26th International Conference
ENGINEERING MECHANICS 2020
Brno, Czech Republic, November 24 – 25, 2020

MODEL OF THE PROCESS OF OPERATING RAIL TRANSPORT MEANS

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Abstract: *The process of using public transport trams is characterized by a period of changing phases of use. For units that carry out a transport task, it is important to have tools (of varying complexity in complexity) to analyze and forecast the state of the system, and to facilitate decisions related to process control. It was assumed that in the set of technical objects operated in the test object, disjoint subsets of homogeneous objects can be distinguished from the point of view of the test. The following considerations include a subset of such objects. The results of completed model tests confirmed the expected model responses to changes in the value of its parameters. This proves the correctness of the calculations made and the model's usefulness for initial calculations, the forecasted state of the analyzed system after changing the scope of impacts.*

Keywords: Tram, Operation, Markov process, State of serviceability vehicle, Operating condition.

1. Introduction

Increasing degree of automation of production and service processes as well as technical and technical progress and others) in the data structure.

Both obsolete technological devices that are damaged, their emergency components, as well as planned serviced maintenance and reconstruction of usable potential (repairs) in a way depending on the impact on the efficiency of the availability of economic services. Increasingly, in the use of machines (in enterprises), computer systems are introduced to support maintenance services. One of the basic functions of computer programs supporting traffic handling is the registration of data on the operation of machines. After the implementation of this type of system, you can automatically generate periodic reports containing various types of main applications, including those defined by the software. Similar processes have been described (Łukasiewicz, 2018 and Ligaj, 2018).

2. Object and subject of research

The object of research is generally understood machine exploitation system. Controlled processes that are components of the operation process are implemented in this system. The rationality of this system's operation determines the efficiency of the use of machines and the possibilities of achieving these goals by these machines.

As an example, the real operation system for tram trams of the urban agglomeration of over 400,000 was chosen residents. This system belongs to the class of real and action systems with purposeful behavior. Controlling the processes implemented in this system makes it possible to achieve the set goals.

The communication system carries out the tasks forming the work cycle in turn: f_1 - the phase of activating the elements, f_2 - the phase of task implementation, f_3 - the service phase, f_4- organizational stop (waiting phase for putting into service). In the phase of implementation of tasks $f_{2,}$ individual elementary subsystems of the <C-OT> type (driver - tram) perform the assigned transport tasks. Due to the possibility of damage

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to the tram or the driver's unfitness, the time taken to complete the transport tasks by individual elementary subsystems is random. In the examined exploitation system, the damaged tram is directed to the airworthiness subsystem, where it is subject to renewal (service) processes. After completing the service processes, we pass task-oriented vehicle is directed to carry out tasks or to the so-called parking place (if the vehicle cannot undertake the task immediately after completing the service due to the schedule of transport tasks implemented in the system). The duration of vehicle servicing (vehicle stay in the airworthiness assurance system) is random. (Musiał, 2017 and Muślewski, 2018)

In order to restore, as soon as possible, the condition of vehicles that have been damaged during the implementation of transport tasks, so-called units are used technical emergency. The scope of services (repairs) carried out by operators of technical emergency units is limited by the existing technical equipment of these units and the need to perform services outside the service station. The time to restore the airworthiness condition (by operators of technical emergency units) is also random. The vehicle, which as a result of the actions of operators of technical emergency units has been restored to the condition of fitness, is directed to the implementation of the transport task (undertakes interrupted implementation of the task).

It is important in terms of ensuring the continuity of the performance of transport tasks and the technical and economic efficiency achieved by the system that during the f_2 phase of the working cycle as many vehicles as possible are in a state of task-worthiness and carry out transport tasks. This is influenced by such factors as: characteristics of the vehicles used, type of equipment and number of service stations service stations and technical ambulance units, equipping technical ambulance units with diagnostic equipment, the nature of transport tasks carried out, the manner and scope of service processes implementation and others. Therefore, there is a possibility to influence the system's ability to perform undertaken transport tasks. Therefore, there is a need to assess (forecast) the impact of actions taken in the system on the operation process and system behavior. In connection with the above, a method of building a model of the exploitation process was developed, the study of which allows forecasting the impact of selected decision variants on the course of the analyzed process (Landowski, 2004 and 2016).

