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FEATURES OF QUALIMETRIC ESTIMATION OF THE EDUCATIONAL AND LABORATORY COMPLEX «CHEMISTRY»

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Abstract – Features of qualimetric estimation of Educational and Laboratory Complex «Chemistry» designed and produced at Tomsk Polytechnic University were reported. A simplified qualimetric method for the quality estimation of the product for quality management was chosen. Complicating factors in the estimation of a complex product were shown. Comparison of the quality of the product with analogues existent in the markets of countries of CIS was carried out.

Keywords: qualimetry, quality estimation, simplified approach to the estimation

1. INTRODUCTION

Quality estimation of any product is a very complicated process, and requires a complex and systematic approach for the solution. The quality of a product depends on many factors. It's very difficult to take into account all these factors, which is why different methods of mathematical modelling, multivariable prediction, and algorithms with numerical and non-numerical models must be utilized. In this paper, we present a method to estimate the quality of the complex product, which consists of some separated parts. This fact complicated the quality estimation.

An object of estimation was Educational and Laboratory Complex Chemistry (or ELC Chemistry). The ELC Chemistry was designed and produced at Tomsk Polytechnic University to carry out some laboratory works on physical chemistry (thermochemistry, phase and chemical equilibrium, solution thermodynamics, conductometry, potentiometry, electrolysis, chemical kinetics and catalysis) at technical schools and colleges [1]. The complex includes a unit of electrochemical measurements, a thermostat and a calorimeter, a unit for liquids phase equilibrium examination, and a central controller (Fig.1). The controller can be connected to a personal computer, controls all the above-mentioned units, includes built-in current and voltage sources and allows measurement of temperature, potential difference, pH, electric current, and resistance.

The aims of the quality estimation were determination of a position of the product in the market**,** and ways to raise the quality of the product. Chosen for these purposes was a simplified qualimetric method for the quality estimation [2, 3]. This simplified method is characterized by maximum allowable error, and minimum allowable reliability of results. However, it is less laborious to compare with an accurate method and it allows us to achieve our aims.

The algorithm of quality estimation by a simplified method is shown in [2].

Since the accurate analogies consisting of the same units were not found, to estimate the quality of the ELC CHEMISTRY as a whole, the quality of each unit was estimated separately, and then the multifunctionality of the object was taken into account.

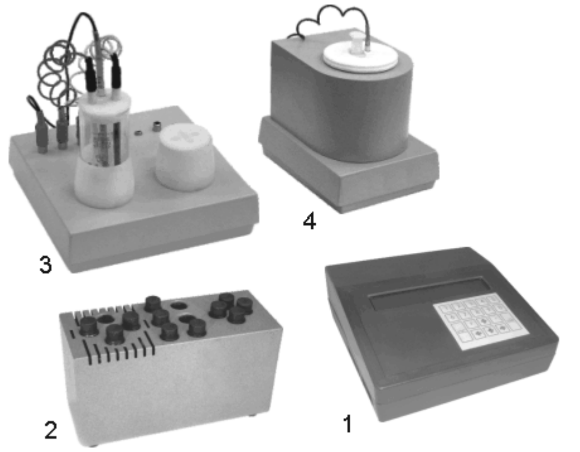

Fig. 1. Educational and laboratory complex CHEMISTRY 1 – controller; 2 – unit for liquid phase equilibrium examination; 3 – unit for electrochemical measurement; 4 – thermostat, calorimeter

2. DETERMINATION OF SITUATION OF ESTIMATION

At the first step of development of the quality estimation method**,** the situation of the estimation was defined, i.e. the following aspects were taken into account:

1. Students and teachers of colleges, and servicemen and repairmen of the complex were main users.
2. Processes of production, service, and storage were taken into account from all of the processes of the product cycle.

