The evaluation of the expert competence in field of metrology difference methods

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Abstract. The practical results of evaluation of the expert’s competence for a few field of measurement for difference methods are presented. Comparison of results of evaluation of expert competence difference methods is made. Results of evaluated concordance of expert’s data for a few fields of measurement are shown. Special software and universal software are used for processing received expert’s data.

1. Introduction
The group expert evaluation is widely used in various fields [1-5]. They are intended to resolve problematic issues concerning certain activities to find solutions. For this is expedient to consider the opinions of qualified experts with special skills or knowledge in particular field [6-9]. Considering the practical competence of each expert is involved for group expert evaluation taking into account their objective professional data allows increasing the reliability and accuracy of such group expert evaluation.

The Rasch model or analysis is used to measure latent traits like attitude or ability. This model is a lot simpler and intuitive than many other models, and created from actual data. People can also be placed on the same measurement scale [10,11]. In [12] has been one attempt to link metrological and psychometric (Rasch) characterisation of man as a measurement instrument. In [13] a gentle introduction to Rasch measurement models for metrologist is presented. Establishing a link of the got results at the expert’s evaluation by means of Rasch model with expert’s competence requires further researches with an aim from comparableness with the got results by other evaluation methods.

Authentic knowledge of the real status of measurements of certain physical quantity is very important. The real status of measurements should be considered in two main approaches: traditional approach (calibration, verification and testing of measuring instruments for definition of the metrological characteristics, metrological expertise of methodologies of the measurements, etc.) [14,15], and not traditional approach (expert’s evaluation of status of measurements for improvement of metrological work in concrete field, etc.) [16,17]. Second approach can be one of the useful means solution of noted issue. An account the practical competence of each expert for evaluation of status of measurements allows to increase confidence level of expert’s evaluation.

2. Practical evaluation of expert competence in field of metrology
In [18] there suggested methodology of evaluation of expert’s competence that belong to the sphere of comparative evaluation of level of expert competence in various fields of activities. For
implementation of suggested methodology, corresponding criteria are set for the numerical score of expert competence of certain field.

Within the framework of realization of expert’s evaluation of the real status of measurements on the specially worked out criteria for evaluation of expert competence: E1 – education; E2 – total work experience; E3 – experience in field of metrology; E4 – experience of expert work in field of metrology; E5 – work status. The quantitative descriptions of expert’s competence were appraised by means of special software (“Competence UD 1.1” and “Competence AHP 1.1” [19,20]) for ten fields of measurements.

The view of these software windows for 21 experts for measurement of time and frequency are shown in Figure 1 with evaluated results, for example. 6 experts (“Competence UD 1.1”) and 7 experts (“Competence AHP 1.1”) from 21 evaluated experts (29 % and 33 % accordingly) have a level below than set (least competent experts) by evaluation with using Pareto principle (80/20) and Laurence curve.

Figure 1. Results of evaluation of expert’s competence for measurement of time and frequency (a – software “Competence UD 1.1”; b – software “Competence AHP 1.1”).
3. Comparison of results of evaluation of expert competence difference methods
Values of used competence coefficients $k_k$ are in range from 0 – minimum to 1 –maximum. Competence coefficients ($k_{UD}$ – for method evaluation with taking into account uncertainty data (UD), $k_{AHP}$ – for method evaluation which based on Analytic Hierarchy Process (AHP) [15,18]) for all experts as average $k_k$ ($k_{UD}$ or $k_{AHP}$) and for difference methods (method UD and method AHP) for ten field of measurement are given in Table 1 (AC is alternating current, DC is direct current, $U$ is voltage, $k$ is transformation coefficient).

Table 1. Competence coefficients and variations of expert’s competence coefficient for UD and AHP methods for all field of measurements.

