The Regularity Model of the Average Daily Mileage and Trip Length Influence on Actual Frequency of Car Engineering Servicing

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Abstract. In the article, it is shown that car dependability depends strongly on actual frequency of car engineering servicing, which can differ significantly from the standard one. Actual frequency is influenced by a great number of factors. The most essential factors are the car's daily mileage and trip length.
To define the influence regularities of these factors on actual frequency of engineering servicing, an imitating model and a software for its realization were developed. Model's adequacy was proved experimentally.
On the base of simulation experiments, influence regularities of the daily mileage and trip length on actual frequency of car engineering servicing were defined, and analytical models describing these regularities were developed.

1. Introduction

Dependability is the most important car characteristic. It is considered while forming a park structure [1], planning resource needs necessary for car operation [2, 3], and estimating the influence on the environment [4]. To provide the demanded availability level, efficiency, and ecological compatibility of cars, engineering servicing is carried out.

Engineering servicing is a complex of operations or an operation carried out to maintain availability or serviceability of a car when using as intended, waiting, keeping, and transporting. Engineering servicing frequency is a time period between the given type of engineering servicing and the next engineering servicing of the same type, or a more complex one.

Actual engineering servicing frequency differs from the standard value in many cases. Reliability measure and technical readiness coefficient change in this connection. One of the reasons of variation of operating time before engineering servicing is car daily mileage change.

Daily mileage is influenced by many factors. First of all, those are operating conditions, which determine a car's speed, and driving skill. With aging, the car is operated less intensively. That phenomenon is associated with the downtime increase caused by elimination of failures and malfunctions [2].

Changing of daily mileage leads to variation of actual engineering servicing frequency. Unstable operation intensity does not allow carrying out engineering servicing at the exact standard frequency. Thus, actual engineering servicing frequency varies in a wide interval and differs significantly from the standard. Variation of actual engineering servicing frequency is defined by the planning method of putting a car into service, the change of car daily mileage, and the relation between the standard engineering servicing frequency and daily mileage.

2. Research method

When considering the regularities of the average daily mileage and trip length influence on actual engineering servicing frequency, the following axioms are taken as initial principles:

1 – actual engineering servicing frequency is a sum of random values of trip length in a period between two subsequent engineering servicing complexes;

2 – if a trip length is less than a daily mileage, then actual engineering servicing frequency is a sum of random values of daily mileage;

3 – if a trip length (daily mileage) is a random value, then engineering servicing frequency is also a random value.

There are two possible approaches to examine the considered regularity: 1 – the studied system is not structured, but is presented as a black box, then actual engineering servicing frequency is related to a trip length (daily mileage) by empirical models; 2 – the studied system is structured, and on the base of that structure a model of a system on the whole is created; considering that the examined process is stochastic, it is rational to use a simulation model.

The second approach should be preferred, because it allows to obtain a result in changeable conditions.

On the base of the axioms and analysis of the system of actual engineering servicing frequency forming, an simulation model was developed. Its algorithm is presented in the figure 1. Modelling is carried out in the following order.

1. The following data are being input: mathematical expectation of the daily mileage (M_{Lc}, km), variation coefficient of the daily mileage (V_{Lc}), the standard value of engineering servicing frequency ($L^{(н)}_{TO}$, km), allowable deviation of engineering servicing frequency (dL_{TO}, km), modelling time ($T_м$, days), car quantity (A), and the number of the daily mileage distribution law (Z_L).

2. The initial state of operating time after the latest engineering servicing is generated ($L_{\sum i}$, km). The number of a day (j) and the number of a car (i) are equated to 1. After that the values of trip length (L_{pi}) and daily mileage (L_c) are generated.

3. The values of trip length and daily mileage are compared. If the trip length is bigger than the daily mileage, then the value of daily mileage is extracted from the value of trip length ($L_{\text{pi}} = L_{\text{pi}} – L_{\text{c}}$).

