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# IMPROVEMENT OF THE METHOD FOR CALCULATING THE LEVEL OF VEHICLE OCCUPANCY FOR A SINGLE VEHICLE

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## ABSTRACT

*The article discusses the improvement of the methodology for calculating the level of congestion of vehicles per vehicle. To assess the significance of the influence of operating conditions on the technical readiness of vehicles, the method of expert assessments was used; the methods of mathematical statistics were used in processing the answers of experts and assessing the errors of improved methods for monitoring operational factors.*

**KEYWORDS:** *Workload level, Development of road transport, Operating conditions, Technical readiness of vehicles.*

## INTRODUCTION

At the present stage of development of road transport, based on the impossibility of quickly renewing a worn-out vehicle fleet, an important and urgent task is to increase the technical readiness of vehicles and the efficiency of their use. One of the main directions for solving this problem is taking into account technical readiness when planning the stages and volumes of maintenance. In cases of constantly changing load, changes in a wide range of climatic conditions of operation and the complexity of control of operating conditions, the introduction of expensive diagnostic tools for the main components is not advisable [1-2]. If it is not possible to introduce control methods for the main technical and operational characteristics and the complexity of the implementation of direct diagnostics, it is advisable to use methods of indirect control of the technical readiness of vehicles.

**LITERATURE REVIVE**

To increase the efficiency of using the fleet of vehicles is inextricably linked with the need to take into account its actual readiness when planning the periods and volume of maintenance. The work of E.S. Kuznetsova, R.K. Khasanova, N. Ya. Govorushchenko, G.M. A.G. Sergeeva, V.A. Bondarenko, A.P. Boldina, M.M. Bolbas, V.P. Voronov V.P., I.B. Gurvich, I.E. Dyumin, B. S. Kleiner and other authors is devoted to taking into account the operating conditions when planning the repair of motor vehicles and optimizing the overhaul run. In the direction of developing means and methods for diagnosing technical readiness and monitoring the operating conditions of transport means, the works of E.S. Kuznetsova, R.Kh. Khasanova, N. Ya. Govorushchenko, V.P. Voronova, N.N. Yakunin.

Among the works devoted to determining the technical readiness of vehicles during operation, two main directions can be distinguished - direct (improvement of diagnostic tools) and indirect (improvement of methods for monitoring operating conditions). The presented work is devoted to the subsequent improvement of methods for monitoring operating conditions. The purpose of the study is to develop a comprehensive methodology for managing technical readiness based on monitoring operating conditions.

**MATERIALS AND METHODS**

To solve the tasks set in the work, there is a systematic approach. To assess the significance of the influence of operating conditions on the technical readiness of vehicles, the method of expert assessments was used; the methods of mathematical statistics were used in processing the answers of experts and assessing the errors of improved methods for monitoring operational factors [3-5]. An analytical method for the distribution of passenger traffic was used to calculate the level of loading of vehicles. The theory of fuzzy sets is used to build a model of the influence of operating conditions on the statistics of vehicle failures. Relevant is the improvement of methods for monitoring the operating conditions of vehicles and the development of methods for accounting for their changes when planning maintenance stages. Increasing the competitiveness of any road transport enterprise is inextricably linked with the need for widespread introduction of resource-saving technologies. The main direction of solving this problem is to increase the efficiency of the use of vehicles.

**RESULTS AND DISCUSSION**

Traditional methods of determining the mass of vehicles using scales are successfully used in industry, but in the conditions of suburban and urban traffic, their use is unjustifiably expensive and difficult. Among the analytical methods of calculation, one can single out as the main direction - the control of passenger traffic using the dynamic probability of their distribution. Since the installation of on-board systems is undesirable under the conditions under consideration, we will consider the mathematical foundations for calculating passenger traffic and test it for the bus route. To predict the level of congestion at interchange and passenger-forming points, it is proposed to use the theory of graphs and dynamic probabilities of the distribution of passenger flows that enter and exit at the stopping points. The method is based on the assumption that passengers who enter a point at a given time interval are sent from other points in proportion to the probabilities of passengers leaving. Imagine a sequence of vertices (transfer points) and arcs (route sections) that make up the route considered in the example [5-7].