3. Opportunity to modernize the product in the future, due to the possibility of decisions to update the complex, i.e. addition of new units, improvement of old programs, and development of new ones for online data processing.
4. Longevity of the product is limited by depreciation of the complex.
5. Novelty of the estimation object was taken into account.
6. Places where the product is used are laboratory rooms at colleges, and specialized laboratories.
7. Environmental and climatic conditions which might affect the quality of the object are temperature and relative humidity of ambient air, atmospheric pressure, dust, steam from chemically active substances, destroyed insulation of wires, and an electromagnetic field.
8. Electromagnetic radiation is a property reflecting the product's action on the environment
9. Rectors, Heads of Departments, etc. of Russia and countries of CIS are likely customers.
10. The estimation of the quality of the ELC "Chemistry" performed on the base of an integral product-quality index.

3. PLOTTING HIERARCHICAL STRUCTURE of THE PROPERTIES by EXPERT METHOD

At the second step of the development of the quality estimation method, the hierarchical structure of the properties ("tree of properties") was plotted. The "truncated tree of properties" of the product is shown in Fig. 2. Branching of the "tree" is continued up to the simple properties of the object.
A complete "tree" consists of 7 levels. "Integral quality of the product" (1) is on the first level, "Quality" (2) and "Efficiency" (3) are on the second level. Properties of the ELC Chemistry at a stage of preparation for use (4) – which is divided into properties in storage (6), transit (7), installation (8), power supply (9), repair and service (10), dismantling (11) – and at a stage of use (5) – which is divided into properties of the unit for electrochemical measurement (12), the unit for liquid phase equilibrium examination (13), the thermostat, calorimeter (14), the controller (15) – are on the third level of "the tree". An example of the subsequent levels of the unit for electrochemical measurement is shown in Fig. 3. Ergonomical (17) and aesthetic (18) properties are shown only partially. "The full tree" consists of 170 simple properties, all of which we could not consider in our work. The properties of "the sub-tree" 5 were taken into account.

4. DETERMINATION of WEIGHTS

At the third step of the estimation, weights for all the properties were determined [3]. The Delphi method for determination of weights was used. Development engineers and experienced customers of the ELC Chemistry, numbering six members, acted as experts.

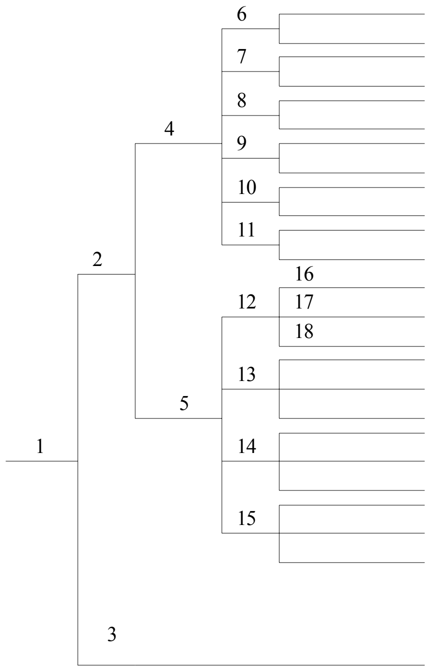

Fig. 2. "Truncated tree of properties" (5 levels) of the ULC Chemistry

The results of the estimation of weights for the unit for electrochemical measurement are shown in Table I. Conformity between the experts was tested using a coefficient of concordation [4]:

$$W = \frac{12S}{N^2(n^3 - n)} \tag{1}$$

Checking of significance of the coefficient of concordation was performed on the basis of the following criterion:

$$\chi^2 = N(n-1)W \tag{2}$$

The value of χ^2 was compared with the value of χ^2_α taken from special tables for confidence level α and corresponding degree of freedom $\nu = n-1$.
If $\chi^2 < \chi^2_\alpha$ we could presume that the estimations of the experts correlated.
The coefficient of concordation for our expert group was 0,89 and the estimations of experts correlated.

The weights were determined for all the simple properties of the controller, the unit for liquid phase equilibrium examination, the thermostat and calorimeter and for each level according to a method described in [5].

