Modeling the weight of criteria for determining the technical level of agricultural machines

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Abstract. The article presents the results of theoretical research on the methodological provisions of the weight of the criteria in determining the technical level of agricultural machinery. The expediency of using relative, in parts of change, values of evaluation indicators, which allows to objectively and reliably obtain the value of the weight of the criteria in determining the technical level of agricultural machinery. The applied problem of determining the weights of the criteria in the study of the technical level of combine harvesters is considered. Five criteria are substantiated: reduction of direct costs, reduction of energy consumption, reduction of labour costs, reduction of material consumption, increase of reliability. The weight of the criterion reflects the degree of its importance in the rank of the sequence, their values are in the range 0...1. Five indicators are substantiated: operating costs, direct fuel costs, specific labour costs, specific material consumption, failure time. It is established that in the process of operation of the combine harvester Slavutich KZC-9M with a reduction of 30% of operating costs, the weight in determining the technical level is 0.1473. Studies have shown that a 25% reduction in direct fuel consumption is 0.1228 weight in determining the technical level of the combine harvesters.

1. Introduction
Prospects of technical solutions of agricultural machines are substantiated by their technical level [1]. Under the technical level of agricultural machinery is understood the degree of perfection of this technical solution in comparison with the basic model of the agricultural machinery [2]. The basic domestic [3] or foreign agricultural machine can serve as a basic sample [4]. Often the task of determining the technical level of agricultural machinery is reduced to a comparative assessment of domestic [5] and foreign agricultural machinery [6] when using them in the given natural and economic conditions of the country [7]. The solution of such a problem is considered in this article.

Solving this problem requires the following four steps.

Stage 1. Substantiation of evaluation criteria [8] and nomenclature of indicators of agricultural machinery [9].
Stage 2. Identification of alternatives to technical solutions of machine-tractor units [10] or technological complexes of agricultural machines [11].

Stage 3. The choice of method for calculating the technical level of agricultural machinery [12] and multicriteria evaluation [13].

Stage 4. Analysis of results [14] and development of proposals for decision making [15].

All four stages form the basis of the overall methodology of systems analysis [16]. To perform these steps [17], a variety of methods are proposed [18], including in regulations [19]. In this case [20], a generalized method for agricultural production is not and cannot be, because the evaluation criteria [21] and the nomenclature of indicators are different for different machine-tractor units [22]. However, common to all tasks is the fact that in the third stage it is necessary to determine and use the weight of the criteria [23].

The use of weights is provided by almost all existing methods of assessing the technical level of the agricultural machine [24], because the indicator of the technical level is a complex indicator [25], in the calculation of which weights are used [26]. The value of the coefficient of technical level of an agricultural machine depends on how objectively justified the weights [27]. Hence the conclusions for deciding on the use of this machine-tractor unit [28].

2. Purpose of research
The purpose of the research is devoted to the method of substantiation of the weight of the criteria in determining the technical level of agricultural machinery. The use of relative, in parts of change, values of evaluation indicators will allow to objectively and reliably obtain the value of the weight of the criteria.

3. Materials and methods
Consider the problem of determining the weight of the criteria in the study of the technical level of combine harvesters. On the basis of the analysis of normative documents [29], forecasts of development of equipment for assembly of grain crops the following evaluation criteria [30] and the indicators corresponding to them are chosen (table 1).

| Criterion                        | Indicator                          | The unit of measurement of the indicator |
|---------------------------------|------------------------------------|----------------------------------------|
| Reduction of direct costs       | Operational expenses               | (UAH/ha)                               |
| Reducing energy consumption     | Direct fuel consumption            | (l/ha)                                 |
| Reducing labor costs            | Specific labor costs               | ({people-hours}/ha)                    |
| Reducing material consumption   | Specific material consumption      | (kg/ha)                                |
| Improving reliability           | Earnings on failure                | (hours)                                |

The weight of the criterion reflects the degree of its importance in the rank of the sequence [31], their values lie in the range 0...1 and are determined in the following ways: cost regression dependencies [32]; equivalent ratios [33]; expert assessments [34]; limit and nominal values [35].

The method of cost regression dependencies is used when conducting a comparative assessment of costs for the creation and operation of agricultural machinery, depending on the technical level of the machine itself. It can be used when assessing the technical level of domestically produced or developed agricultural machinery. It is impossible to estimate foreign-made agricultural machines by this method, because the costs of creating an agricultural machine are unknown.

The method of equivalent ratios is used in cases where it is possible to justify the relationship between the number of agricultural machinery produced and the values of their technical level. For agricultural machinery, such a connection cannot be detected, even if it exists.

The method of expert assessments is used when other methods cannot be applied. Although this method is recommended by many authors and regulations, the resulting weights are subjective.
Therefore, the method of limit and nominal values should be preferred, because it is an analytical method, and the limit values of evaluation indicators can be justified on the basis of analysis of changes in existing technical solutions of agricultural machinery over a period of time. The proposed formula for determining the weight $V_i$ by the method of limit and nominal values has the form:

$$V_i = (p_{ih} - p_{in})^{-1} \cdot (\sum_{i=1}^{n}(p_{ih} - p_{in})^{-1})^{-1},$$

where $p_{in}$ – the limit (forecast) value of the indicator of the $i$-th criterion of the technical level of agricultural machinery; $p_{ih}$ – nominal value of the indicator of the $i$-th criterion of the technical level of agricultural machinery; $n$ – the number of indicators of the technical level of agricultural machinery.

