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Car integral performance index simulation

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*Introduction.*The paper is devoted to the comparison and evaluation of the quality of a car using the method of mathematical simulation of the integral performance index. The work objectives were to develop a mathematical modeling technique for the integral performance index, to draw up a step sequence of quality assessment, to analyze most common brands of passenger cars on the domestic market, to sum up and validate the result obtained.

Materials and Methods. The sequence of simulating the integral performance index is proposed. Numerical modeling of the integral performance index is carried out on the example of six most common brands of passenger cars on the domestic market.

Results. A method of modeling the integral performance index is developed. A step sequence of the analysis is described. An additive form of determining the integral performance index which provides combining single, unrelated quality indices into a complex indicator in the process of comparison is proposed.

Discussion and Conclusions. The proposals presented can be used in the process of assessing and diagnosing the competitiveness of not only cars, but also of other products with a large set of independent quality indicators.

Keywords*:* modeling, integral index, quality requirements, motor car, performance specifications, additive method, weight coefficient.

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Introduction. To obtain, systematize, describe and apply accumulated knowledge and information in any field of activity, a universal simulation technique is most widely used. Mathematical modeling is systematically supported and updated in many fields of science. Mathematical modeling provides combining accumulated knowledge and real processes including mental ones [1], combining the ability to reproduce the properties of a real or created object, process or phenomenon using another object, process or phenomenon.

Quality is a combination of consumer properties unrelated to each other through technical characteristics that must satisfy current and future needs [2]. At the same time, a close relationship between quality and requirements can be traced. Requirements are specific features and conditions that correspond to consumer preferences throughout the life of the product. Product requirements are laid at the design stage [3, 4].

However, quality and requirements have some inconsistency [5, 6]. This is most pronounced in the discrepancy between the declared technical qualities of the goods and the requirements of consumers. This is due to the constant change in consumer requirements depending on technology development, as well as the financial and cultural condition of the population.

Depending on the number of characterized properties and on their influence on the quality of the product, quality indices are divided into simple and complex. A simple index enables to characterize one property or one dependence of quality on the technical and operational characteristics, while a complex index combines several characteristics.

There is a concept of direct and inverse indices. An increase in direct indices causes an increase in quality; an increase in inverse indices causes a decrease [7].

After analyzing the classification of product quality indices (Fig. 1), we can conclude that the integrated index is a special case of a complex index. An integrated quality index characterizes the ratio of the overall useful effect during the operation of a given product to the cumulative costs of its purchase, operation or consumption [8].

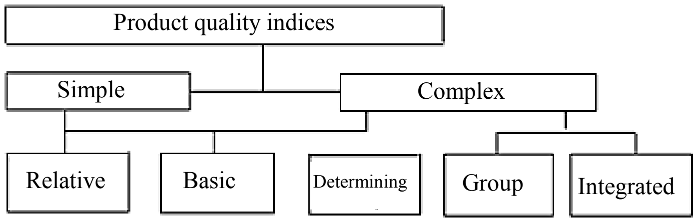

Fig. 1. Classification of product quality indices

Simulation technique for the integrated index of product quality.

The definition of a quality index by an example of a car is carried out in the sequence:

• goal setting;

• selection of prototypes for comparison and choice of the optimum alternative;

• selection of parameters characterizing the product from the standpoint of the consumer;

• determination of averages of quality indices;

• combining averages into one index for each brand;

• analysis of the integrated indices obtained for all prototypes;

• decision-making on product quality control.

The greatest difficulties are the selection of characteristics and obtaining the averages of these data [9] since there are no common techniques for forming a list of quality indices and transforming each index into a numerical form. To determine the integrated quality index, its additive form is widely used, i.e., the weighted average summation, which allows combining simple, unrelated quality indices into a complex index. It is used in cases when decisions are made on the economically best option if several prototypes are available on the market. That is, this technique is most suitable for modeling an integrated index of car quality.