<table>
<thead>
<tr>
<th>Field of measurement</th>
<th>Number of experts</th>
<th>$k_{UD}$</th>
<th>$k_{AHP}$</th>
<th>$R_{UD}$</th>
<th>$R_{AHP}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Electrical power</td>
<td>26</td>
<td>0.40</td>
<td>0.15</td>
<td>0.60</td>
<td>0.85</td>
</tr>
<tr>
<td>2 Electrical capacity</td>
<td>14</td>
<td>0.64</td>
<td>0.33</td>
<td>0.36</td>
<td>0.67</td>
</tr>
<tr>
<td>3 Electrical inductance</td>
<td>14</td>
<td>0.61</td>
<td>0.17</td>
<td>0.39</td>
<td>0.83</td>
</tr>
<tr>
<td>4 Phase shift angle</td>
<td>11</td>
<td>0.54</td>
<td>0.19</td>
<td>0.46</td>
<td>0.81</td>
</tr>
<tr>
<td>5 Time and frequency</td>
<td>21</td>
<td>0.58</td>
<td>0.30</td>
<td>0.42</td>
<td>0.70</td>
</tr>
<tr>
<td>6 Voltage AC</td>
<td>12</td>
<td>0.56</td>
<td>0.20</td>
<td>0.44</td>
<td>0.80</td>
</tr>
<tr>
<td>7 High-voltage DC</td>
<td>14</td>
<td>0.54</td>
<td>0.18</td>
<td>0.46</td>
<td>0.82</td>
</tr>
<tr>
<td>8 High-voltage AC ($U$)</td>
<td>15</td>
<td>0.54</td>
<td>0.18</td>
<td>0.46</td>
<td>0.82</td>
</tr>
<tr>
<td>9 High-voltage AC ($k$)</td>
<td>16</td>
<td>0.54</td>
<td>0.17</td>
<td>0.46</td>
<td>0.83</td>
</tr>
<tr>
<td>10 High AC current</td>
<td>15</td>
<td>0.54</td>
<td>0.20</td>
<td>0.46</td>
<td>0.80</td>
</tr>
<tr>
<td>Average:</td>
<td></td>
<td>0.54</td>
<td>0.20</td>
<td>0.45</td>
<td>0.79</td>
</tr>
</tbody>
</table>

The variation of competence coefficient for experts was calculated on a formula:

$$ R = k_{\text{max}} - k_{\text{min}} = 1 - k_{\text{min}}, $$

where: $k_{\text{max}}$ and $k_{\text{min}}$ are maximal and minimal competence coefficient for experts accordingly.

The got variations of competence coefficient $R$ for measurement of time and frequency amount such values: $R_{UD}$ is 0.42 and $R_{AHP}$ is 0.70.

Results of competence evaluation of 21 experts’ of difference methods (method UD and method AHP) for measurement of time and frequency are shown on Figure 2, for example.

![Figure 2](image-url)
The correlation of the evaluation results, which got UD and AHP methods, is obvious. Results got for method AHP have a more great range of values of competence coefficient $k_{AHP}$.

The evaluated average grades taking into account the expert’s competence for difference methods (method UD and method AHP) and for ten fields of measurement (see Table 1) are presented on Figure 3.

The correlation of the evaluation results got two methods is obvious, but values of competence coefficient for method AHP ($k_{AHP}$ from 0.40 to 0.64, average for ten field of measurement is 0.54) are smaller that values of competence coefficient for method UD ($k_{UD}$ from 0.12 to 0.33, average for ten field of measurement is 0.20).

For the analysis of concordance of the obtained data were used Kendall’s coefficient of concordance and Pearson’s $\chi^2$ criteria. Results of evaluated concordance of expert’s data for ten fields of measurement are presented on Figure 4.

