A Method for Evaluating the Effective Use of Digital Technologies in Monitoring the Technical Condition of Vehicles During their Operation

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Abstract: The article presents a developed method for evaluating the effectiveness of the use of digital technologies in monitoring the technical condition of vehicles during their operation, which uses as evaluation criteria such indicators as the annual volume of maintenance work, the change in annual volume during maintenance and the number of maintenance operations. Based on these criteria, an optimization model was formed to assess the introduction of digital technologies when monitoring the technical condition of vehicles during their operation. In combination with the use of means of remote monitoring of the technical condition of vehicles using a matrix QR code, the method makes it possible to effectively use digital technologies on the vehicle in the process of their operation.

1 INTRODUCTION

Digital technologies play a significant role in monitoring the technical condition of vehicles. They provide operational monitoring and feedback on the operation of various systems and components of vehicles, allowing operators and drivers to make timely and informed decisions.

Operational control of the technical condition includes constant monitoring of systems and nodes, data analysis and detection of deviations from the norm. This allows you to respond to problems in a timely manner and prevent possible malfunctions.

The practical implementation of digital technologies for monitoring the technical condition of the vehicle includes the installation of systems capable of remote diagnostics, as well as data analysis and notification of possible problems or malfunctions to the relevant services. These systems are also capable of analyzing data to identify trends and predict possible problems in the future (Safiullin, 2019).

2 RESEARCH METHODOLOGY

To assess the technical condition of vehicles, there are various diagnostic tools and methods. One of the most common tools are engine analyzers, also known as universal motor testers. They allow diagnostics and analysis of engine operation using a wide range of measurements and tests.

Additionally, there are complex electrical measuring devices that allow real-time measurements of various engine operating parameters. These devices allow you to obtain waveforms of electrical signals that can be used to assess the condition of both the electrical and mechanical parts of the engine.

A distinctive feature of complex measuring instruments, unlike diagnostic scanners, is their independence from a specific electronic control system. This means that such devices can be used on cars with any control system (Belikova, 2021).

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The main disadvantage of these systems is the high labor costs, which entails the downtime of the vehicle. Therefore, there is a need to develop and evaluate systems capable of performing remote vehicle diagnostics. Having analyzed the means of vehicle diagnostics, it can be concluded that at present there is a need to develop systems capable of monitoring and evaluating the technical condition of vehicles without human intervention.

In goal to improve the control of the technical condition of vehicles during their movement, a simplified structure of an automated control system based on a matrix QR code was developed (Figure 1). This system includes the use of a special code on the vehicle, which can be read using a mobile device or a specialized reader.

The advantage of this control system is its simplicity and accessibility. Interaction with the system is carried out via mobile devices, which allows you to quickly receive information without the need to use complex and expensive readers.

The use of a matrix QR code to monitor the technical condition also contributes to improving the safety and reliability of vehicle operation. In case of malfunctions, operators and drivers can quickly take the necessary measures to prevent subsequent breakdowns.

Thus, an automated system for monitoring the technical condition based on a matrix QR code is a convenient and effective way to obtain information about the condition of vehicles in real time.

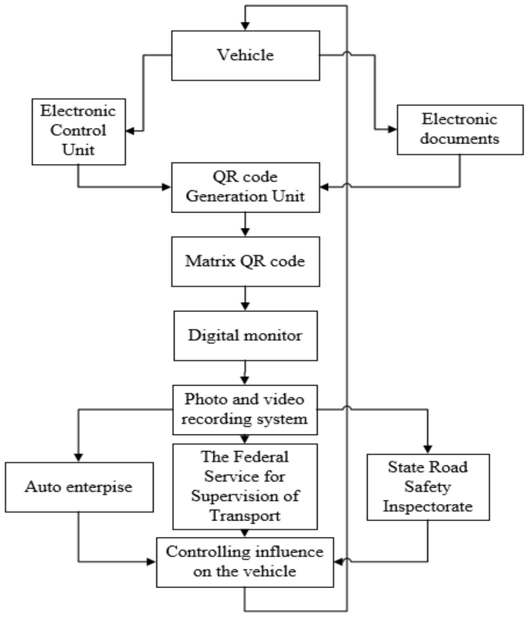

Figure 1: Simplified structure of an automated system for monitoring the technical condition of a vehicle based on a matrix QR code.

Thus, an automated system for monitoring the technical condition based on a matrix QR code is a convenient and effective way to obtain information about the condition of vehicles in real time.

This method allows remote diagnostics, as well as receiving and processing documents related to the transportation process, etc. At the same time, in the future, this method will allow us to derive criteria for evaluating the effectiveness of the functioning of a vehicle, in the input indicators of which other data related to the state of transport infrastructure, road users and road conditions can be incorporated (Figure 2) (Safiullin, 2019).

