# OPERATIONAL QUALITY OF A TRUCK IN EXPERT'S ASSESSMENT

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## Abstract

The article presents the results of expert assessment of the quality of three different branches of trucks in terms of their suitability for long-term rental. The expert assessment is faster and cheaper compared to the analogous evaluation obtained on the basis of operational tests, hence the purpose of this article is to assess the accuracy of the results obtained in expert studies. The reliability characteristics of vehicles, such as: readiness, probability of first failure and distribution of mileage between successive repairs, were used as parameters for empirical quality assessment. Operational tests covered three groups of 30 vehicles. As part of the research, changes in vehicle technical readiness occurring during operation were also assessed. The failures of individual functional systems of the vehicle were also analyzed and compared with the results of expert studies. The expert assessment was based on a questionnaire regarding the overall assessment of the reliability and performance of cars. 32 experts - appraisers, with good knowledge of the construction of cars of the tested brands participated in these studies. On the basis of comparisons of the results of the expert assessment with the results of empirical studies, conclusions were drawn regarding the correctness of the assessment made by experts.

**Keywords:** operational quality, reliability, maintenance, expert's assessment

## 1. Introduction

Quality is defined as the degree to which the product or service meets the requirements of the recipient. "Operational quality" can be defined as the degree of compliance with the requirements set by the operator, such as the requirements for the use and operation of the object. The requirements set are always directly dependent on the recipient (user) and always have a subjective - individual character [21]. Users performing the same work have similar requirements. Common requirements result from the aim function that is assigned to the activities performed. In the case of trucks, the overriding purpose of the aim

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is a paid for profit-making transport of goods. Regardless of the type of transport order, one of the basic requirements is always to deliver the goods on time. For this reason, an important feature of the vehicle should be defect-free operation. Since vehicles defects occur always and must be rectified, the reliability parameter, that is technical readiness, can be used as an indicator of vehicle quality. The technical readiness indicator defines average value of the probability with which the vehicle was in the state of suitability over its entire lifetime. The same value will be obtained when there are many defects with short repair times or few defects with correspondingly longer repair times. Determining the readiness requires gathering information from a long period of operation. An easier and often used method of assessing the quality of a vehicle is the expert method. The expert, taking into account selected features of the vehicle, makes a subjective assessment of its quality. The article presents the results of expert quality assessment of three makes of trucks. The expert assessment was compared with the results of operational tests regarding the reliability of these vehicles.

## 2. Empirical comparative studies on operational quality

The empirical comparative tests of operational quality involved three samples of trucks of various makes in the number of 30 each. The cars were operated under long-term rental conditions for the distribution of food products. These were comparable vehicles from the same production period and with similar operational mileage. The examined makes were marked as: A make, B make and C make. Readiness was chosen as the basic parameter characterizing the operational quality of vehicles [20,22,23].

The technical readiness indicator was determined as the ratio of the total time of the vehicles suitability state to its sum with the total repair time.

$$K_g = \frac{\sum_{i=1}^{n} T_i}{\sum_{i=1}^{n} T_i + \sum_{i}^{n} \tau_i}$$

where:

$T_i$ – i-th operating time between repairs,

$\tau_i$ – time of performing the i-th repair.

Time values were specified in days. In the case of short repairs, it was uniformly assumed that they lasted one day, regardless of the actual - "clock" time of their duration. This way, the time of delivery of the vehicle for the repair and the time of its receipt were taken into account. The time of repair which lasted longer, was taken into account in the manner in which it was recorded in the operating documentation, which means that it was the time between the date of acceptance for the repair and the date of delivery of the vehicle. The days of acceptance and delivery of the vehicle were treated as completely devoted to conducting repairs. The readiness indicator was calculated in relation to the mileage intervals of 50,000 km.

Figures 1-3 present the results of calculations of technical readiness changes for three makes of vehicles tested.