To test the validity of the chosen calculation method, we use the results of the last reference study carried out for route networks. The method provides for the calculation of the dimensionless relative intensity of sources, calculated for a certain period of time.

$$J_N = \frac{Q_{BX_N}}{\sum_{\phi=1}^{N_{пункт}} Q_{BX_\phi}} < 1 \qquad (1)$$

Where $J_N$ – the intensity of passengers at point $N$;

$N$ - Conditional item number;

$Q_{BX_N}$ - The number of passengers entering the transfer point (the point for which the value is calculated);

$\varphi$ - The serial number of the item;

$N_{пункт}$ – The total number of active route points;

$Q_{BX_\varphi}$ - The number of passengers entering the point with numbers $\varphi$.

From expression (11) it can be seen that $\sum_{\varphi=1}^{N_{пункт}} J_\varphi = 1$. Similarly, for each vertex, the dimensionless relative intensity of the exit of passengers is calculated

$$q_N = \frac{Q_{ВЫХ_N}}{\left(\sum_{\phi=1}^{Nпункт} Q_{ВЫХ_\phi}\right)} < 1 \qquad (2)$$

где $q_N$ - the relative intensity of the exit of passengers for point $N$;

$Q_{ВЫХ_N}$ – The number of passengers leaving at the transfer point;

$Q_{ВЫХ_\varphi}$ – The number of passengers leaving at point $N$ with numbers for the period of time for which the calculations are carried out.

The assumption about the constancy of the distribution of passenger flows that enter and leave the network nodes in expressions (1) and (2) is justified for a certain sense of the sampling period in time. The period should correspond to the period of time due to the length of the network route itself and the conditions for the functioning of the city's enterprises. Therefore, to approximate the calculation results to real ones and to test the method, we will choose a time interval from 10.00 to 11.00 and carry out calculations for each node (point). The calculation results are summarized in the table (Table 1.).

Based on the results of calculations, we find the proportion of the direction of movement of the flow of passengers entering the point. In accordance with the method, we use the expression for calculating the shares of passenger traffic

$$\vec{Q}_{BX_N} = \frac{Q_{BX_N} \cdot \sum_{\phi=N+1}^{N пунктт} Q_{BЫX_\phi}}{\sum_{\phi=1}^{N_{пункт}} Q_{BЫX_\phi}} \qquad (3)$$

Where $\vec{Q}_{BX_N}$ - the proportion of passengers entering point $N$, and will go to the point with serial numbers starting from $(N+1)$ до $N_{пункт}$.

Further direction of movement of the flow of passengers leaving at the point

$$\vec{Q}_{BЫX_N} = \frac{Q_{BЫX_N} \cdot \sum_{\phi=1}^{N-1} Q_{BX_\phi}}{\sum_{\phi=1}^{N_{пункт}} Q_{BX_\phi}} \qquad (4)$$

Where $\vec{Q}_{BЫX_N}$ - the proportion of passengers leaving at point $N$ and arriving from point with serial numbers from 1 to $(N-1)$

**TABLE 1 RESULT OF CALCULATIONS OF THE INTENSITY OF PASSENGER TRAFFIC**

| **Nodes (interchange and passenger-forming points)** | **Number of passengers, people** | | **Dimensionless Intensities** | |
|---|---|---|---|---|
| | **incoming** $Q_{BX_N}$ | **outgoing** $Q_{BЫX_N}$ | **at the entrance** $J_N$ | **on exit** $q_N$ |
| **1-3** | **962** | **1031** | **0,20874355** | **0,2237** |
| **4** | **548** | **290** | **0,11883593** | **0,063** |
| **5** | **234** | **196** | **0,05083055** | **0,0426** |
| **6** | **95** | **157** | **0,0207746** | **0,0341** |
| **7-13** | **699** | **967** | **0,15166761** | **0,2099** |
| **14** | **549** | **292** | **0,1188359** | **0,062** |
| **15** | **449** | **301** | **0,09749751** | **0,0654** |
| **16** | **301** | **131** | **0,06540313** | **0,0286** |
| **17** | **75** | **72** | **0,01628573** | **0,0158** |
| **18** | **430** | **459** | **0,09324717** | **0,0996** |
| **19** | **30** | **72** | **0,00659236** | **0,0157** |
| **20** | **103** | **218** | **0,02242269** | **0,0473** |
| **21** | **180** | **313** | **0,03922887** | **0,068** |
| **22** | **97** | **159** | **0,05083054** | **0,0428** |
| **23** | **124** | **106** | **0,02708505** | **0,0232** |
| **24** | **130** | **57** | **0,028191** | **0,0124** |
| **25-26** | **453** | **312** | **0,09749749** | **0,0651** |