The performance of the following equation is required for each level:

$$\sum q_i = 1 . \tag{3}$$

5. SIMPLIFIED METHOD of ESTIMATION

The next step of the quality estimation was searching of analogies for comparison of ELC Chemistry with similar commodities in the markets of Russia and the countries of CIS, using patent documentation, bulletins, catalogues, and the Internet. The product with the same units was not found, but some of the analogies for the unit for electrochemical measurement are shown in Table 2.

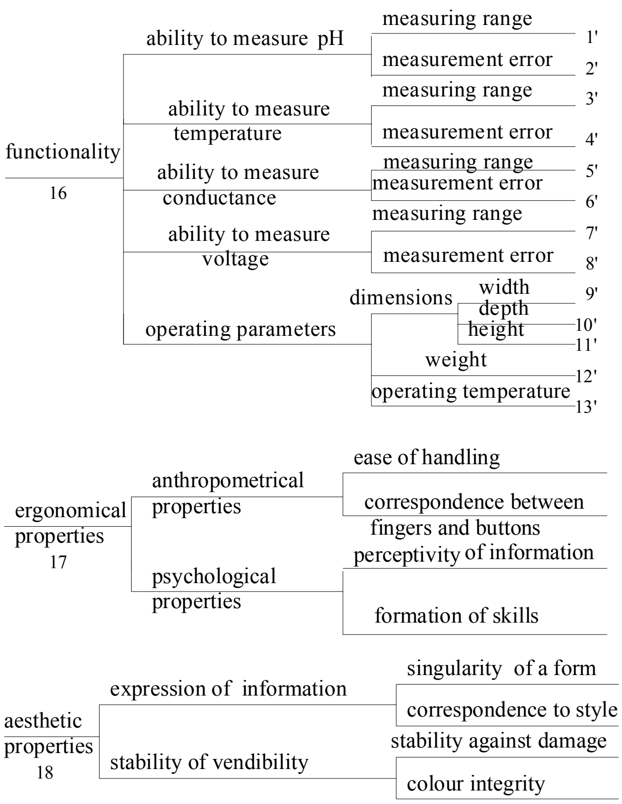

Fig. 3. The branches of "the sub-tree of properties" of the unit for electrochemical measurement

TABLE 1. Results of estimation of weights of the unit for electrochemical measurement

Product-quality index	Weights. prescript experts						$\hat{q}$
	1	2	3	4	5	6	
1'	0,8	0,9	0,8	0,7	0,8	0,9	0,82
2'	1	1	1	1	1	1	1
3'	0,7	0,8	0,8	0,7	0,6	0,7	0,72
4'	1	1	1	1	1	1	1
5'	0,8	0,8	0,8	0,8	0,7	0,9	0,80
6'	1	1	1	1	1	1	1
7'	0,8	0,9	0,8	0,8	0,8	0,9	0,83
8'	1	1	1	1	1	1	1
9'x10'x11'	0,1	0,2	0,2	0,2	0,1	0,2	0,17
12	0,1	0,2	0,2	0,2	0,1	0,2	0,17
13	0,4	0,3	0,2	0,3	0,2	0,3	0,28

The process of quality estimation by a simplified method includes 3 steps [3]:
1. determination of values of absolute product-quality indexes;
2. calculation of values of relative product-quality indexes;
3. estimation of a complex product-quality index.

The values of the absolute product-quality indexes were determined using the documentary method. (i.e. the main technical data were found in service forms and records). The numerical values of absolute product-quality indexes Q_i were determined only for the properties which are situated on the last level of the whole or truncated tree.

TABLE 2. Analogues of the unit for electrochemical measurement

Specifications / Analogue	Measuring range	Accuracy	Operating temperature (ambient)
Computer measuring unit (L-micro)	-50…10 V	1 %	0…60
Multimeter Anion 4155 (Laverna)	-2000…2000 mV	0.1%	1…40 °C
pH-meter-millivoltmeter pH-150 M (Laverna)	-1999…1999 mV	0.2%	-10…100 °C
Anion 7051 (Ekros)	-1000…1000 mV	0.2%	1 – 40 °C
Unit for Electrochemical Measurements of ELC Chemistry	-3…3 V	1 %	10 – 30 °C

In this step we have to solve two problems concerned with determination of the complex product-quality index:

- the problem of comparability of the values of the absolute product-quality indexes;
- the problem of combination of all the indexes into a complex index, which will characterize the quality of the product.