4. The car number is increased by 1. Then it is checked if the car number is bigger than the car quantity.

If it is not, it is checked whether the trip length is equal to 0. If it is, a value of trip length is generated and all steps are repeated. If it is not, a value of daily mileage is generated and all steps are repeated.

If the car number is bigger than the car quantity, then the day number is increased by 1, and it is checked whether the day number is bigger than the modelling time. In case when a number of realizations N_{realiz} is set, the quantity of the carried out engineering servicing complexes is checked. If $N_{\text{TO}} >= N_{\text{realiz}}$, or the modelling cycle is finished, the values of actual engineering servicing frequency are printed. The program work is finished. If it is not, the car number is increased by 1 and all steps are repeated.

5. If the trip length is less than the daily mileage, then the daily mileage value is added to the operating time after the latest failure ($L_{\sum} = L_{\sum} + L_{\text{c}}$).

6. The value of the operating time after the latest engineering servicing and the standard of engineering servicing frequency are compared. If the operating time is bigger or equal to the standard, it is checked if the operating time is bigger than the sum of values of the standard and the allowable deviation of engineering servicing frequency. If it is, then the actual engineering servicing frequency (L_{TO}) is equated to the differential of the values of the operating time after the latest engineering servicing and daily mileage ($L_{\text{TO}} = L_{\sum\text{i}} – L_{\text{c}}$), the value of the operating time after the latest engineering servicing complex is equated to the daily mileage value, and the value of the operating time after the

latest engineering servicing complex for the previous day is equated to 0.

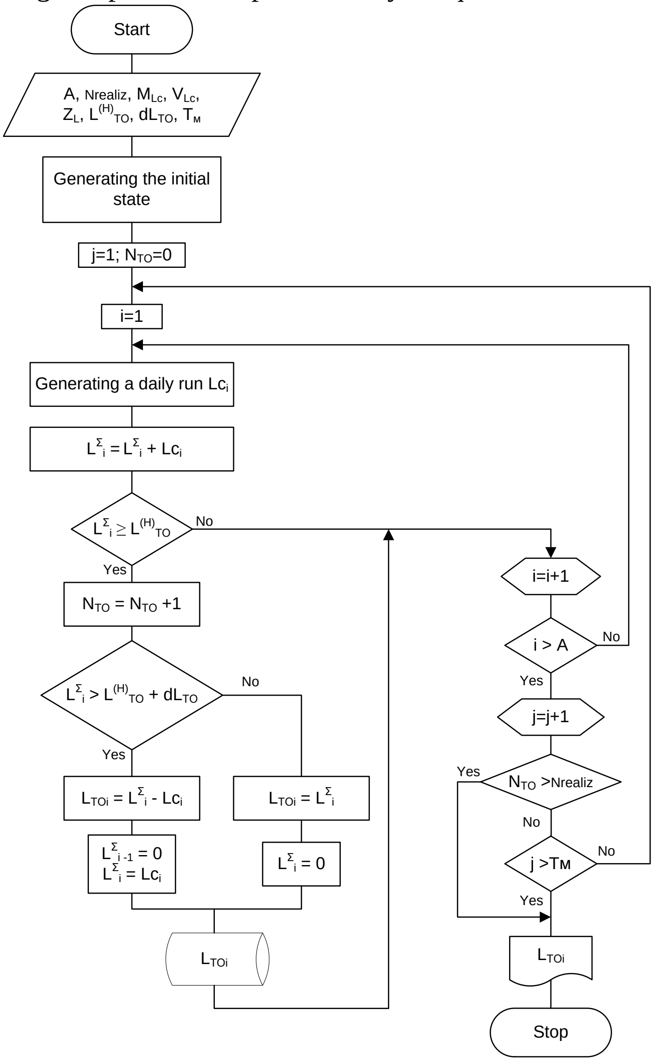

Figure 1. The imitating model algorithm of the average daily mileage and trip length influence on actual engineering servicing frequency.

