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SIMULATION OF THE MODEL OF TECHNICAL OBJECT AVAILABILITY CONTROL

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Abstract: *The paper presents the description of algorithm for calculation characteristics of simulation model for the operation process realized at the transport system. The model presented in the paper constitutes an integral element of the developed complex method of quality control in elaborate technical object performance systems. In this method stochastic models were implemented, including Markov and semi-Markov decisive processes as well as genetic and evolutionary algorithms. Due to the adopted assumptions, it will be possible to use the constructed models for evaluation and control of operation process because of various criteria such as availability and reliability of technical objects, efficiency as well as safety of complex performance systems. In the example presented in the paper, the evaluation criteria consist of the availability of technical object as well as unit income generated in the states of the modeled operation process. On the basis of the results of research carried out at an existing means of transport operation system, entry data for the model were obtained and simulation experiments were carried out. As a result, typical values for the analyzed characteristics of the performance of technical system were designated.*

Keywords: Technical object, Availability, Simulation model.

1. Introduction

The problem of controlling operation process carried out at complex technical systems on the basis of a selected criterion of evaluation is presented in many papers (eg.: Kulkarni, 1995, Lee, 2000, Marbach et al., 2001 and Woropay et al., 2007). In the paper (Grabski, 2010), the analyzed model is the safety control of marine ships developed with the use of precise semi-Markov decisive processes and Howard algorithm. Also in the paper (Migawa et al., 2016) for the evaluation of availability of technical objects the semi-Markov decisive model was used, in which the selection of control strategy was realized via genetic algorithm. However, in the paper (Knopik et al., 2016) the authors delineated optimal solution of criterion function defining income generated in operation system in the case of decreasing number of secondary failures of vehicle electrical system.

Significant complexity of the modeled operation processes carried out in real systems of technical objects operation and maintenance involves the need to use appropriate methods and tools including computer simulation programs providing the possibility of effective studies of models representing the operation processes and an analysis of the obtained results (Marbach et al., 2001 and Muślewski et al., 2016). Depending on the kind of analyzed research problems, appropriate mathematical models as well as methods of delineating optimal and quasi-optimal solutions were implemented (Grabski, 2010, Knopik et al., 2016, Migawa et al., 2016 and Zastempowski et al., 2014).

2. Simulation model of availability control

The program developed for simulation of the operation process makes it possible to perform simulation

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experiments for different numbers of operational events (changes in the process states), intervals of simulation time both for an individual technical object and a group of technical objects. In the simulation program, successive duration times of the operation process states are determined by generating pseudorandom numbers yielding values form exponential, gamma, normal, logarithmic-normal and Weibull distributions. The structure of the simulation program was created so that the simulation experiment will be able to reflect a set of the analyzed technical objects and the sequence of events happening to each technical object in the analyzed real system.

In Fig. 1 there is a block scheme depicting operation of the program for the model of technical objects operation process.

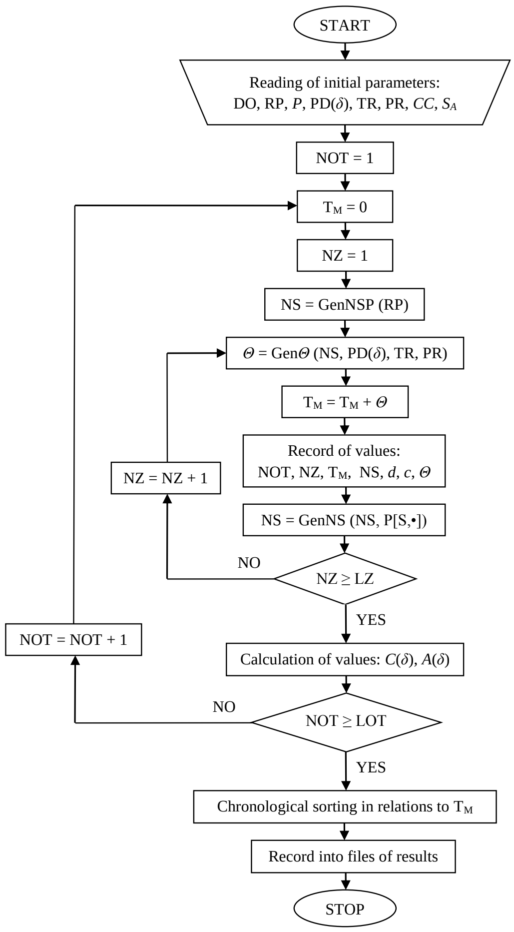

Fig. 1: Block scheme depicting operation of the program for technical objects operation process simulation model.

In order to carry out a simulation experiment it is necessary to prepare a set of defined input data:

a) DO (general data characterizing the simulation experiment):
   LOT – number of technical objects used in the simulation experiment,
   LZ – number of a technical object events in the simulation experiment,
   m – number of the process states, defined on the basis of a set of the modeled operation process states,
   LD – number of decisions possible to be made in particular states of the modeled operation process,
   Lδ – number of strategies δ possible to be used in the simulation experiment;
b) RP (the process initial distribution);
c) *P* (matrix of probabilities of the process states changes);
d) PD (matrix of probability of decision choice in the process states);
e) TR, PR (types and parameters of time distributions of being in particular states of the process);
f) *CC* (matrix of unit profit in the process states);
g) S_A (set of the process availability states).

