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Integrated software tools supporting decision making on identification, prediction and optimization of complex technical systems operation, reliability and safety
Part 1
Integrated software tools description

Abstract

The paper is composed of six parts and presents the software tools created in the scope of the Poland-Singapore Joint Research Project, the Integrated Safety and Reliability Decision Support System - IS&RDSS. In the paper first part, there are briefly described all computer programs with pointed aims. Dependencies between computer programs and possible transitions using this integrated package of software tools are presented at the scheme-algorithm. In the remaining paper parts, there is presented the application of the computer programs, being in the package of software tools, to the reliability analysis of an exemplary complex technical system.

1. Introduction

One of the project result stages is integrated package of tools for Complex Industrial Systems and Processes Safety and Reliability Optimization. Included computer programs CP 8.1-8.16 are supplemented by Tasks 8.1-8.16, [6]-[21] of the Workpackage WP8.

2. Description of the integrated package of software tools

The computer programs CP 8.1-8.16 are used in tasks of package WP9 in particular cases for real technical systems i.e. port, shipyard and maritime transportation systems. The computer programs along with the description are also included into the training courses directed to industry in the scope of WP11.

In *Figure 1* there is presented the scheme of the integrated package of software tools.

The computer program CP 8.1 is used for identification of the operation processes of complex technical systems. The aims of the program CP 8.1 are:

- identification of the unknown basic parameters of the system operation processes;
- verification the hypotheses concerning the unknown forms of the distribution functions of the conditional sojourn times in the particular operation states on the basis of empirical data coming from the operation processes of complex technical systems;
- determining the probabilities of the initial operation states of the system operation process and the probabilities of the system operation process transitions between the operation states;

- estimation the unknown parameters of the distributions of the conditional sojourn times of the system operation process in the particular
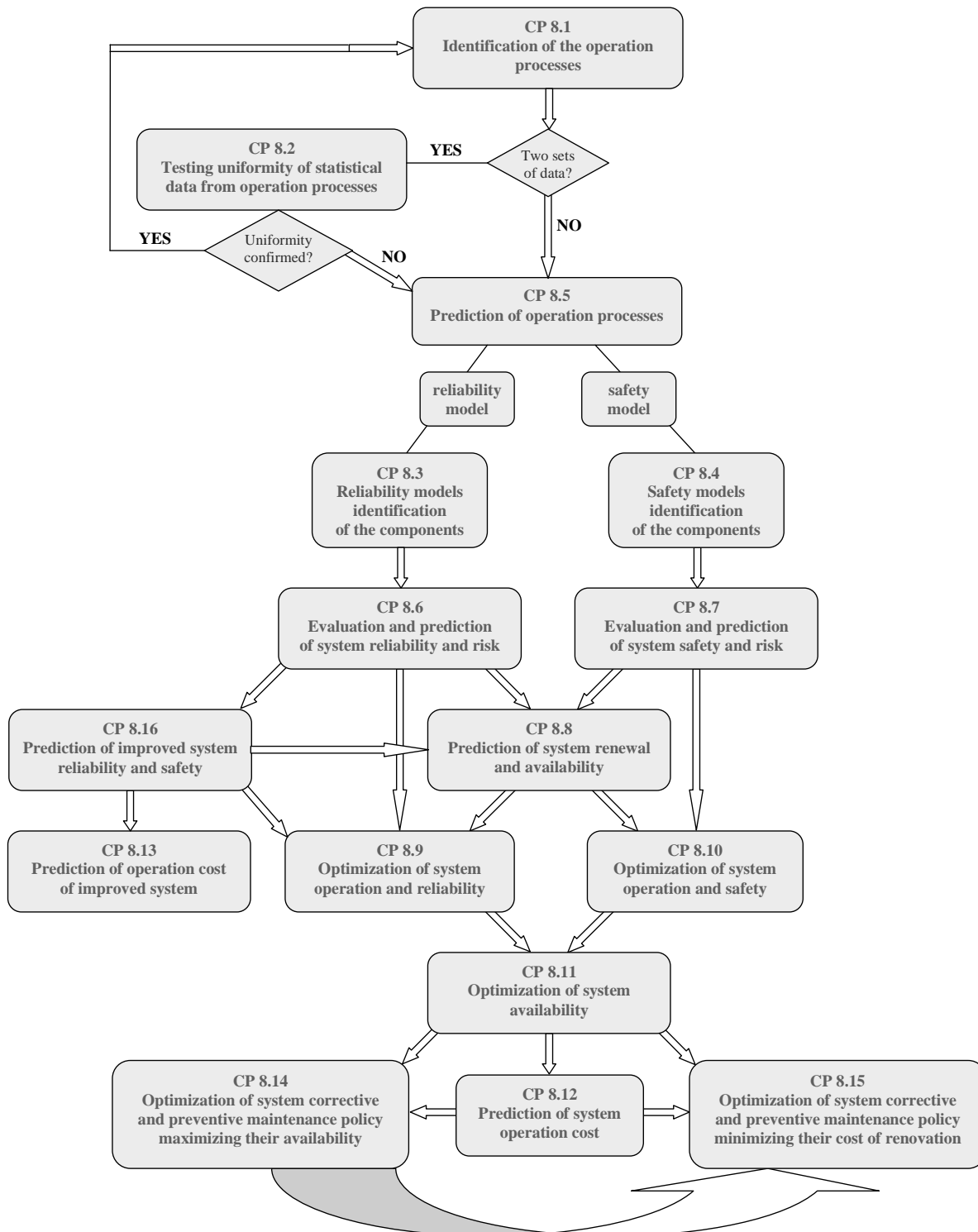

Figure 1. The scheme of the integrated package of software tools.

operation states as the suitable for these variables uniform, triangular, double trapezium, quasi-trapezium, exponential, Weibull, normal and chimney distributions;

- testifying the hypotheses about the fitting empirical distributions with the distinguished distributions;
- in the case of the hypotheses acceptance, the computer program allows to determine the theoretical mean values of the sojourn times of the system operation process in the particular operation states, if the hypotheses are rejected, the program allows to find the empirical values of the mean values of these variables.