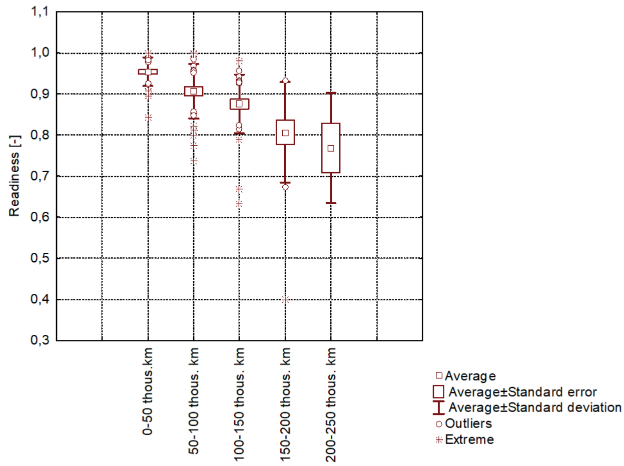


Fig. 1. Technical readiness of the A make vehicles

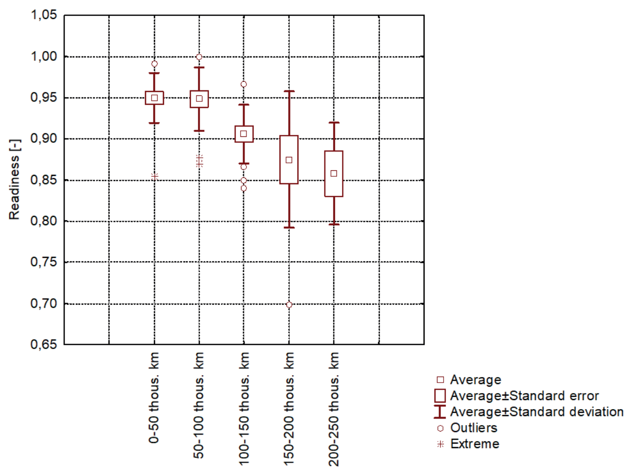


Fig. 2. Technical readiness of the B make vehicles

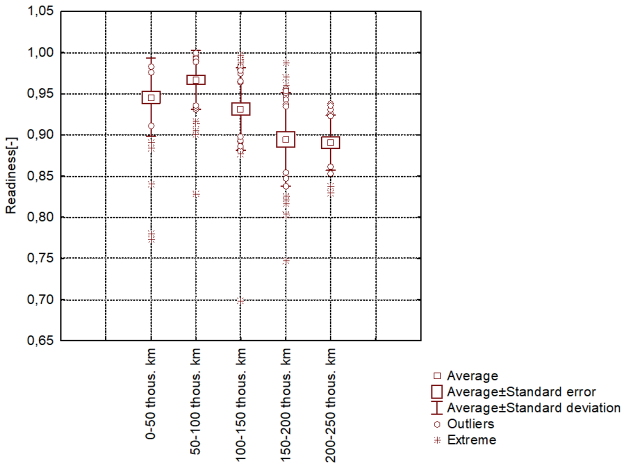


Fig. 3. Technical readiness of the C make vehicles

The changes in readiness presented in Fig. 1-3 as a function of the operational course are of a decreasing nature. In order to determine whether the obtained values are "big" or "small" it was decided to compare them with the average value for all makes (this is shown in Fig. 4). The comparison shows that the A brand cars were characterized by readiness lower than the average, and cars of B and C brands higher than the average for all makes. In the first operational period, the readiness of all vehicle makes was comparable.

