( E_4 \) | \( E_5 \) | \( E_6 \) | \( E_7 \) | \( E_8 \) | \( E_9 \) | \( E_{10} \) | \( E_{11} \) | \( E_{12} \) | \( E_{13} \) |
|-----------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total rank, \( S_i \)       | 31 | 40 | 84 | 35 | 17 | 69 | 76 | 36 | 78 | 84 | 70 | 84 | 75 |

| Technical expert, \( E_i \) | \( E_{14} \) | \( E_{15} \) | \( E_{16} \) | \( E_{17} \) | \( E_{18} \) | \( E_{19} \) | \( E_{20} \) | \( E_{21} \) | \( E_{22} \) | \( E_{23} \) | \( E_{24} \) | \( E_{25} \) | \( E_{26} \) |
|-----------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total rank, \( S_i \)       | 65 | 70 | 39 | 75 | 81 | 75 | 45 | 90 | 67 | 45 | 100 | 46 | 50 |

The sum of points earned for each TE on the ranking BCM, is the sum of the corresponding line items of electoral matrix. The final ranking of consensus in accordance with the BCM is:

\[ \beta_{BM} = \{ E_{24} > E_{21} > E_3 - E_{10} - E_{12} - E_{10} - E_{12} > E_{18} - E_9 > E_7 > E_{13} > E_{17} > E_{19} > E_{11} > E_{15} > E_6 > E_{22} > E_{14} > E_{26} > E_{25} > E_{20} - E_{23} > E_2 > E_{16} > E_8 > E_4 > E_5 \}. \]

3.2 Comparison results of evaluation of technical expert’s competence by two methods

For TE competence evaluation involved a group of 26 TE in field of electric power measurements whose competence were evaluated by two methods.

Calculated competence coefficients \( k_{UD} \) and \( k_{BM} \) are presented in Table 2.

**Table 2.** Competence coefficients for technical experts by using two methods.

| Technical expert | \( k_{UD} \) | \( k_{BM} \) |
|------------------|---|---|
|                  | 0.58 | 0.60 |
|                  | 0.88 | 0.85 |
|                  | 0.56 | 0.40 |
|                  | 0.60 | 0.81 |
|                  | 0.57 | 0.86 |
|                  | 0.88 | 0.91 |
|                  | 0.91 | 0.91 |
|                  | 0.88 | 0.91 |

| Technical expert | \( k_{UD} \) | \( k_{BM} \) |
|------------------|---|---|
|                  | 0.82 | 0.86 |
|                  | 0.65 | 0.70 |
|                  | 0.39 | 0.75 |
|                  | 0.81 | 0.75 |
|                  | 0.45 | 0.45 |
|                  | 0.90 | 0.67 |
|                  | 0.45 | 1.00 |

Statistical data for 26 TE in field of metrology are shown in Figure 3 for two methods.
Figure 3. Results of evaluation of technical experts’ competence

TE number \( E_{20}, E_{23}, E_2, E_{16}, E_8, E_4, E_1, E_5 \) were rated as the least competent and TE number \( E_{24} \) as the most competent by BCM;

TE number \( E_8, E_{20}, E_3, E_{16}, E_1, E_4, E_5 \) were rated as the least competent and TE number \( E_{24} \) is also as the most competent with the help of software “Competence TE 1.0”.

Both methods have determined that TE numbers \( E_1, E_2, E_4, E_5, E_8, E_{16}, E_{20} \) are not competent. And TE number \( E_{24} \) is the most competent. TE number \( E_5 \) is the least competent. Competence of TE number \( E_{23} \) needs further analysis.

For visualization of the conclusions of the above construct a correlation curve of distribution of competence coefficients for the two methods is presented (Figure 4).
Figure 4. Results of evaluation of the technical expert’s competence by two methods for electric power measurements.

Conclusion
The proposed improved method evaluation of TE competence in the field of electric power measurement allows effectively assesses the competence of the TE in any field of activity. This method is the basis of the developed software “Competence TE 1.0”. The comparative analysis made it possible to demonstrate its efficiency. The data ranking helps to efficiently identify, among a group of TE the most and least competent.

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