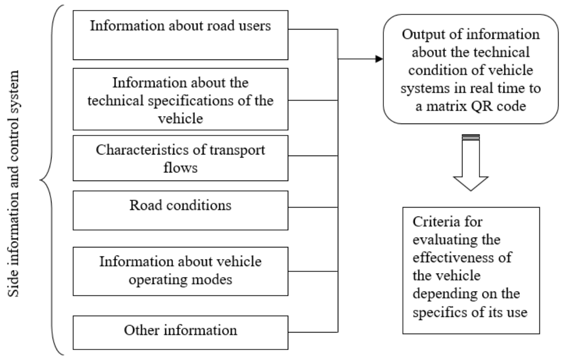

Figure 2: The model of information output by means of a matrix QR code.

3 RESULTS AND DISCUSSION

3.1 Research Results

The practical implementation of this method is to create technical solutions capable of automating vehicle diagnostics. For this purpose, patents have been developed and obtained for the following inventions:

- patent for invention No. 2739652 "Automated system for monitoring environmental parameters of internal combustion engines of vehicles" (Safiullin, 2020);
- patent for invention No. 2724072 "Simulation system for motor oil quality control for vehicles" (Safiullin, 2019);
- patent for invention No. 2782630 "Automated complex for monitoring fuel quality of internal combustion engines of vehicles" (Safiullin, 2020);
- patent for invention No. 2792386 "Automated system for remote diagnostics of vehicle technical condition based on matrix QR-code" (Safiullin, 2023).

The invention "Automated system for remote diagnostics of vehicle technical condition based on matrix QR-code" allows you to read information about the environmental parameters of the vehicle, as well as about the quality of oil and fuel used in the vehicle and, as a result, output a QR code with these parameters, which in turn can be automatically read and processed by systems photo-video recordings (Safiullin, 2014).

Based on the proposed method and technical solutions, an algorithm for the functioning of an automated system for remote monitoring of the technical condition of the vehicle was developed in Figure 3.

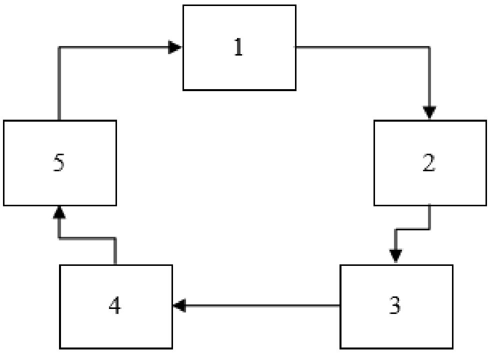

Figure 3: The algorithm of functioning of the automated system for remote monitoring of the technical condition of the vehicle: 1 – Collecting data from the vehicle; 2 - Ordering spare parts, planning car maintenance or repair; 3 - Carrying out car maintenance or repair; 4 - Vehicle operation; 5 - Monitoring vehicle parameters.

The implementation of this algorithm will improve the safety of vehicle operation, as well as reduce downtime, optimize operating costs and increase efficiency during vehicle operation. Also, remote and constant monitoring of the technical condition of the vehicle will extend the life of the vehicle components and assemblies (Komarov, 2008).

Taking into account digitalization and the development of automated systems, there is a need for their assessment. For this purpose, a method has been developed that allows evaluating the effectiveness of the use of digital technologies in monitoring the technical condition of vehicles during their operation (Safiullin, 2017). This method is shown in Figure 4.

3.2 Research Results

The implementation of this method will allow solving such tasks as optimizing maintenance and repair processes, improving the reliability of vehicles, reducing accidents and operating costs, as well as evaluating the implemented automated systems.

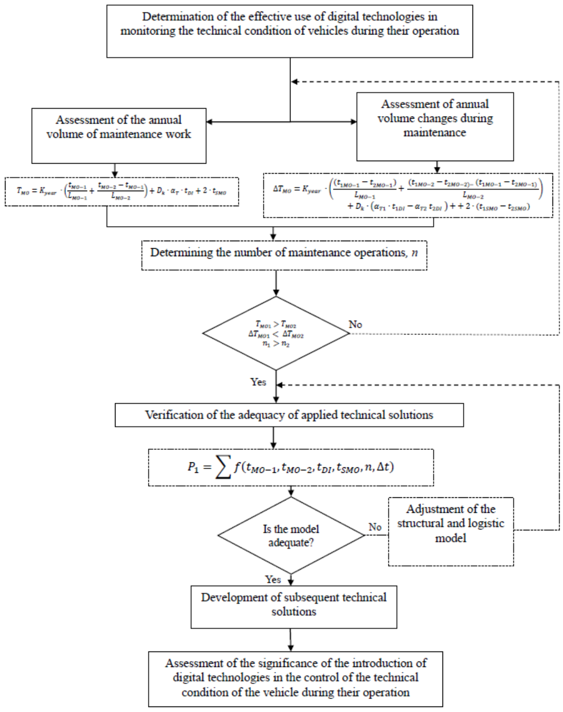

Figure 4: A method for evaluating the effective use of digital technologies in monitoring the technical condition of vehicles during their operation.