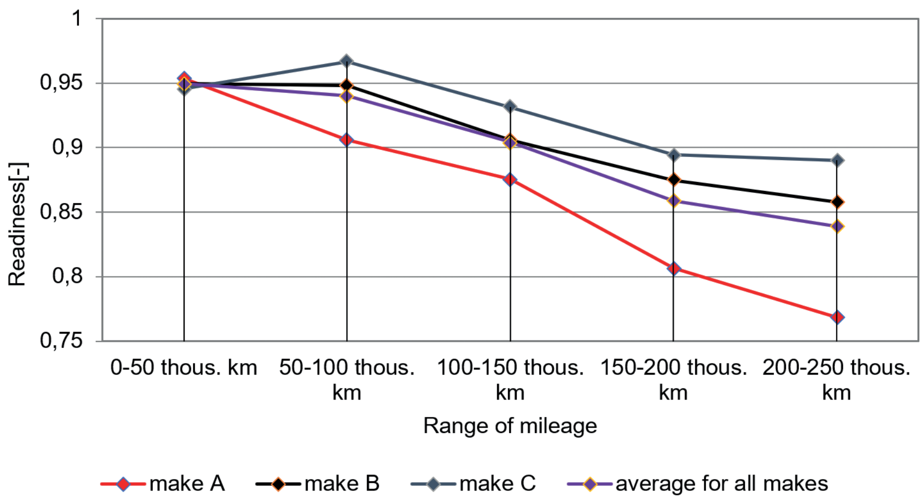


Fig. 4. Comparison of readiness changes with respect to the average for all makes

The Figure 5 summarizes the average "readiness" in the whole observed period of operation.

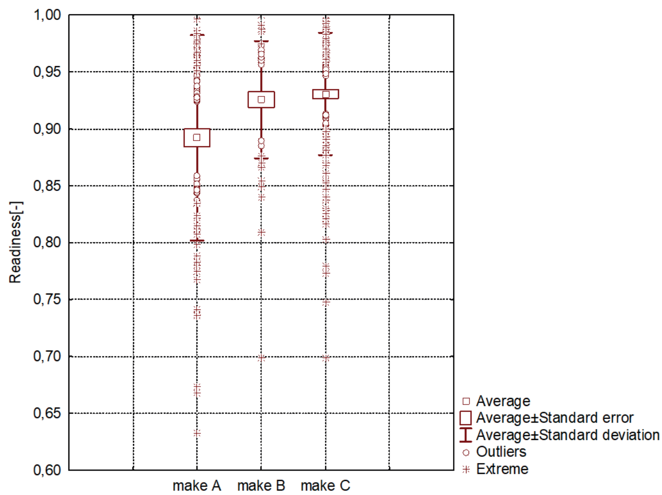


Fig. 5. Comparison of averaged readiness in the entire observed period of operation

Table 1 presents descriptive statistics of the readiness of the tested vehicles for the total observed operational period.

Table 1. Descriptive statistics of vehicle technical readiness for the whole observed operational period

| Statistical parameter | A make | B make | C make | All makes |
|---|---|---|---|---|
| Average | 0,8920 | 0,9256 | 0,9306 | 0,9165 |
| Median | 0,9125 | 0,9295 | 0,9433 | 0,9327 |
| Standard deviation | 0,0902 | 0,0514 | 0,0538 | 0,07059 |
| Minimum | 0,4 | 0,6983 | 0,6986 | 0,4 |
| Maximum | 1 | 1 | 1 | 1 |

In addition, a non-parametric comparison was carried out of three independent samples for the obtained average readiness values for the entire observed period of operation.

In this case, one make was compared with the other in pairs. The results are presented in Table 2. These results allow to check the null hypothesis $H_0$ of the equality of averages based on the Student's – t test.

**Table 2. Results of readiness comparison of three vehicle makes as independent samples**

| Group 1 against Group 2 | Tests for independent samples. Calculated Student's t- statistics | | | | | |
|---|---|---|---|---|---|---|
| | Average Group 1 | Average Group 2 | $t$ | $df$ | $p$ | - |
| A aganist B | 0,892029 | 0,925655 | -2,563 | 179 | 0,011173 | |
| A aganist. C | 0,892029 | 0,930649 | -4,717 | 309 | 0,000004 | |
| B aganist C | 0,925655 | 0,930649 | 0,6054 | 236 | 0,545471 | |
| | $n_1$ | $n_2$ | σ- Gruop1 | σ- Gruop2 | F-Fischera | p varinces |
| A aganist B | 127 | 54 | 0,09024 | 0,05149 | 3,07128 | 0,000012 |
| A aganist C | 127 | 184 | 0,09024 | 0,05381 | 2,81251 | 0,000000 |
| B aganist C | 54 | 184 | 0,05149 | 0,05381 | 1,09200 | 0,723203 |