The mass transported by a bus with serial number n, which was in the control time interval between points $N$ and $N + 1$, can be obtained from the expression:

$$\overline{M}^{N,N+1} = \frac{G_{N,N+1}\cdot m_{\text{ПАС}}}{\text{КВ}} = \frac{\sum_{\phi=1}^{N} Q_{\text{ВХ}_{\phi}}\cdot\left(\sum_{\rho=N+1}^{N_{\text{пункт}}} Q_{\text{ВЫХ}_{\rho}}\right)\cdot m_{\text{пас.ср}}}{\sum_{\rho=1}^{N_{\text{зас}}} Q_{\text{ВЫХ}_{\rho}}\cdot \text{КВ}} \qquad (5)$$

Where $\overline{M}^{N,N+1}$ - the average mass transported by the bus, which was involved in the transportation of passengers during the estimated period of time;

$m_{\text{пас.ср}}$ - Average passenger weight (accepted $m_{\text{пас.ср}}$ = 70 kg);

$\text{КВ}$ - The number of buses that were recorded on the site for the period of time during which the calculations were carried out. Based on the data, we will construct a comparative diagram of the actual and theoretical load of the route sections (Fig. 1.).

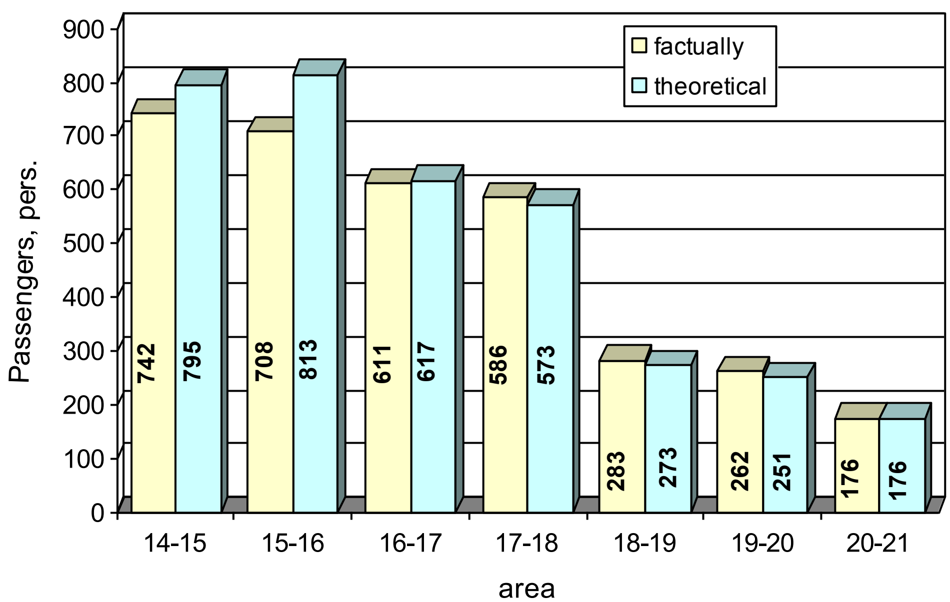


**Figure 1 the Workload of the Sections of the Calculated Route from 10:00 to 11:00**

Analysis of the results of calculating the congestion of the sections shows that the error does not exceed 10%, and in 10 cases out of 14 it did not exceed 5%.

As a result of processing the error data using the STATISTICA program, the Quick Basic Stats module, the following values were obtained:

Mean = 4.135714 - average value of the error;

SD = 4.558273 - standard (root-mean-square) deviation.

