1. Introduction
The complex technical systems consist of a large number of subsystems and components. Furthermore, the operation processes of this class of the systems are complicated. Thus, there is the problem with inability to accurately describe the transitions between states. Changes of the complex technical systems operation states imply the changes of reliability structures of these systems and sometimes even a change the reliability characteristics of their components. In this case, the semi-Markov approach [1], [2], [4] is a good description of complex technical systems operation processes [1].

2. The complex technical systems operation processes
According to [5], we assume that the system during its operation process is taking \( v, v \in N \), different operation states. Further, we define the system operation process \( Z(t), t \in (-\infty, +\infty) \), with discrete operation states from the set of states \( Z = \{z_1, z_2, \ldots, z_v\} \). Moreover, we assume that the system operation process \( Z(t) \) is semi-Markov [1], [2], [4] with the conditional sojourn times \( \theta_{b_l} \) at the operation states \( z_b \) when its next operation state is \( z_{l}, \ b, l = 1,2,\ldots,v, \ b \neq l \).

2.1. Input preliminary parameters of complex technical system operation processes
Under general assumptions, to predict the basic characteristics of semi-Markov model [1], [2], [4] of the complex technical system operation processes, we should define its necessary following input preliminary parameters [5]:
- the duration time \( \theta \) of the system operation process,
- the number \( v \) of the operation states of the system operation process,
- the vector of probabilities \( [p_{b_0}(0)]_{1\times v} \) of the system operation process initial operation states, where \( p_{b_0}(0) = P(Z(0) = z_b) \) for \( b = 1,2,\ldots,v \),
- the matrix of probabilities \( [p_{b_0}]_{1\times v} \) of the system operation process transitions between the operation states, where \( p_{b_0} = 0 \) for \( b = 1,2,\ldots,v \).
- the mean values $M_{b\ell} = E[\theta_{b\ell}]$ of the conditional sojourn times $\theta_{b\ell}$ at the operation states $z_{b\ell}$ when its next operation state is $z_{b\ell}$, $b, l = 1,2,...,v$, $b \neq l$.

2.2. Prediction of complex technical system operation processes

When the basic parameters, describe in Section 2.1 are given and from the formula for total probability, the mean values of the unconditional sojourn times $\theta_{b\ell}$, $b, l = 1,2,...,v$, of the system operation process at the operation states $z_{b\ell}$, $b, l = 1,2,...,v$, are given by [5]:

$$M_{b\ell} = E[\theta_{b\ell}] = \sum_{l=1}^{v} p_{b\ell} M_{b\ell}, \quad b, l = 1,2,...,v,$$

(1)

where $p_{b\ell}$ are the input probabilities of transitions between the operation states defined as the matrix of probabilities and $M_{b\ell}$ are the input conditional mean values of the conditional sojourn times $\theta_{b\ell}$, defined in [1], [6].

The limit values of the transient probabilities at the particular operation states $p_{b}(t) = P(Z(t) = z_{b\ell}), t < 0, +\infty, \quad b, l = 1,2,...,v$, are given by

$$p_{b\ell} = \frac{\pi_{b} M_{b\ell}}{\sum_{l=1}^{v} \pi_{l} M_{l}}, \quad b, l = 1,2,...,v,$$

(2)

where $M_{b\ell}$, $b, l = 1,2,...,v$, are given by (1), while the steady probabilities $\pi_{b}$ of the vector $[\pi_{b}]_{1v}$ satisfy the system of equations

$$\begin{bmatrix} \pi_{b} \\ \sum_{l=1}^{v} \pi_{l} \end{bmatrix} = \begin{bmatrix} \pi_{b} \\ [p_{b\ell}] \end{bmatrix}, \quad \sum_{l=1}^{v} \pi_{l} = 1.$$

(3)

Other practically interesting characteristics of the system operation process possible to obtain are its total sojourn times $\hat{\theta}_{b\ell}$ in the particular operation states $z_{b\ell}$, $b, l = 1,2,...,v$, in the fixed operation time $\theta$. It is well known [5] that the system operation process total sojourn times $\hat{\theta}_{b\ell}$ in the particular operation states $z_{b\ell}$, for sufficiently large operation time $\theta$ have approximately normal distribution with the expected value given by

$$E[\hat{\theta}_{b\ell}] = p_{b\ell} \theta, \quad b, l = 1,2,...,v,$$

(4)

where $p_{b\ell}$ are given by (2).