Markings: $t$ – value of Student's t - statist, $d_f$ – number of degrees of freedom, $p$ – calculated level of risk, $n_{1,2}$ - samples number, $\sigma$ - standard deviation in groups, $F$- value of Fisher's F- statistics for comparison of variances, $p$ variances - the level of risk for the Fischer's test

The calculations made allow to verify the zero hypothesis $H_0$ on the equality of readiness averages. When comparing makes A against B and A against C, critical values $t_{\alpha=0,05,df}$ are (-1,653411) and (-1,6498) respectively, and they are larger than the calculated test statistics t, which allows to reject the null hypothesis. This can be interpreted as a statistically significant difference in the technical readiness of these makes. When comparing makes B and C the critical value $t_{\alpha=0,05,df}$=0,05,df = -1,651336 and it is smaller than the calculated $t$ = 0,6054, which does not allow to reject the null hypothesis. It can be concluded that the differences in readiness of these makes are statistically insignificant, and therefore the makes are comparable.

The results of the Fischer test were interpreted in a similar way. Critical values of statistics $F_{\alpha=0,05,n_1,n_2}$ for the comparison of makes A against B and A against C are 1,488072 and 1,303930, respectively. These values are smaller than calculated in the F statistics test, which allows to reject the hypothesis on the equality of readiness variances for these makes. When comparing makes B and C $F_{\alpha=0,05,n_1,n_2}$ = 1,407542, which in turn means that the hypothesis about the equality of technical readiness variances of these makes can not be rejected. At this stage, it should be noted that the B and C makes are comparable in terms of their technical readiness, and at the same time significantly differ from the A make.

Additional parameters defining the operational quality, the values of which were decided to compare were: cumulative distribution of the mileage course to the first defect and the cumulative distribution of the inter-repair mileage course. The values of these parameters have been determined based on empirical studies and the expert method.

The distribution of mileages to the first defect approximated by the Weibull distribution is shown in Figure 6. It should be noted that the reliability resulting from the first failure is a measure of the quality of the design and vehicles manufacture. In this aspect the level of reliability is not affected by the vehicle repairs conducted.

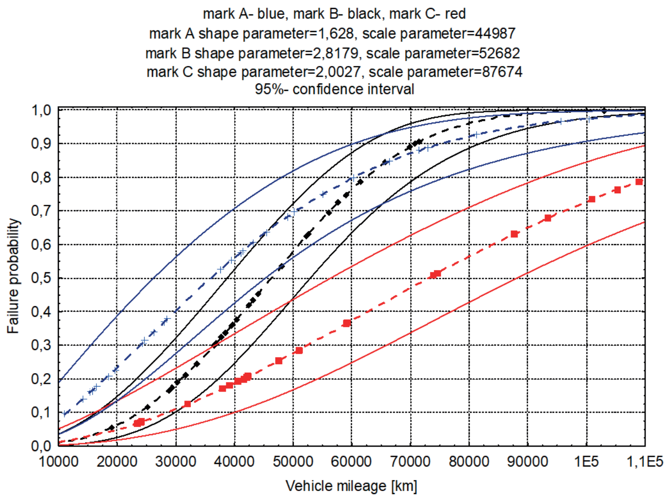


**Fig. 6. Comparison of the cumulative distributions of the mileages course to the first defect**

From the presented characteristics of the mileages to the first defect it appears that 50% of vehicles will suffer defect after travelling about 34 000 km for the A make, 47 000 km for the B make and 73 000 km for the C make.

Inter-repair mileages are a direct measure of the quality of vehicle renovation and an indirect measure of their corrective susceptibility /repair friendliness/ (understood here as an ease to perform effective repair). Comparing reliability resulting from inter-repair mileages of the vehicles tested is shown in Fig. 7. Similarly as before, it can be seen that 50% of vehicles have inter-repair mileages over: 6800 km for the make C, 5800 km for make B and around 4300 km for make A.