3. A homogeneous Markov process as an example of an analysis of the use process

The mathematical process of tram processing is the stochastic process $\{X(t), t \geq 0\}$. The analyzed stochastic process $\{X(t), t \geq 0\}$ has a finite phase space S, $S = \{S_1, S_2, ..., S_n\}$. It was assumed that the model's operation is subject to a homogeneous Markov process $\{X(t): t \in R+\}$ with a finite set of positions S. States analyzed process of the stochastic distinguished condition of the distinguished operational state of the vehicle. Using a homogeneous Markov process for mathematical modeling of the use process, the basic assumption was made that this process is good enough, from the point of view of the research objective, maps the modeled real use process same as (Muślewski, 2015 and 2018).

As a result of the identification of the system of public transport trams and the exploitation process implemented in it, many operational states of the vehicle were identified that are relevant for the analysis of the operation of the examined system. For the purposes of illustration of the considerations among the states, the following tram operating states were analyzed (Landowski, 2004 and 2017):

S_1 - state of use - a state in which a streetcar with an operator performing the assigned transport tasks;

S_2 - service status in the airworthiness subsystem that occurs when, e.g. explained possible impossible to remove outside the service station by the output ambulance units;

S_3 - the state of waiting for the implementation of transport tasks at the beginning or end stops;

S_4 - waiting for the implementation of transport tasks in the tram depot.

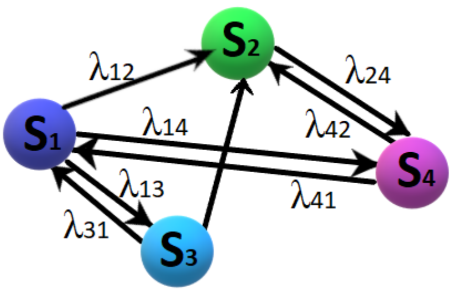

Fig. 1: Graph directed operating systems.

Possible transitions between the distinguished operating states of the tram were determined and illustrated in Fig. 1. For the distinguished operating tables evaluated the intensity matrix of process changes $\{X(t), t \in T\}$ (Landowski, 2018a).

By $P_i(t) = P\{X(t) = Si\}$, the answer indicates that at time t process $\{X(t), t \geq 0\}$ appears in the state $S_i \in S$. It was assumed that the initial state process X(t) is the state S_1, i.e. the initial distribution of the analyzed process is in the form (Landowski, 2004 and Landowski, 2018b):

$$P\{X(0) = S_1\} = l \quad (1)$$

$$P\{X(0) = S_i\} = 0 \text{ for } i \neq 1, S_i \in S \quad (2)$$

The intensities $\lambda_{i,j,}$ i, j = 1, 2, 3, 4 changes of process states $\{X(t), t\geq 0\}$ from the state $S_i \in S$ to the state $S_j \in S$ are included in the transition matrix Λ

$$\Lambda = \begin{vmatrix} -\lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} \\ 0 & -\lambda_{22} & 0 & \lambda_{24} \\ \lambda_{31} & \lambda_{32} & -\lambda_{33} & 0 \\ \lambda_{41} & \lambda_{42} & 0 & -\lambda_{44} \end{vmatrix}$$

After simplifying the entry, the transition intensity matrix Λ allows you to build a system of differential equations of the form:

$$\begin{cases} P_1(t) = -\lambda_{11}P_1(t) + \lambda_{31}P_3(t) + \lambda_{41}P_4(t) \\ P_2(t) = \lambda_{12}P_1(t) - \lambda_{22}P_2(t) + \lambda_{32}P_3(t) + \lambda_{42}P_4(t) \\ P_3(t) = \lambda_{13}P_1(t) - \lambda_{33}P_3(t) \\ P_4(t) = \lambda_{14}P_1(t) + \lambda_{22}P_2(t) - \lambda_{44}P_4(t) \end{cases} \quad (3)$$

