Studying quality of diagnosing rolling stock at service enterprises of automobile transport

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Abstract. The article focuses on one of the car service market components being a car diagnostic system and, in particular, on the effectiveness of the activities of diagnostic operators. The objective of this study was an experimental assessment of the effectiveness of the proposed methods for improving the training of diagnostic operators. The results of testing hypotheses on the correct diagnosis by a group of specialists on the technical condition of passenger car engines are presented.

1. Introduction
Under the conditions of modern market relations, automobile service is developing rather progressively. The market of car services is sale of services over maintaining vehicles as well as restoring capability in the event of its loss over the entire period of use (fig. 1). This includes not only monitoring and diagnostics services but also warranty services, seasonal maintenance and repair of both a car and its components, including the body.

After analyzing the list of services [4, 5, 6, 7] provided by car service centers, it should be noted that car diagnostics is an integral part of the market for these services and currently such services are more and more in demand.

Diagnosing faults can become quite simple if it is done logically. The first step in diagnosing any malfunctions should be to determine the cause of malfunction as accurately as possible. By accidental search, it is also possible to diagnose a malfunction. However, this may require a large investment of time and replacement of serviceable parts, which is disadvantageous.

The engine may not start for many reasons, and you will save time and effort by turning from one test to another, which increases the chances of detecting a malfunction.

There are many malfunctions that interfere with the normal car operation, engine starting. However, there are much more malfunctions causing its poor operation. Although experienced diesel mechanics can often find the cause of a malfunction immediately, specialists who do not have such an experience are advised not try to guess the reason. Using a methodical and systematic approach, it is possible to save time and money and increase the likelihood of detecting a malfunction.
To determine the cost of maintenance and repair of automobiles and their units, it is necessary to have sufficiently complete information on all facilities and planned volumes of work. Lack of such information as well as its incorrect presentation causes great difficulties in coordinating interaction between engineering, technical, financial and economic services. In the end, the decision is made not on the basis of objective criteria but subjectively, based on the prevailing power balance at wheeled transport enterprise [5, 6].

Currently, the number of cars equipped with electronic fuel injection systems has sharply increased, which has caused a significant increase in demand for services related to the diagnosis of technical condition and repair of such cars. Engine management systems need more thorough and effective diagnostics. Herewith, such a factor as a vehicle technical condition concerning engine management systems becomes very important since it affects the traction and speed indicators of a car as a whole. The problem of diagnosing a technical condition and repair of an engine management system can be solved by using new special technical means and measuring instruments.

Adaptation algorithms frequently incorporated into control systems hide malfunctions that gradually arise during operation. Therefore, the same engine satisfactory operation has to be judged by the following indirect signs that not every diagnostic operator can detect: increased fuel consumption, deterioration of dynamic characteristics, etc. It should be noted that some devices like sensors and actuators give errors that exceed their maximum permissible values. And this fact cannot be ignored, since diagnosis in this case becomes inferior, and, therefore, unreliable. [8, 11, 16].

This is quite enough to state that the diagnosis of complex automotive equipment, which would be reliable and, therefore, effective needs new methods, new algorithms, and new technical means. At the same time, it is necessary for both developers and manufacturers of automotive equipment to think not only about those who work on the assembly line, but also about those who will operate vehicles, diagnose and repair them.
Diagnostics is the basis of high-quality maintenance and repair. An important link in this chain is a person (operator-diagnostician) and their professional qualifications, knowledge, skills and experience, while the errors in the diagnosis and determination of repair volumes lead to repeated work, which means significant financial losses not only to customers, but also entire enterprises, etc. [7, 9, 14].

2. Materials and methods
The purpose of this study was an experimental effectiveness evaluation of the proposed methods aimed to improve diagnostic operators training.

According to the task to use the mathematical apparatus of operations research [1, 2], two hypotheses were suggested. They are as follows: zero H0 being the proportion of specialists in the initial group of experts distinguishing the proposed values of the diagnostic parameter, that is, diagnosing accurately, are the same for the studied groups of experts with various qualifications; alternative H1 being the proportion of specialists in the initial set of experts who distinguish the proposed values of the diagnostic parameter, that is, diagnosing precisely, are not the same for the various groups of experts studied [1].