3. Description of the computer program for prediction of the complex technical systems operation processes

The presented computer program is based on methods of identification the complex technical system operation processes presented in Section 2.2 and given in [5]. The computer program is written in Java language with using SSJ V2.1.3 library. The SSJ library is a Java library, developed in the Department d’Informatique et de Recherche Operationelle (DIRO) at the Universite de Montreal, gives the support of stochastic simulations. The online documentation of SSJ can be found at the website http://www.iro.umontreal.ca/~simardr/ssi/indexe.html.

This program is composed of one panel with two parts: “INPUT” and “OUTPUT”. First part is used to read the input preliminary parameters of system operation process, i.e.: - the number $v$ the operation states of the system operation process, - the duration time $\theta$ of the system operation process, - the matrix of probabilities of the system operation process transitions between the operation states, - the matrix of the mean values of the conditional sojourn times $\theta_{b\ell}$ at the operation states $z_{b\ell}$ when its next operation state is $z_{b\ell}$. When the reading data is finished, the computer program automatically predicts the characteristics of the system operations process. Then the following results of the program are show in the section “OUTPUT”: - the unconditional mean values $M_{b\ell} = E[\theta_{b\ell}]$, $b, l = 1,2,...,v$, of sojourn times $\theta_{b\ell}$, $b, l = 1,2,...,v$, at the particular operation states, - the limit values of the transient probabilities $p_{b\ell}$, $b, l = 1,2,...,v$, at the particular operational states, - the expected value $E[\hat{\theta}_{b\ell}] = p_{b\ell} \theta$, $b, l = 1,2,...,v$, of total sojourn times $\hat{\theta}_{b\ell}$ in the particular operation states $z_{b\ell}$, $b, l = 1,2,...,v$, in the fixed operation time $\theta$. 

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4. Computer-aided prediction of unknown characteristics of operation process of the port oil transportation technical system operation process

We consider the operation process of the port oil transportation system [3]. It is the main part of the Oil Terminal in Dębogórze that is designated for the reception from ships, the storage and sending by carriages or by cars the oil products such like petrol and oil. It is also designated for receiving from carriages or cars, the storage and loading the tankers with oil products.

The considered terminal is composed of three parts A, B and C, linked by the piping transportation systems with the pier. The unloading of tankers is performed at the pier placed in the Port of Gdynia. The pier is connected with terminal part A through the transportation subsystem $S_1$ built of two piping lines composed of steel pipe segments with diameter of 600 mm. In the part A there is a supporting station fortifying tankers pumps and making possible further transport of oil by the subsystem $S_2$ to the terminal part B. The subsystem $S_2$ is built of two piping lines composed of steel pipe segments of the diameter 600 mm. The terminal part B is connected with the terminal part C by the subsystem $S_3$. The subsystem $S_3$ is built of one piping line composed of steel pipe segments of the diameter 500 mm and two piping lines composed of steel pipe segments of diameter 350 mm. The terminal part C is designated for the loading the rail cisterns with oil products and for the wagon sending to the railway station of the Port of Gdynia and further to the interior of the country.

The oil pipeline system consists three subsystems $S_1$, $S_2$, $S_3$:
- the subsystem $S_1$ composed of two identical pipelines, each composed of 178 pipe segments of length 12m and two valves,
- the subsystem $S_2$ composed of two identical pipelines, each composed of 717 pipe segments of length 12m and two valves,
- the subsystem $S_3$ composed of three different pipelines, each composed of 360 pipe segments of either 10 m or 7,5 m length and two valves.

Taking into account the expert opinion on the operation process of the considered port oil pipeline transportation system we fix the number $\nu = 7$ of the pipeline system operation process states and we distinguish the following as its seven operation states:
- an operation state $z_1$ – transport of one kind of medium from the terminal part B to part C using two out of three pipelines in subsystem $S_3$,
- an operation state $z_2$ – transport of one kind of medium from the terminal part C (from carriages) to part B using one out of three pipelines in subsystem $S_1$,
- an operation state $z_3$ – transport of one kind of medium from the terminal part B through part A to pier using one out of two pipelines in subsystem $S_2$ and one out of two pipelines in subsystem $S_1$,
- an operation state $z_4$ – transport of two kinds of medium from the pier through parts A and B to part C using one out of two pipelines in subsystem $S_1$, one out of two pipelines in subsystem $S_2$ and two out of three pipelines in subsystem $S_3$,
- an operation state $z_5$ – transport of one kind of medium from the pier through part A to B using one out of two pipelines in subsystem $S_1$ and one out of two pipelines in subsystem $S_2$,
- an operation state $z_6$ – transport of one kind of medium from the terminal part B to C using two out of three pipelines in subsystem $S_3$, and simultaneously transport one kind of medium from the pier through part A to B using one out of two pipelines in parts $S_1$ and one out of two pipelines in subsystem $S_2$,
- an operation state $z_7$ – transport of one kind of medium from the terminal part B to C using one out of three pipelines in part $S_3$, and simultaneously transport second kind of medium from the terminal part C to B using one out of three pipelines in part $S_3$.