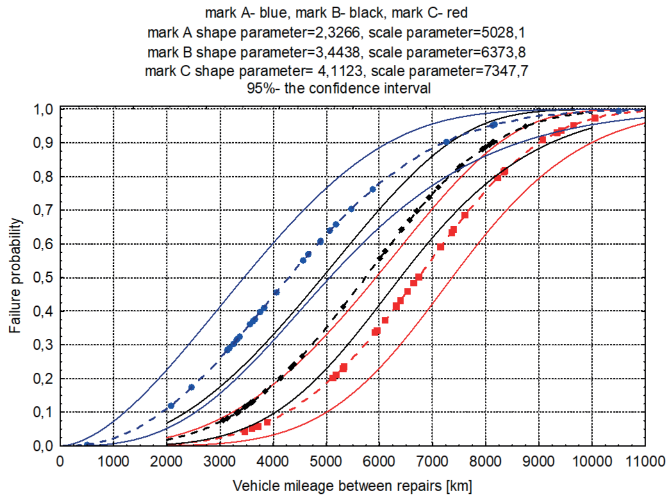


Fig. 7. Comparison of cumulative distributions of the inter-repair mileage courses

## 3. Expert assessment of the operational quality

The empirical reliability indicators presented above have also been evaluated using the expert study method [1,5,24]. These tests were based on a survey on the general assessment of the vehicles' reliability. The survey formulates the following evaluation criteria:

1. How do you rate the average mileage of the vehicle to the first defect (to the nearest 10000 km)?
2. The mileage of vehicles between defects (with an accuracy of up to 10000 km).
3. Elements (subassemblies) of the vehicle with the highest defectibility (give a maximum of three).
4. Assessment of the operational quality of the vehicle with respect to its reliability (on a scale of 1 to 10).

32 experts took part in the survey. The criterion for the selection of experts included:

- professional qualifications in the field of expertise concerning automotive technology or road traffic,
- professional experience in the issues of truck operation and technical road transport servicing.

The results of expert survey in relation till the mileage to the first defect and inter-repair mileages are presented in Fig. 8 and 9 and Tables 3 and 4.

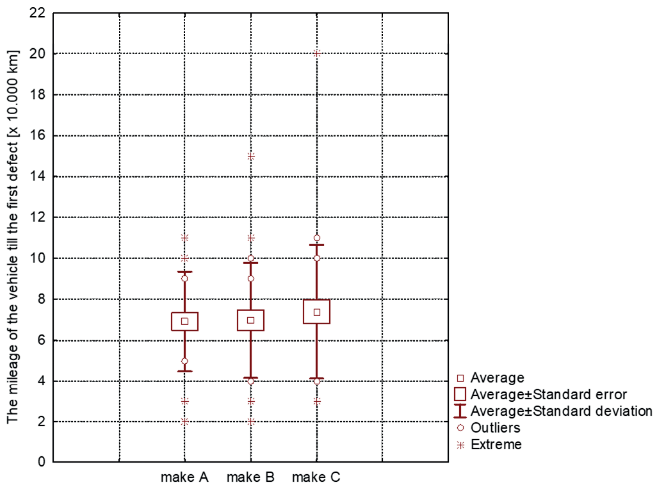


Fig. 8. The mileage of the vehicle till the first defect according to the survey

### Table 3. Statistical characteristics of the results of the questionnaire on the mileage of the vehicle to the first defect

| Car make | A make | B make | C make |
|---|---|---|---|
| Average [km] | 69 062 | 69 677 | 73 870 |
| Median [km] | 70 000 | 70 000 | 70 000 |
| Standard deviation [km] | 24 410 | 28 105 | 32 626 |
| Minimum [km] | 20 000 | 20 000 | 30 000 |
| Maximum [km] | 110 000 | 150 000 | 200 000 |
| Number of results | 32 | 31 | 31 |

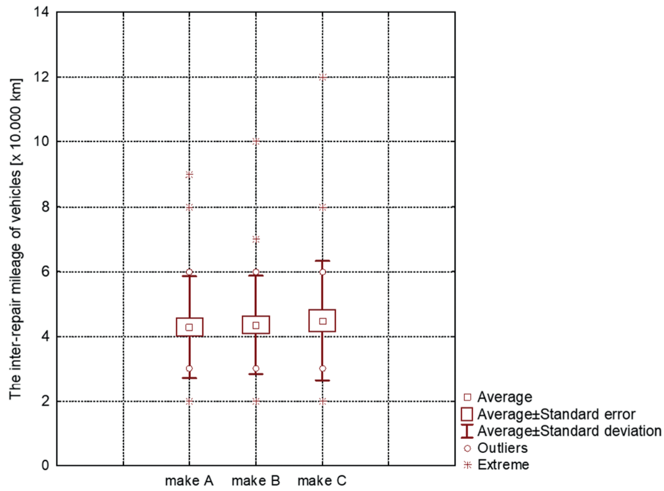


Fig. 9 The inter-repair mileage of vehicles according to the questionnaire surveys