4. Results and discussion

The use of formula (1) gives results that contradict the essence of technical progress in agricultural engineering and agricultural operation. Let's show it on a simple example. Calculate the weights according to three criteria, the values of which and the results of calculations by formula (1) are given in table 2.

**Table 2. Example of using dependence (1) to determine the weight of the criteria.**

| Evaluation indicator            | The value of indicators | The weight of the criterion |
|---------------------------------|-------------------------|-----------------------------|
| Operating costs, (UAH/ha)       | 20                      | 10                          | 0.270 |
| Energy intensity, ([kWh]/ha)    | 8                       | 4                           | 0.676 |
| Operating time on failure, (hours) | 50                     | 100                         | 0.054 |

This example shows that it is desirable to double all indicators. It was expected that the weights for all criteria should be the same, but this did not happen. Therefore, formula (1) is not suitable for determining the weight, because the value of the weight is not affected by the relative differences between the limit and nominal value, and their absolute values.

We have proposed such a ratio to determine the weight of the criteria of the technical level of agricultural machinery, which allows to implement this feature. The greater the relative difference between the limit and nominal values for this criterion, the greater the weight. If this difference is equal to zero, the nominal value has reached the limit level, then the weight is also equal to zero. Therefore, to determine the weight of the criteria of the technical level of agricultural machinery, it is proposed to use not absolute values, but relative, i.e. the share of improvement of the criterion in the future. Then the formula for determining the weight will take the form:

$$V_i = (1 - q_i) \cdot (\sum_{i=1}^{n}(1 - q_i))^{-1},$$

where $q_i$– the share of improvement of the $i$-th criterion of the technical level of agricultural machinery in the future:

$$q_i = p_{in} \cdot (p_{ih})^{-1},$$

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Depending on the direction of improvement of the technical level of agricultural machinery, one of two formulas is used to calculate $q_i$. If, in accordance with the requirements of technical progress, the indicator needs to be reduced, then formula (3) is used, and if the indicators need to be increased, then formula (4) is used. The nominal values are the average statistical values of the technical level of agricultural machinery, which were achieved during the assessment of the technical level for domestic machinery. The limit values of the indicators are substantiated by the results of the forecast of the development of agricultural technologies and equipment, taking into account the current level achieved by foreign firms. The advantage of the proposed method is that it is not necessary to know the numerical values (marginal and nominal), it is enough to know by what percentage or how many times
you need to improve this indicator in order to then express the relative change in the share. This feature is quite important when using data on foreign machines, the achieved indicators of which are used in setting the limit values. For example, the operating costs of the Slavutich KZS-9M combine should be reduced by 30%. Then $q_l = (100 - 30)/100 = 0.70$. Let the energy consumption need to be reduced 1.4 times. Then $q_l = 100/140 = 0.714$.

Table 3 shows the values of changes in selected indicators for the period up to 2020, which are based on scientific and technical forecast of agricultural machinery for harvesting grain crops, and which should be used to assess the technical level of combine harvesters and the weight of criteria calculated by the formula (2).

Table 3. Limit values of technical level indicators and their weight for combine harvesters.

| Indicator                  | The value of indicators | The value of change in indicator | $q_l$  | $V_i$  |
|----------------------------|-------------------------|---------------------------------|--------|--------|
| Operational expenses      | 100% 70%               | reduce by 30%                   | 0.70   | 0.1473 |
| Direct fuel consumption   | 100% 75%               | reduce by 25%                   | 0.75   | 0.1228 |
| Specific labor costs      | 1.00 0.714             | reduce by 1.4 times             | 0.714  | 0.1405 |
| Specific material consumption | 100% 60%            | reduce by 40%                   | 0.60   | 0.1965 |
| Earnings on failure       | 60 ha 240 ha           | not variable                    | 0.200  | 0.3939 |

It is established that in the process of operation of the combine harvester Slavutich KZC-9M with a reduction of 30% of operating costs, the weight in determining the technical level is 0.1473. Studies have shown that a 25% reduction in direct fuel consumption is 0.1228 weight in determining the technical level of the combine. Note that the obtained weights for the given conditions of improvement of the evaluation indicators reproduce the objective values. These values are normalized, i.e. $\sum V_i = 1$.

5. Conclusions
The proposed model of substantiation of the weight of the criteria of agricultural machinery in determining the technical level of machinery allows to obtain results objectively and reliably, as it provides for the use of relative, in fractions of the values of evaluation indicators.

It is established that in the process of operation of the combine harvester Slavutich KZC-9M with a decrease of 30% of operating costs, the weight in determining the technical level is 0.1473. Studies have shown that a 25% reduction in direct fuel consumption is 0.1228 weight in determining the technical level of the combine.

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