Moreover, we fix that there are possible the transitions between all system operation states. The input necessary parameters of the port oil piping transportation system operation process are as follows [3]:
- the oil piping system operation time is $\theta = 1$ year = 365 days,
- the number of the piping system operation states is $\nu = 7$,
- the initial probabilities $p_{b}(0), b = 1,2,...,7$ of the piping system operation process transients in the particular states $z_b$ at the moment $t = 0$, are
$$[p(0)]_{1,7} = [0.34, 0.05, 0, 0, 0.23, 0.19, 0.19],$$
- the transition probabilities $p_{bl}, b,l = 1,2,...,7$, of the piping transportation system operation process
from the operation state \( z_6 \) into the operation state \( z_7 \) are

\[
[p_{67}] = \begin{bmatrix}
0 & 0.022 & 0.022 & 0 & 0.534 & 0.111 & 0.311 \\
0.2 & 0 & 0 & 0 & 0 & 0 & 0.8 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0 & 0.023 & 0.233 & 0.233 & 0.095 \\
0.488 & 0.023 & 0 & 0.023 & 0.233 & 0.233 & 0.095 \\
0.516 & 0.064 & 0 & 0.226 & 0.194 & 0 & 0
\end{bmatrix}
\]

- the mean values of the conditional sojourn time of the system operation process in the particular operation states

\[
M_{12} = 1920, \quad M_{13} = 480, \quad M_{15} = 1999.4, \\
M_{16} = 1250, \quad M_{17} = 1129.6, \quad M_{21} = 9960, \\
M_{27} = 810, \quad M_{31} = 575, \quad M_{47} = 380, \\
M_{51} = 874.7, \quad M_{52} = 480, \quad M_{54} = 300, \\
M_{56} = 436.3, \quad M_{57} = 1042.5, \quad M_{61} = 325, \\
M_{65} = 510.7, \quad M_{67} = 438, \quad M_{71} = 874.1, \\
M_{72} = 510, \quad M_{75} = 2585.7, \quad M_{76} = 2380.
\]

As there are no realizations of conditional sojourn times \( \theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7, \theta_{14}, \theta_{15}, \theta_{17}, \theta_{22}, \theta_{23}, \theta_{24}, \theta_{25}, \theta_{27}, \theta_{31}, \theta_{41}, \theta_{42}, \theta_{43}, \theta_{45}, \theta_{46}, \theta_{51}, \theta_{61}, \theta_{63}, \theta_{64}, \theta_{71} \) and \( \theta_4 \), it is impossible to estimate their conditional mean values \( M_{14}, M_{15}, M_{17}, M_{22}, M_{23}, M_{24}, M_{25}, M_{27}, M_{31}, M_{41}, M_{42}, M_{43}, M_{45}, M_{51}, M_{61}, M_{63}, M_{64}, M_{71}, M_{24} \).

This data are loaded to the computer program and it is shown in its “INPUT” window (Figure 1).

After the basic input data, the following output characteristics are got as the results of computer program in “OUTPUT” for considered technical system operation process (Figure 2):
- the unconditional mean sojourn times in the particular operation states,
- the limit values \( p_{67} \) of the transient probabilities at the operational states \( z_6 \),
- the expected values of the total sojourn times \( \hat{\theta}_b \), \( b = 1, 2, ..., 7 \), of the system operation process in particular operation states \( z_6 \), \( b = 1, 2, ..., 7 \), during the fixed operation time.

![Figure 1. Basic parameters of the port oil transportation system operation process](image)

![Figure 2. Characteristics of the port oil transportation system operation process](image)

5. Conclusion

The presented computer program is used for prediction of the unknown characteristics of complex technical systems operation processes. It is based on methods and algorithms given in [5]. This program allows us to automatically find the unknown characteristics of complex technical systems operation processes. In the article presented program have been used to prognosis unknown characteristics of the port oil transportation system operation process.

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