### Table 4. Statistical characteristics of survey results regarding the average mileage of vehicles between successive defects

| Car make | A make | B make | C make |
|---|---|---|---|
| Average [km] | 42 812 | 43 548 | 44 838 |
| Median [km] | 40 000 | 40 000 | 40 000 |
| Standard deviation [km] | 15 705 | 15 176 | 18 415 |
| Minimum [km] | 20 000 | 20 000 | 20 000 |
| Maximum [km] | 90 000 | 100 000 | 120 000 |
| Number of results | 32 | 31 | 31 |

The comparison of the results of empirical studies and expert studies shows that in both cases the C make was the most reliable, whereas the most unreliable, the make A. However, this is a very general assessment with low credibility of numerical data.

The next assessment given to the experts concerned components and elements most often subject to defects. The results of this assessment and the corresponding list of defects of the selected functional systems of vehicles covered by empirical tests are shown in Figures 10 and 11. It was found that satisfactory consistency of the results applies only to the electrical system and vehicle suspension system.

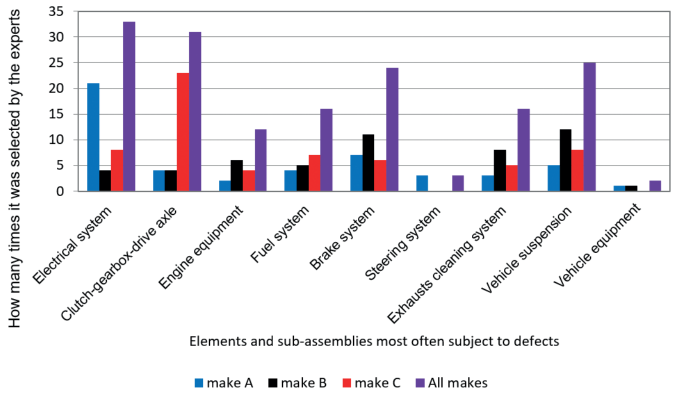


Fig. 10. Elements and subassemblies chosen by experts as most often subject to damage

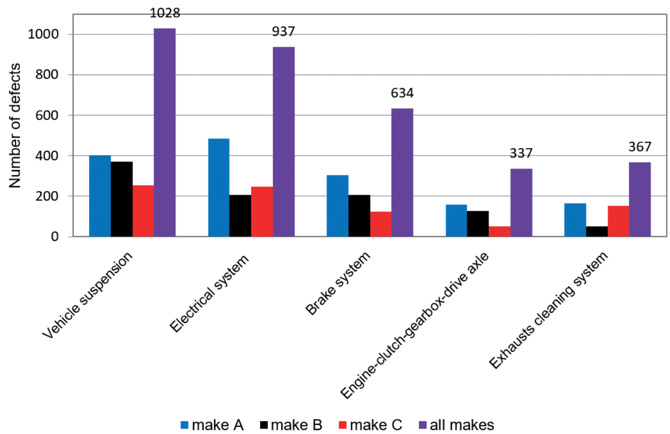


Fig. 11. List of the empirical number of repairs related to selected vehicle functional systems

The last opinion of experts concerned the general assessment of the operational quality of selected vehicle makes and the indication of the two most important criteria for selecting a vehicle for long-term rental. The following features were considered:

1. value of the rental instalment,
2. prestige of the vehicle make,
3. ecological standards met,
4. fuel costs,
5. reliability (defect-free operation),

6. residual value (the difference between the purchase and resale price),
7. costs of repairs,
8. defect rectification time (average repair time).