If it is not, the actual engineering servicing frequency is equated to the value of the operating time after the latest engineering servicing, and that operating time is equated to 0. In both cases, the trip length is equated to 0, the actual engineering servicing frequency is saved, and the steps from the paragraph 4 are repeated.

7. If the operating time after the latest engineering servicing is less than the standard value of engineering servicing frequency, then the actions from the paragraph 4 are carried out.

The next research step is aimed to define the regularities of the daily mileage and trip length influence on actual engineering servicing frequency. Actual engineering servicing frequency is characterized by the average value $\overline{L_{\text{TO}}^{(\Phi)}}$ and variation coefficient $V_{L_{\text{TO}}}$. Daily mileage is considered when it is bigger or equal to a trip length. In other cases, it is of no importance, and a trip length is considered. A trip length (daily mileage) is also characterized by the average value L_{p} and variation coefficient $V_{L_{\text{p}}}$.

3. Results

To check the adequacy of the model of daily mileage and trip length influence on actual engineering servicing frequency, actual engineering servicing frequency values received in transport enterprises of the open society "Surgutneftegaz" on the base of a passive experiment were compared to calculated values obtained with the simulation model for the same conditions. Assessment of the imitating model adequacy to the experimental data at counting the values of the average engineering servicing frequency was carried out with the help of Fisher's coefficient. The dispersion relation is 13.80. With 0.99 probability, that value is bigger than the table one. The standard approximation deviation is 1.86 %.

To determine the type of a two-factor model of a trip length and its variation coefficient influence on actual frequency, a full factorial simulation experiment was carried out. The numerical values of the model parameters were defined, and its statistical characteristics were calculated. The model is presented in the figure 2 in a graphical form. It is of the following type:

$$\overline{L_{\text{TO}}^{(\Phi)}} = 1.03 + 0.71.$$

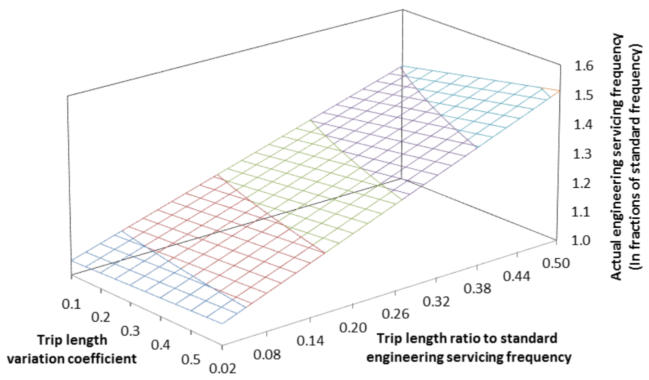

Figure 2. Influence of the average value and variation coefficient of trip length on the average actual engineering servicing frequency.

A two-factor model of the relation between the variation coefficient of engineering servicing frequency and a trip length and its variation coefficient is of the following type (figure 3):

$$V_{L_{\text{TO}}} = 0.013 + 0.22L_{\text{p}} + 0.05V_{L_{\text{p}}} + 0.34L_{\text{p}}V_{L_{\text{p}}} + 0.008L_{\text{p}}^2 - 1.23L_{\text{p}}^2V_{L_{\text{p}}}.$$

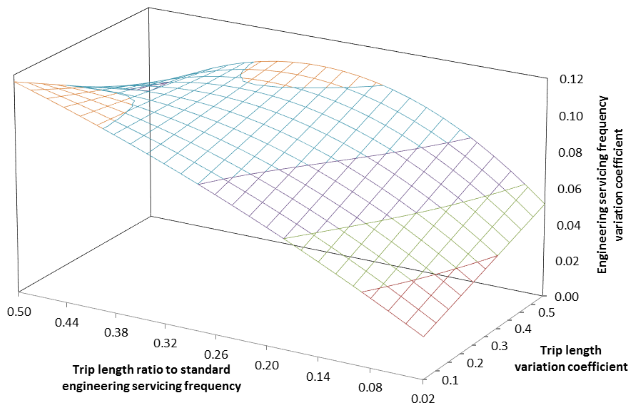

Figure 3. Influence of the relative trip length in fractions of the standard engineering servicing frequency and trip length variation coefficient on engineering servicing frequency variation coefficient.