Improvement of the method, namely, an increase in the accuracy of calculations, can be obtained by taking into account the time spent by passengers to overcome the route. This approach can be implemented with a period of control of passenger traffic close to the interval of bus traffic (5-7 minutes). Combining the described calculation method with the approach proposed in, the improvement of the method for calculating the level of bus congestion was carried out by taking into account the time shift in determining the dynamic probability of passengers leaving the route and, accordingly, the congestion of the route section. The value of the time shift corresponds to the time of passenger movement from the point, the passenger flows of which are taken into account, to the point of the network, for which the calculations are carried out. The improved method makes it possible to increase the accuracy of determining passenger traffic at any time interval. Let us take T - the sampling interval in time, then it is expedient to express the time of the passenger's movement between points in the number of intervals T, which is spent on overcoming the route section. A matrix is formed with data on the time that the passenger should spend on moving between points of the route

$$Y_{\bar{t}} = \begin{vmatrix} 0 & \bar{t}_{12} & \ldots & \bar{t}_{1N} \\ \bar{t}_{21} & 0 & \ldots & \bar{t}_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{t}_{N1} & \bar{t}_{N2} & \ldots & 0 \end{vmatrix} \quad (6)$$

Where $Y_{\bar{t}}$ - spent time matrix;

$\bar{t}_{NN}$ - The number of intervals T, which the passenger must spend on the movement between the points of the route;

Matrix with data on the number of passengers who are at the transfer point:

$$U_S^{BX} = \left| Q_{BX_1}(S) \quad Q_{BX_2}(S) \quad \ldots \quad Q_{BX_N}(S) \right| (7)$$

Where $U_S^{BX}$ - matrix of the number of passengers who are at the transfer point;

*S* is the ordinal number of the period T from the conditional start of time;

$Q_{BX_N}(S)$ - The number of passengers who entered point *N* during period *S*.

Similarly to expression (8), a matrix is compiled with data on the number of passengers who left the route at the point. Expressions (7) and (8) form the basis for improving the method for determining the dynamic probability of passengers leaving at point N for the period with the serial number S.

$$q_N(S) = \frac{Q_{BЫX_N}(S)}{\left[\sum_{\phi=1}^{N_{пункт}} Q_{BX_\phi}\left(S - \bar{t}_{N\phi}\right)\right] - Q_{BX_N}(S)} \quad (8)$$

Where $q_N(S)$ - the probability of passengers leaving at point N during the period S;

$Q_{ВИХ_N}(S)$ - The number of passengers who got off at point N during period S.

The workload of the site is determined as:

$$G_{N,N+1}(S)=\sum_{\phi=1}^{N} Q_{BX_\phi}\left(S-\bar{t}_{N\phi}\right)\cdot\sum_{\rho=N+1}^{N_{пункт}} q_\rho\left(S+\bar{t}_{N,N+1}+\bar{t}_{N\rho}\right) \qquad (9)$$

Where $G_{N,N+1}(S)$ - the workload of the section between points $N$ and $N+1$ for a period of time $S$.

Substituting expression (19) into (20), we have:

$$G_{N,N+1}(S)=\left\{\sum_{\varphi=1}^{N} Q_{BX_\varphi}\left(S-\bar{t}_{N\varphi}\right)\right\}\times$$

$$\times\sum_{\rho=N+1}^{N_{пункт}}\left\{\frac{Q_{ВЫХ_\rho}\left(S+\bar{t}_{N,N+1}+\bar{t}_{N\rho}\right)}{\left[\sum_{\phi=1}^{N_{зас}} Q_{BX_\phi}\left(S+\bar{t}_{N,N+1}+\bar{t}_{N\rho}-\bar{t}_{\phi\rho}\right)\right]-Q_{BX_\rho}\left(S+\bar{t}_{N,N+1}+\bar{t}_{N\rho}\right)}\right\} \qquad (10)$$

The workload of the section (10) in a certain period of time will determine the workload of the bus following the section. The above expression (10) does not take into account the uneven boarding of passengers on buses, however, unlike (6), it makes it possible to obtain the value of the congestion level for any period of time. When additional research is carried out and the corresponding coefficients are formed, the expression can be supplemented.

## CONCLUSION

The study of operating conditions using the method of expert assessments and processing of the results by the mathematical apparatus of statistics made it possible to identify the most significant factors that affect the technical condition of vehicles, and to calculate the weighting coefficients of factors that need to be controlled: mileage (0.2139), the level of workload (0, 1798), the average technical speed (0.1476), as well as the quality of the road surface (0.1837). Considering that during the operation of the convoy, vehicles are operated with different loads, a method for mediated monitoring of technical and operational characteristics for each individual vehicle has been developed, which made it possible to individually record the characteristics. The developed method is based on a complex analysis of the parameters of the functioning of the existing means of monitoring the modes of operation of the objects of a motor vehicle, which leads to an increase in the efficiency of determining the technical condition of vehicles.

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