To do this, an evaluation experiment was conducted. It implied the correct diagnosis of the technical condition of a car engine (the brand was not taken into account) by a group of specialists in the amount of 60 people. In the course of the experiment, the following restrictions were observed: the subject of the study was diagnosing at Tyumen maintenance stations; the object of study was a car engine; the measured diagnostic parameter was the change in compressed air leaks through the cylinders of a warmed-up engine, a device used for measurements was the pneumotester K-272; the age of diagnostic operators was not taken into account; confidence coefficient value accepted in the study was as follows: \( \alpha = 0.95 \); deviations of the measured parameter values in a positive or negative direction from the real one were not taken into account. Only downswings or upswings of the actual value of the diagnostic parameter (first-order error \( \alpha_d \) being false malfunction, second-order error \( \beta_d \) being skip malfunction, respectively) was recorded.

**Table 1. Initial conditions**

| Diagnostic Value | Qualification of a diagnostic operator | Row totals |
|------------------|--------------------------------------|------------|
|                  | Average Value | Average technical Value | Highest Value |                   |
| Smaller          | Value | Notation | Value | Notation | Value | Notation | Value | Notation |
| Actual           | 10    | A       | 15    | B       | 4     | C       | 29    | A+B+C    |
| Larger           | 7     | D       | 9     | E       | 4     | F       | 20    | D+E+F    |
| Column totals    | 20    | A+D+G   | 30    | B+E+H   | 10    | C+F+I   | 60    | ---      |

To assess the hypotheses put forward in this paper, we used the Pearson \( \chi^2 \) criterion [1]. The classical formula for calculating \( \chi^2 \) has the following form [2]:

\[
\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(f_o - f_e)^2}{f_e}
\]  

(1)

where: \( r \) is the number of columns in the source table \( r = \{i, \text{where } i = 1 \div r\} \);
\( c \) is the number of rows in the source table \( c = \{j, \text{where } j = 1 \div c\} \);
\( f_o \) is observed (empirical) frequency of expert falling within a given interval (cell of the original table);
\( f_e \) is expected (estimated) frequency of experts falling within a given interval.
Table 2. Data for calculating the criterion $\chi^2$

| Cell | $f_o$ | $f_e$ | $f_o-f_e$ | $(f_o-f_e)^2$ |
|------|-------|-------|-----------|---------------|
| A    | 10    | 9.66  | 0.34      | 0.12          |
| B    | 15    | 14.5  | 0.50      | 0.25          |
| C    | 4     | 4.83  | -0.83     | 0.69          |
| D    | 7     | 6.66  | 0.34      | 0.12          |
| E    | 9     | 10.00 | -1.00     | 1.00          |
| F    | 4     | 3.33  | 0.67      | 0.45          |
| G    | 3     | 3.66  | -0.66     | 0.44          |
| H    | 6     | 5.50  | 0.50      | 0.25          |
| I    | 2     | 1.83  | 0.17      | 0.03          |

Calculations of the expected frequency $f_e$ were performed for each cell of the original table. To do this, the final frequencies of the column and the row in which a cell was located were multiplied, and then the resulting product was divided by N.

Table 3. Calculation results

| Cell | $f_e$ | $(f_o-f_e)^2$ | $f_e$ |
|------|-------|---------------|-------|
| A    | 9.66  | 0.12          |       |
| B    | 14.50 | 0.25          |       |
| C    | 4.83  | 0.69          |       |
| D    | 6.66  | 0.12          |       |
| E    | 10.00 | 1.00          |       |
| F    | 3.33  | 0.45          |       |
| G    | 3.66  | 0.44          |       |
| H    | 5.50  | 0.25          |       |
| I    | 1.83  | 0.03          |       |

Having performed the corresponding calculations by the described method, we obtained the value $\chi^2 = 0.78$. A critical value $\chi^2$ was selected from the tables for a given $\alpha$ level. If the calculated value $\chi^2$ exceeds the critical value or is equal to it, the hypothesis $H_0$ can be rejected.

To select the critical value of $\chi^2$, it is necessary to determine the number of degrees of freedom:

$$S = (r - 1)(c - 1) = (3 - 1)(3 - 1) = 4$$

(2)

$r$ is the number of columns in the source table; $c$ is the number of rows in the source table.

The critical value of $\chi^2$ at $\alpha = 0.95$ and $S = 4$ was 0.711. In this case, we rejected the $H_0$ hypothesis and adopted the alternative $H_1$ hypothesis.

3. Conclusion

1. As a result, an almost complete quantitative ratio of true and error diagnoses was revealed.
2. It is obvious that using a one-factor model in the presented example, it is not possible to make a qualitative analysis of the results.
3. To ensure the possibility of a better analysis, it is necessary to introduce an additional factor, for example, age limit, time of day, etc.
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