In each moment of the simulation experiment in which the modeled operation process undergoes change (for the analyzed technical object) the following data is being entered into the file of results: number of the technical object NOT, number of the current event NZ, time of the current event (current time of model T_M), number of the model current state NS, current decision *d*, value of unit profit *c* related to the object's being in the process current state, generated value of the object's being in a current state Θ.

Next, values of functions applied in the simulation program are determined for the set of data generated during the simulation experiment (for the used strategy δ):

– value of the mean unit profit $C(\delta)$:

$$C(\delta) = \frac{\sum_{i=1}^{Z} c_i \cdot \Theta_i}{\sum_{i=1}^{Z} \Theta_i} \tag{1}$$

where:

c_i – *i*-th performance of a unit profit connected with being in the states of the modeled operation process $S = \{1, 2, \ldots, m\}$,

Θ_i – *i*-th time of the object's being in the states of the modeled operation process $S = \{1, 2, \ldots, m\}$,

$Z = LOT \cdot LZ$ – number of events (changes of the model states) for a specified number of technical objects;

– value of the technical object availability function $A(\delta)$:

$$A(\delta) = \frac{\sum_{i=1}^{Z} \Theta_i(S_A)}{\sum_{i=1}^{Z} \Theta_i} \tag{2}$$

where:

$\Theta_i(S_A)$ – *i*-th time of the object's being in the modeled operation process states belonging to availability states $S_A \in S = \{1, 2, \ldots, m\}$.

Fig. 1 has been completed with the following symbols: GenNSP – generation of the model initial state number, GenNS – generation of the model current state, GenΘ – generation of the time value of being in the model state.

For 9th state semi-Markov model of the means of transport operation process presented in the paper (Migawa et al., 2016) as well as data obtained from tests of the existing operation system, simulation experiments were carried out.

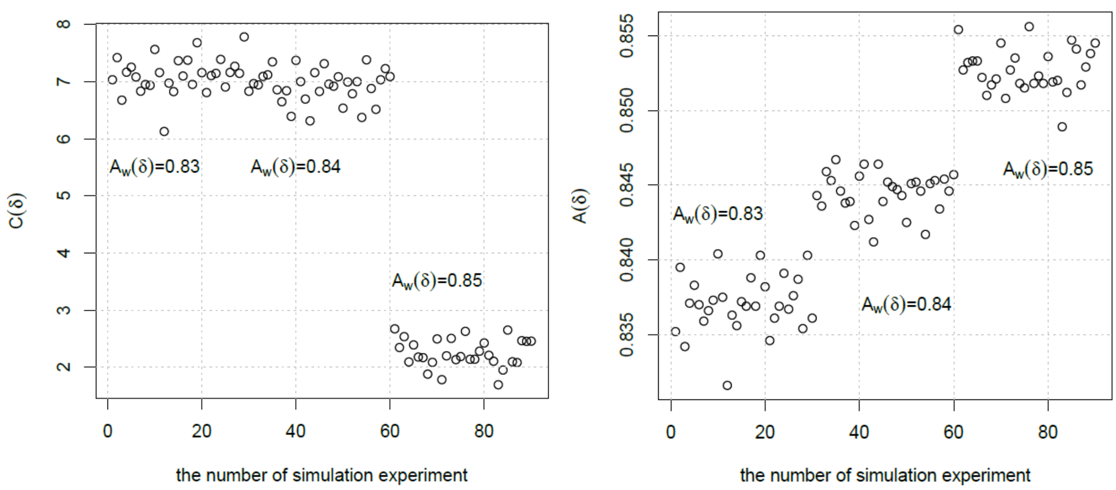

Fig. 2: Values of mean unit income as well as availability of technical object on the basis of simulation experiments for individual control strategies.

In Fig. 2 typical results of simulation experiments were presented for three selected strategies of technical object operation control process δ, so that the designated availability of technical objects $A(\delta)$ was at least equal to expected availability $A_w(\delta)$ for appropriate realization of transport tasks (for $A_w(\delta)$ = 0.83; 0.84, 0.85). Experiments carried out consisted of 30 rounds of operation simulation process for each analyzed strategy δ. As a result of the realization of simulation experiments, sets of 30 values of mean unit income $C(\delta)$ as well as 30 values of technical object availability $A(\delta)$ were obtained.

Mean values were designated for the results of carried out simulation experiments: unit income as well as availability of technical object (means of transport), presented in Tab. 1.

Tab. 1: Values of mean unit income as well as availability of technical object obtained on the basis of simulation program.

$A_w(\delta)$	$C(\delta)$ [PLN/h]	$A(\delta)$
0.83	7.1066	0.8371
0.84	6.9229	0.8445
0.85	2.2451	0.8527

3. Conclusions

One of the ways to facilitate effective evaluation and control of the quality of performance of complex technical object operation systems is implementing mathematical and simulation models for description and analysis of processes of operation carried out in these systems. Models of this type may be utilized for quality evaluation and control of complex technical systems performance from the point of view of various evaluation criteria such as: costs, income, reliability, availability, safety, efficiency, etc.

The simulation model of the operation process presented in the paper facilitates evaluation of the quality of the performance of analyzed technical system from the point of view of selected evaluation, i.e. mean income per time unit as well as technical object availability. On the basis of the obtained typical results it may be concluded that ensuring a higher level of availability of technical objects results in the necessity for additional expenses, at the same time resulting in decrease of unit income generated in operation system.

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