Based on this method, the following criteria were proposed for evaluating the implemented digital systems:

The annual volume of maintenance work, including work on maintenance operation-1 (MO-1), maintenance operation-2 (MO-2), seasonal maintenance operation (SMO), daily inspection (DI):

$$T_{MO} = K_{year} \cdot \left(\frac{t_{MO-1}}{L_{MO-1}} + \frac{t_{MO-2} - t_{MO-1}}{L_{MO-2}}\right) + \\ + D_k \cdot \alpha_T \cdot t_{DI} + 2 \cdot t_{SMO}, \tag{1}$$

where t_{MO-1}, t_{MO-2}, t_{DI}, t_{SMO} - the labor intensity of MO-1, MO-2, DI, SMO, man-hour; L_{MO-1}, L_{MO-2} - the frequency of MO-1, MO-2, km; K_{year} - annual mileage, km; D_k - the number of calendar working days per year; α_T - correction factor.

A criterion is also proposed in the form of a change in the annual volume during maintenance:

$$\Delta T_{MO} = K_{year} \cdot \left(\begin{array}{l} \dfrac{(t_{1MO-1} - t_{2MO-1})}{L_{MO-1}} + \\ + \dfrac{(t_{1MO-2} - t_{2MO-2})}{L_{MO-2}} - \\ - \dfrac{t_{1MO-1} - t_{2MO-1}}{L_{MO-2}} \end{array} \right) + \\ + D_k \cdot \left(\alpha_{T1} \cdot t_{1DI} - \alpha_{T2} \, t_{2DI} \right) + \\ + 2 \cdot \left(t_{1SMO} - t_{2SMO} \right) \quad (2)$$

where t_{1MO-1}, t_{1MO-2}, t_{1DI}, t_{1SMO} - the labor intensity of MO-1, MO-2, DI, SMO before making changes, man-hour; t_{2MO-1}, t_{2MO-2}, t_{2DI}, t_{2SMO} - the labor intensity of MO-1, MO-2, DI, SMO after making changes, man-hour; α_{T1}, α_{T2} - correction factors.

Based on these criteria, the evaluation of the introduction of digital technologies in the control of the technical condition of vehicles in the process of their operation are the following relationship:

$$\begin{array}{l} f\left(T_{MO}, n\right) \rightarrow min, \\ f\left(\Delta T_{MO}\right) \rightarrow max, \end{array} \quad (3)$$

where n - the number of maintenance and repair operations.

On the basis of which an optimization model was formed to assess the introduction of digital technologies when monitoring the technical condition of vehicles during their operation:

$$P_1 = \Sigma \, f\left(t_{MO-1}, t_{MO-2}, t_{DI}, t_{SMO}, n, \Delta t\right), \quad (4)$$

where Δt - time to receive vehicle data.

Based on this, it can be concluded that it is possible to evaluate the effectiveness of the introduction of digital technologies on the vehicle with the help of the annual volume of work on maintenance, also by changing the labor intensity during maintenance and the number of operations required to monitor the technical condition of the vehicle (Safiullin, 2017).

4 CONCLUSIONS

In the course of the study, the set goals were achieved and the tasks related to increasing the efficiency of using digital technologies in monitoring the technical condition of vehicles during their operation were solved. The results of the work are of great practical importance and can be used to improve existing approaches and develop new methods in the field of remote monitoring of the technical condition of vehicles.

One of the key tasks of the work was to develop a new method for evaluating the effective use of digital technologies in monitoring the technical condition of vehicles during their operation. This method allows you to evaluate the effectiveness of the digital technologies being implemented on vehicles using criteria such as: the annual volume of maintenance work, changes in the annual volume during maintenance. An optimization model is proposed to assess the introduction of digital technologies when monitoring the technical condition of vehicles in the process of their operation.

According to the results of the study, technical solutions were developed: " Automated system for monitoring environmental parameters of internal combustion engines of vehicles"; " Simulation system for motor oil quality control for vehicles"; " Automated complex for monitoring fuel quality of internal combustion engines of vehicles"; " Automated system for remote diagnostics of vehicle technical condition based on matrix QR-code", capable of performing automatic remote monitoring of the technical condition of vehicles.

Also, as a result of the research, an algorithm for the functioning of an automated system for remote monitoring of the technical condition of vehicles was developed.

Thus, the developed method and technical solutions can be used by management bodies, transport companies and other interested parties to monitor the technical condition of the vehicle and improve the system of maintenance and repair.

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