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Critical Infrastructure Operation Process Modelling

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The operation processes of real technical systems are very complex and it is difficult to analyse these systems reliability, safety and availability with respect to changing in time their operation conditions that often are essential in this analysis. The complexity of the systems' operation processes and their influence on changing in time the systems' structures and their components' reliability and safety characteristics is often very difficult to fix. Usually, the system environment and infrastructure have either an explicit or an implicit strong influence on the system operation process. As a rule, some of the initiating environment events and infrastructure conditions define a set of different operation states of the technical systems in which the systems change their reliability and safety structure and their components reliability and safety parameters. A convenient tool for analysing this problem is semi-Markov modelling (Grabski, 2002, 2014; Kołowrocki, 2014) of the systems operation processes proposed in this chapter.

In the multistate critical infrastructure (Lague et al., 2015; Xue, 1985) operation process modelling we start with the critical infrastructure operation process parameters (OPP) defining. For the critical infrastructure operation process the following parameters are defined:

- the number of operation states (OPP1);
- the operation states (OPP2);
- the initial probabilities of the operation process staying at particular operation states (OPP3);
- the probabilities of transition between the operation states (OPP4);
- the mean values of the sojourn times at the operation states (OPP5).

Next, the following critical infrastructure operation process characteristics (OPC) that can be either calculated analytically using the above parameters of the operation process or evaluated approximately by experts are introduced:

- the mean values of the operation process unconditional sojourn times at the operation states (OPC1);
- the limit values of transient probabilities of the operation process at the particular operation states (OPC2);
- the mean values of the total sojourn times of the operation process at the particular operation states, during the fixed critical infrastructure opetation time (OPC3).

Applications of the proposed critical infrastructure operation process parameters and characteristics can be made for the evaluation of the operation process parameters and prediction of the operation process characteristics of the port oil terminal critical infrastructure. We consider the port oil terminal critical infrastructure impacted by its operation process placed at the Baltic seaside that is designated for receiving oil products from ships, storage and sending them by carriages or trucks. The considered terminal is composed of three parts *A*, *B* and *C*, linked by the piping transportation system with the pier (see: Figure 1).

The main technical assets of the port oil terminal critical infrastructure are:

- asset A_1, the port oil piping transportation system;
- asset A_2, the internal pipeline technological system;
- asset A_3, the supporting pump station;
- asset A_4, the internal pump system;
- asset A_5, the port oil tanker shipment terminal;
- asset A_6, the loading railway carriage station;
- asset A_7, the loading road carriage station;
- asset A_8, the unloading railway carriage station;
- asset A_9, the oil storage reservoir system.

The asset A_1, the port oil piping transportation system, operation is the main activity of the port oil terminal involving the remaining assets $A_2 - A_9$ and determining their operation processes.
The functional scheme of the asset A_1, the port oil piping transportation system, is presented in Figure 1.

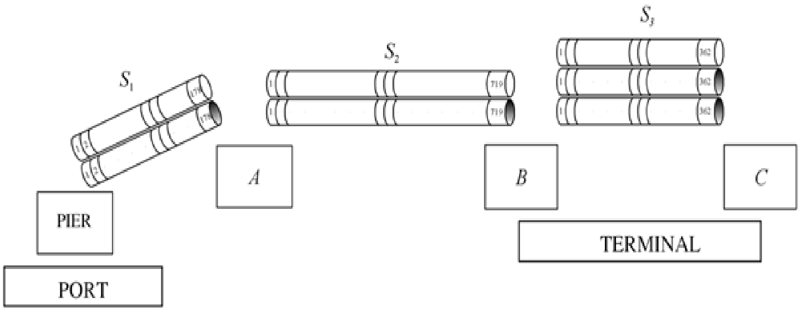

Fig. 1. The functional scheme of the port oil piping transportation system.

As a consequence of the achieved new results, the further research could be focused on safety analysis of multistate ageing complex systems (Kołowrocki, 2014) and critical infrastructure networks (Lague et al., 2015), considering their ageing (Szymkowiak, 2019), inside dependencies (Kołowrocki, 2020), outside impacts, including separate and joint operation and climate-weather change impacts (Kołowrocki, 2021) and the use of the achieved results to improve their safety (Magryta-Mut, 2023), strengthen their resilience and mitigate the effects of their degradation and failures (Bogalecka, 2020).

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