The formula for calculating the complex integrated index [10]:

$$K_i = \sum_{i=1}^{n} \alpha_i \cdot \bar{X}_i,$$

where α_i is weight coefficient of the i-th parameter; $\bar{X}_i$ is the averaged quality index for the i-th parameter; n is the number of parameters to compare.

To determine the weight coefficient, an expert method is used according to the expression:

$$\sum_{i=1}^{n} \alpha_i = 1.0.$$

The algorithm of the calculations used can be traced on the example of choosing the best option for buying a car (Fig. 2).

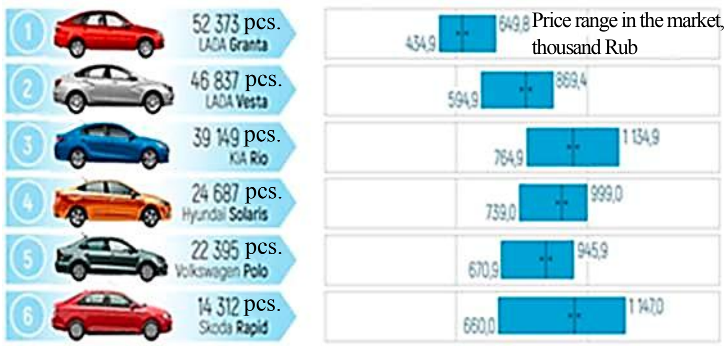

Fig. 2. Popular sedans at the domestic market

The analysis was carried out on the bestselling cars at the domestic market. The hierarchy is implemented by price characteristics.

Study Results. For the purity of the experiment, six sedan cars were compared in the same price category. There are several tens of quality indices; in the calculations, an integrated index was calculated for 6 groups of basic (from the consumer's point of view) quality indices. The initial data for the calculation are given in Table 1. In practice, the use of such quality assessments can take into account a different number of characteristics, even considering the fact that many of them have a rather contradictory effect on quality and, in their physical nature, are very difficult to quantify.

Table 1

Source Data

Car parameter	Model					
	Lada Granta	Hyundai Solaris	Skoda Rapid	Kia Rio	Lada Vesta	Volkswagen Polo
Price, thousand Rub	580	750	680	640	600	690
Mileage, thousand km	50	75	57	26	53	50
Fuel rate, l	7.2	8.3	8.5	6.4	8.7	8.0
Power, kWt	72.07	90.50	80.91	73.50	78.00	80.91
Clearance, mm	170	160	136	160	171	163
Acceleration time, s	11.5	11.0	10.0	13.1	12.8	11.7

An intermediate stage of the calculation is to obtain the averages of the 6 considered quality indices for each model. The weight coefficient is determined by the expert evaluation method, where the human factor (personal preferences) also plays an important role in the assessment and significantly affects the final value of the integrated quality index of the sedans compared. The calculation results are presented in Table 2.

Table 2

Calculation Results

Quality index	Model					
	Lada Granta	Hyundai Solaris	Skoda Rapid	Kia Rio	Lada Vesta	Volkswagen Polo
Rank by sales	1	4	6	3	2	5
Weight coefficient	0.11	0.15	0.25	0.15	0.14	0.20
Integrated quality index	0.32	0.32	0.71	0.48	0.33	0.49
Rank by quality index	5	5	1	3	4	2
Marketability	$55\cdot10^{-5}$	$42\cdot10^{-5}$	10^{-3}	$75\cdot10^{-5}$	$55\cdot10^{-5}$	$71\cdot10^{-5}$

Thus, the maximum quality integrated index belongs to Skoda Rapid and it is 0.71. At the same time, the values of the quality factor of the other compared cars that are in the same price range differ slightly. The values of the competitiveness indicator of the compared sedans are obtained by the ratio of the quality index and the cost of the car. This is also maximum estimator for Skoda Rapid, which is explained by the fact that the buyer of this car for one monetary unit gains more quality than buyers of the prototypes compared.