The Kendall’s coefficient of concordance was calculated on a formula:

$$W = \frac{12S}{M^2(N^3 - N) - M \sum_{i=1}^{Q} T_i},$$

where:

$$T_i = \sum_{q=1}^{Q} (t_{iq} - t_{iq});$$

$S$ is a sum of squares of deviations from middle value;

$T_i$ is common number of the same ranks for $i$-th expert for all criteria of evaluation of the expert competence;

$t_{iq}$ is number of the same ranks for $i$-th expert for all criteria of evaluation of the expert competence;

$Q$ is number group of the same ranks for $i$-th expert for all criteria of evaluation of the expert competence;

$q$ is the same ranks for $i$-th expert for all criteria of evaluation of the expert competence.
The value of Pearson’s $\chi^2$ criteria was calculated on a formula:

$$\chi^2 = \frac{S}{MN(N+1)} - \frac{1}{N-1} \sum_{i=1}^{M} T_i$$

Values of Kendall’s coefficient of concordance changes in limits from 0.32 to 0.68 that corresponds to the “low” (from 0.20 to 0.36), “middle” (from 0.37 to 0.64) and “high” (from 0.64 to 0.80) levels of concordance on a Harrington scale [21,22].

At application of Pearson’s $\chi^2$ criteria was checked up for a condition: $\chi^2 > \chi^2_{T(0.05;M-1)}$, where $M$ is number of criteria that are executed for all fields of measurement (from 18.68 to 54.39).

Kendall’s coefficient of concordance and Pearson’s $\chi^2$ criteria for all field of measurement are given in Table 2.

Table 2. Kendall’s coefficient of concordance and Pearson’s $\chi^2$ criteria for all field of measurement.

<table>
<thead>
<tr>
<th>Field of measurement</th>
<th>Number of experts</th>
<th>$W$</th>
<th>Level of concordance</th>
<th>$\chi^2$</th>
<th>$\chi^2_{T(0.05;M-1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Electrical power</td>
<td>26</td>
<td>0.41</td>
<td>middle</td>
<td>54.39</td>
<td>37.65</td>
</tr>
<tr>
<td>2 Electrical capacity</td>
<td>14</td>
<td>0.67</td>
<td>high</td>
<td>22.81</td>
<td>22.36</td>
</tr>
<tr>
<td>3 Electrical inductance</td>
<td>14</td>
<td>0.33</td>
<td>low</td>
<td>27.03</td>
<td>22.36</td>
</tr>
<tr>
<td>4 Phase shift angle</td>
<td>11</td>
<td>0.44</td>
<td>middle</td>
<td>18.68</td>
<td>18.31</td>
</tr>
<tr>
<td>5 Time and frequency</td>
<td>21</td>
<td>0.59</td>
<td>middle</td>
<td>38.36</td>
<td>31.41</td>
</tr>
<tr>
<td>6 Voltage AC</td>
<td>12</td>
<td>0.38</td>
<td>middle</td>
<td>24.67</td>
<td>19.68</td>
</tr>
<tr>
<td>7 High-voltage DC</td>
<td>14</td>
<td>0.49</td>
<td>middle</td>
<td>33.20</td>
<td>22.36</td>
</tr>
<tr>
<td>8 High-voltage AC (U)</td>
<td>15</td>
<td>0.41</td>
<td>middle</td>
<td>34.32</td>
<td>23.69</td>
</tr>
<tr>
<td>9 High-voltage AC (k)</td>
<td>16</td>
<td>0.35</td>
<td>low</td>
<td>33.53</td>
<td>25.00</td>
</tr>
<tr>
<td>10 High AC current</td>
<td>15</td>
<td>0.32</td>
<td>low</td>
<td>32.22</td>
<td>23.69</td>
</tr>
</tbody>
</table>

5. Conclusion
Different methods of evaluation of expert’s competence are expedient to apply as useful instrument for the comparative estimation of expert’s competence on the basis of their objective data on the set criteria. This allows more reasonably carrying out the selection of the most competent experts for forming of group from the evaluation of certain problem questions in certain fields of activity. The group expert evaluation with involved experts in field of metrology can be a useful tool to establish the real status for specific measurements. Special and universal software can be used for mathematical processing of obtained expert data. It is expedient to conduct an analysis of concordance of the obtained data with using Kendall’s coefficient of concordance and Pearson’s $\chi^2$ criteria.

6. References
[16] Velychko O and Gordiyenko T 2015 Evaluation of competence of the experts in field of metrology and instrumentations. XXI IMEKO World Congress “Measurement in research and industry” (Prague, Czech Republic)