The values of the absolute product-quality indexes of ELC Chemistry have different units of measurement. Obviously, they cannot be combined into the complex product-quality index K_c. The absolute product-quality indexes Q_{es} were normalized, i.e. the absolute product-quality indexes were converted into the relative product-quality indexes, which were expressed in the same non-dimensional scale for the all properties. In this case the relative values of the product-quality indexes K_{rel} were expressed in the scale: from 0 up to 1.

The best values of the product-quality indexes Q_{st} of analogues were accepted as standards for calculation of the values of relative product-quality indexes.

If the large value of a product-quality index reveals higher quality, (i.e. measuring range) we used the following equation:

$$K^{rel} = \frac{Q_{es}}{Q_{st}} \quad (4)$$

If the small the value of a product-quality index shows higher quality (i.e. accuracy), we used the following equation:

$$K^{rel} = \frac{Q_{st}}{Q_{es}} \quad (5)$$

The results of the relative values of product-quality index of the unit for electrochemical measurement and its analogues (A - Multimeter Anion 4151 (Laverna), B - Multimeter Anion 4154 (Laverna), C - Multimeter Anion 4155 (Laverna), D - Anion 7051 (Ekros), Multi-channel Ionomer- Conductivity apparatus Anion-410, Unit for Electrochemical Measurements of ELC Chemistry (Unitech)) are shown in Table 3. Some values of product-quality indexes, such as "measuring range", "operating temperature" were calculated as a difference between max and minimum values.

TABLE 3. Relative values of product-quality index of the unit for electrochemical measurement

Product-quality index	Relative values of product-quality index					
	A	**B**	**C**	**D**	**G**	**E**
1'	1	1	1	0,87	0,87	0,87
2'	1	1	1	0,6	0,6	0,6
3'	1	1	1	1	1	1,8
4'	1	1	1	1	1	2
5'	0,1	0,1	0,1	1	1	1,5
6'	1	1	1	0,5	1	0,75
7'	1	1	1	0,2	0,2	0,1
8'	1	1	1	1	1	4
9'x10'x11'	0,45	1	1	0,19	0,5	0,24
12	0,55	0,55	0,55	1	0,38	0,42
13	1	1	1	1	1	0,51

The last step was estimation of a complex product-quality index. It can be expressed as an arithmetical weighted average, a geometric weighted average, a harmonic weighted average, or a quadratic weighted average. It can be useful to use some combinations of them.

Comparison of the weighted averages, however, showed that the grades of all apparatuses did not depend upon the harmonic weighted average mathematical model.

That is why we used the arithmetical weighted average for quality estimation:

$$K_c = \sum_{j=1}^{n} q_j K_{ij}^{rel}, \quad (6)$$

where K_{ij}^{rel} is the value of relative product-quality index of *i*-th property of j-th object; q_i is weight of *i*-th product-quality index.

The series of ranks for the relative values of product-quality index of the unit for electrochemical measurement is: E>B>C>A>G>D.

An expert method was used for determination of the values of the product-quality indexes of ergonomical and aesthetic properties, because it is difficult to use the other estimation methods in this case.

Two questionnaires for the experts were done for determination of the values of ergonomical and aesthetic properties. A numerical score for each questionnaire was offered. To estimate each property an expert had to answer one or two questions.

The last step of the estimation was comparing all the results obtained. It could be done only by using an expert method, because the results were collected using different scales. The best complex was ELC Chemistry, because it concedes on some properties but it contains four units. There is no analogue which can perform as many measurements .

4. CONCLUSION

In the first steps of the quality estimation for such a complicated object as Educational and Laboratory Complex «Chemistry», a simplified method can be used, but it is necessary to use mathematical modelling at the last steps of the estimation. Comparison of the units of the complex with the analogues was not a problem, but comparing the whole complex with its analogues requires the application of complicated mathematical modelling.

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