Discussion and Conclusions. Recording information about an object of research or design requires using mathematical simulation to store and transmit it in space or in time. The simulation is aimed at building, improving, studying and applying models of actually existing or designed objects for the subsequent assessment of their competitiveness. The integrated quality index is one of the unified indicators that can implement a comparison of indices even with a conflicting effect on quality.

References

1. Teplyakova SV, Cherpakov AV, Kosenko VV, et al. Matematicheskoe modelirovanie nadezhnosti mashin [Mathematical modeling of machine reliability]. In: Proc. Int. Conf. on "Physics and Mechanics of New Materials and Their Applications" (PHENMA 2016): Abstracts&Schedule, 19–22 July, 2016. Indonesia, Surabaya; 2016. P.268. (In Russ.)

2. Teplyakova SV, Cherpakov AV, Kosenko VV, et al. Analiz trebovanii dlya obespecheniya absolyutnoi bezotkaznosti mashin [Analysis of requirements to ensure absolute machine reliability]. In: Proc. Int. Conf. on "Physics and Mechanics of New Materials and Their Applications" (PHENMA 2016): Abstracts&Schedule, 19–22 July, 2016. Indonesia, Surabaya; 2016. P.267. (In Russ.)

3. Saati T, Kerns K. Analiticheskoe planirovanie. Organizatsiya sistem [Analytical planning. Organization of systems]. Moscow: Radio i svyaz'; 1991. 224 p. (In Russ.)

4. Teplyakova SV, Kotesova AA, Kopylov FS, et al. Opredelenie parametrov zakona Veibulla [Determination of the Weibull law parameters] Scientific Life. 2019;14(2):14–18. URL: http://www.sced.ru/ru/index.php? option=com_content&view=article&id=722:nauchnaya-zhizn-02-2019&catid=39& Itemid=156 (accessed 19.12.2019). (In Russ.)

5. Nedoluzhko AI, Smirnov II, Kotesova AA, et al. Ehffektivnost' diagnostiki avtomobilei s ehlektronnymi blokami upravleniya [Efficiency of diagnostics of cars with electronic control units]. In: Proc. 7th Int. Sci.-Pract. Conf. on "Quality in production and socio-economic systems". Kursk: Publ. House of South-West. University. 2019;2:9–12. URL: https://www.elibrary.ru/item.asp?id=37536406 (accessed 04.05.2020). (In Russ.)

6. Kas'yanov VE, Teplyakova SV. Metody obespecheniya absolyutnoi bezotkaznosti detalei mashin [Methods of reliability of machine parts]. Naukovedenie. 2013;3:139. URL: https://naukovedenie.ru/PDF/39trgsu313.pdf (accessed 04.05.2020). (In Russ.)

7. Fedyukin VK, Durnev VD, Lebedev VG. Metody otsenki i upravleniya kachestvom promyshlennoi produktsii: uchebnik dlya vuzov [Methods for assessing and managing the quality of industrial products]. Moscow: Filin" Rilant; 2001. 328 p. (In Russ.)

8. Fatkhutdinov RA. Konkurentosposobnost': ehkonomika, strategiya, upravlenie [Competitiveness: economics, strategy, management]. Moscow: INFRA-M; 2000. 312 p. (In Russ.)

9. Kas'yanov VE, Teplyakova SV. Teoreticheskie osnovy obespecheniya absolyutnoi bezotkaznosti detalei za zadannyi resurs [Theoretical foundations of ensuring absolute reliability of parts for a given resource]. Sovremennyi nauchnyi vestnik. 2015;1(2):59–70. (In Russ.)

10. Kolesov IM, Sycheva NA. Kachestvo i ehkonomichnost' produktsii [Product quality and economy]. Standards and Quality. 2000;9:70–72. (In Russ.)

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Claimed contributorship

S. V. Teplyakova: basic concept formulation; research objectives and tasks setting; computational analysis; data acquisition, analysis and interpretation. A. A. Kotesova: text preparation; formulation of conclusions and of the first version of the paper. N. N. Nikolaev: analysis of the research results; the release paper version revision.

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