The type of a mathematical model of engineering servicing frequency variation influence on the car reliability measure is also determined on the base of a simulation experiment. Analysis of the results obtained for various values of the average engineering servicing frequency showed that the best approximation of the experimental data is provided by a cubic.

The obtained model does not allow judging the considered regularity fully, as the parameter numerical values of the mathematical model of engineering servicing frequency variation influence on reliability measure change, when the average value of actual engineering servicing frequency is changed. For descriptive reasons, on the base of an active simulation experiment, a two-factor model was obtained (figure 4):

$$R(L_{\text{TO}}) = 0.938 + 0.41L_{\text{TO}} - 0.32V_{L_{\text{TO}}} - 0.37L_{\text{TO}}^2 + 0.085V_{L_{\text{TO}}}^2 + 0.022L_{\text{TO}}^3 - 0.83V_{L_{\text{TO}}}^3.$$

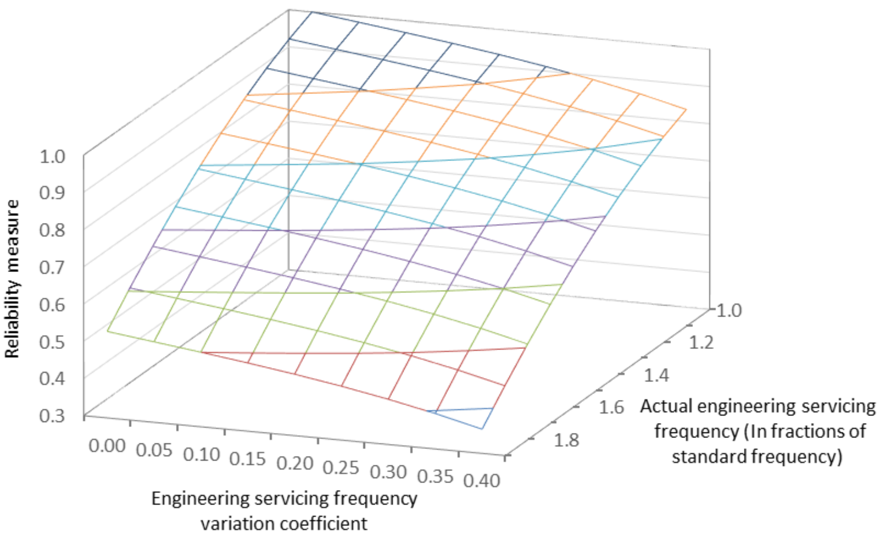

Figure 4. Influence of the average value and variation coefficient of engineering servicing frequency on reliability measure.

The model is adequate to the experimental data with 0.99 probability, the standard approximation deviation is 2.41 %.

4. Inference

On the base of the carried out research, an imitating model of the average daily mileage and trip length influence on actual engineering servicing frequency was developed. Its assessment with Fisher's coefficient proved its adequacy with a probability no less than 0.95. The type of a two-factor model of a trip length and its variation coefficient influence on actual engineering servicing frequency is determined. The type of a two-factor model of relation between engineering servicing frequency variation coefficient and a trip length and its variation coefficient is defined.

It is determined that the influence of engineering servicing frequency variation on car reliability measure is described by a cubic. It is adequate with 0.99 probability.

The obtained results can be used for operational determination and correction of engineering servicing frequency standards in order to provide the demanded level of car reliability when dialy mileage and trip length change.

5. References

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