The results of experts' assessment are presented in Figures 12 and 13 and in Table 5.

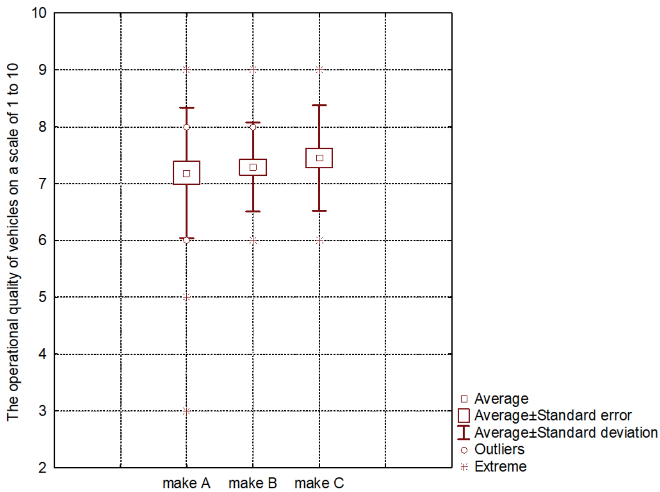


Fig. 12. Assessment of the operational quality of vehicles on a scale of 1 to 10 according to the experts

Table 5. Statistical characteristics of assessment of the operational quality of vehicles on a scale of 1 to 10 according to the experts

| Car make | A make | B make | C make |
|---|---|---|---|
| Average [-] | 7,19 | 7,29 | 7,45 |
| Standard deviation [-] | 1,14 | 0,78 | 0,92 |
| Minimum [-] | 3 | 6 | 6 |
| Maximum [-] | 9 | 9 | 9 |
| Number of results | 32 | 31 | 31 |

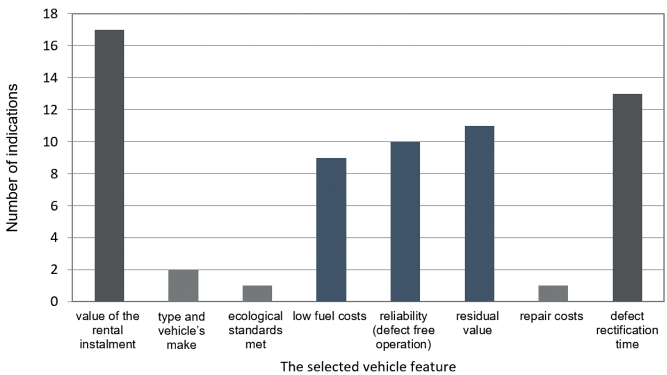


**Fig. 13. Number of indications on the selected vehicle feature - the criterion for selecting a vehicle for the long-term rental**

The operational quality of all vehicle makes has been assessed at a comparable level of 7.20 ÷ 7.40 points on a scale of 0 to 10 points.

As shown in Figure 13, the make selection criteria indicated by the experts were in the following order:

1. financial rate (instalment) of rent (17%),
2. repair time (13%),
3. residual value (11%),
4. reliability (10%),
5. low fuel costs (9%).

## 4. Conclusion

Based on empirical research, the following conclusions can be made:

a) Vehicles of the A make are characterized by the lowest technical readiness. The readiness of B and C make vehicles is comparable.

b) Vehicles of the A make are distinguished by the lowest inter-repair mileages and the smallest mileages to the first defect.

c) The highest inter-repair mileages and the highest mileages to the first defect characterize C make vehicle.

d) Summing up the results of empirical research, the highest operational quality have C make vehicles, and the lowest the A make vehicles.

Based on the results of expert studies, it can be concluded that:

a) The lowest mileages to the first defect characterize vehicles of the A make, while the longest – the vehicles of the C make.

b) The highest quality rating was given to C-make vehicles and the lowest to A-make vehicles.

When comparing the results of expert assessments of vehicles' quality with the results of empirical studies, it can be concluded that expert assessments are consistent with the actual operational characteristics. Therefore, the assessment of operational quality carried out using the expert method can be used in operational practice. However, the limited level of numerical accuracy of the expert method should be taken into account.

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