In order for the system of equations (3) to have an unambiguous solution, the initial conditions determined by the relations (1) and (2) should be assumed. For the analyzed process $\{X(t), t \geq 0\}$ there is a stationary process distribution that does not depend on the initial distribution:

$$\lim_{t\to\infty} P_i(t) = p_i^* \quad (4)$$

The stationary probabilities p_i^* meet the system of equations:

$$\begin{cases} \sum_{i=1}^{n} p_i^* * \lambda_{ij} = 0 \\ \sum_{i=1}^{n} p_i^* = 1 \end{cases} \quad (5)$$

Based on the normalizing condition and the designated matrix Λ a system of equations was determined whose detailed solution is presented in Landowski (2018).

The solution of the system of equations takes the form:

$$p_1^* = y; \quad p_2^* = xy/\lambda_{24}; \quad p_3^* = wy; \quad p_4^* = yz \quad (6)$$

where:

$$w = \frac{\lambda_{13}}{\lambda_{31}+\lambda_{32}}, \; x = (\lambda_{41} + \lambda_{42})z - \lambda_{14} \quad (7), (8)$$

$$y = \frac{1}{1+\frac{y}{\lambda_{24}}+w+z}, \; z = \frac{\lambda_{11}-\lambda_{13}\cdot\lambda_{31}/(\lambda_{31}+\lambda_{32})}{\lambda_{41}} \quad (9), (10)$$

In order to verify the calculations, a calculation example was made. The calculations were made for various values of model parameters reflecting examples of changes in steering forces and an assessment of forecasting the impact of the analyzed events on the implementation of the process was made. Three variants of calculations were made in the presented sample. Calculations made for the values of model parameters estimated for the existing operating conditions of the system (corresponding to the state of the system preceding the effects of simulated events) were marked by "sym. Y".

The calculation variant is marked "sym. X" reflects the impact of reducing the number of so-called secondary damages and changes in the organization of service (lower expected value of random variables denoting the duration of states S_2 and S_3) for the analyzed process. The change in the expected value of the random variable denoting the duration of service (carried out by technical ambulance units and at service station positions may also be the result of other factors, e.g. changes in the organization and conditions of handling processes, increasing the number of operators of technical ambulance units, etc. Last variant) calculations ("sym. Z") illustrates the impact of a change in the organization of transport (shortening the duration of the S_4 state, i.e. shortening the time of the organizational break in carrying out transport tasks, e.g. by carrying out transport also at night) on the value of $P_i(t)$.

Tab. 1: Basic input data used for calculations.

	λ_{12}	λ_{13}	λ_{14}	λ_{24}	λ_{31}	λ_{32}	λ_{41}	λ_{42}
sym. X	0.0041	0.0054	0.0429	0.5556	1.3333	0.3333	0.2500	0.0131
sym. Y	0.0059	0.0115	0.0405	0.3115	0.6667	0.1667	0.2264	0.0121
sym. Z	0.0026	0.0051	0.0181	0.3135	0.6667	0.1667	0.2260	0.0118

The basic data used for the calculations are presented in Tab. 1, while Tab. 2 presents the results of calculations of the limit probabilities for individual calculation variants (determined on the basis of the relationship (6)). The calculations were made using developed computer calculation programs.

Tab. 2: Results of calculations of stationary probabilities.

	p_1^*	p_2^*	p_3^*	p_4^*
sym. X	0.8276	0.0115	0.0026	0.1584
sym. Y	0.7911	0.0271	0.0110	0.1708
sym. Z	0.8944	0.0137	0.0056	0.0864

4. Conclusions

Analysis of changes in the probability values $P_i(t)$ for all calculation variants shows that these probabilities settle after a certain time and reach a value corresponding to the value of the limit probabilities p_i^*. The results of completed model tests confirm the expected reactions of the model to changes in the values of its parameters. This proves the correctness of the calculations made and the usefulness of the model for making preliminary forecasts of the state of the analyzed system after changing the levels of the impact of the examined factors on the system

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