The computer program CP 8.2 is used for testing uniformity of statistical data from operation processes of complex technical systems. The aims of the program CP 8.2 are:

- testing the uniformity of the two sets of statistical data containing the realizations of the conditional sojourn times of the same complex technical system operation process in the fixed operation state coming from two independent experiments;
- if the uniformity of the data is confirmed, the computer program enables joining these two data sets into one set of statistical data that can be used to carry out the identification of the system operation process.

The computer program CP 8.3 is used for reliability models identification of the components of complex technical systems. The aims of the program CP 8.3 are:

- estimation unknown parameters of the exponential distributions of the component conditional lifetimes of the complex technical system in the subsets of reliability states, especially the unknown intensities of component departure from the reliability state subset;
- verification the hypotheses, that system components have exponential multistate reliability functions with intensities of departure from the reliability state subsets estimated by application of the first part of the program.

The computer program CP 8.4 is used for safety models identification of the components of complex technical systems. The aims of the program CP 8.4 are:

- estimation unknown parameters of the exponential distributions of the component conditional lifetimes of the complex technical system in the subsets of safety states, especially the unknown intensities of component departure from the safety state subset;
- verification the hypotheses, that system components have exponential multistate safety functions with intensities of departure from the

safety state subsets estimated by application of the first part of the program.

The computer program CP 8.5 is used for prediction of operation processes of complex technical systems. The aim of the program CP 8.5 is:

- determining the mean values of the unconditional sojourn times of the system operation process at the operation states, the limit values of the transient probabilities of the system operation process at the particular operation states and the system operation process total sojourn times at the particular operation states for the fixed sufficiently large system operation time.

The computer program CP 8.6 is used for evaluation and prediction of the complex technical system reliability and risk. The aims of the program CP 8.6 are:

- evaluation and prediction complex technical system reliability and risk characteristics: the conditional reliability functions in particular operation states, the unconditional reliability function, the mean values and standard deviations of the unconditional lifetimes in the reliability state subsets and in particular reliability states of the considered systems, the system risk function and the moment when the system risk exceeds a permitted level;

The computer program CP 8.7 is used for evaluation and prediction of the complex technical system safety and risk. The aims of the program CP 8.7 are:

- evaluation and prediction complex technical system safety and risk characteristics: the conditional safety functions in particular operation states, the unconditional safety function, the mean values and standard deviations of the unconditional lifetimes in the safety state subsets and in particular safety states, the system risk function and the moment when the system risk exceeds a permitted level;

The computer program CP 8.8 is used for prediction of complex technical systems renewal and availability. The aims of the program CP 8.8 are:

- prediction the characteristics of the renewal and availability of the repairable complex technical system;
- determining the following characteristics for ignored time renovation: the distribution, the expected value and the variance of the time until the *Nth* exceeding of reliability critical state of this system, the distribution, the expected value and the variance of the number of exceeding the reliability critical state of this system up to the particular moment;
- determining the following characteristics in the case when the system renovation time is non-ignored: the distribution function, the expected

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value and the variance of the time until the exceeding the reliability critical state of this system, the distribution, the expected value and the variance of the number of exceeding the reliability critical state of this system up to the particular moment, the distribution function, the expected value and the variance of the time until the system's renovation, the distribution, the expected value and the variance of the number of system's renovations up to the particular moment, the availability coefficient of the system at the particular moment and in the time interval.

The computer program CP 8.9 is used for optimization of complex technical systems operation and reliability. The aim of the program CP 8.9 is:

- determining the optimal characteristics of the complex technical system reliability and risk: the optimal unconditional reliability function of complex technical multistate system, the optimal mean values of unconditional lifetimes of complex technical multistate systems in the reliability state subsets, the optimal risk function of complex technical multistate system and the optimal moment when the system risk exceeds a permitted level.

The computer program CP 8.10 is used for optimization of complex technical systems operation and safety. The aims of the program CP 8.10 are:

- determining the optimal characteristics of the complex technical system safety and risk: the optimal unconditional safety function of complex technical multistate system, the optimal mean values of unconditional lifetimes of complex technical multistate systems in the safety state subsets, the optimal risk function of complex technical multistate system and the optimal moment when the system risk exceeds a permitted level.

The computer program CP 8.11 is used for optimization of complex technical systems availability. The aims of the program CP 8.11 are:

- predicting the optimal characteristics of the complex technical system renewal and availability;
- determining the distribution of the optimal time until the successive exceeding of reliability critical state, the expected value and the variance of the optimal time until the successive exceeding the reliability critical state, the distribution of the optimal number of exceeding the reliability critical state up to a fixed moment of time and the expected value and the variance of the optimal number of exceeding the reliability critical state at a fixed moment of time the case when the system

is repairable and the time of their renovation is ignored;

- determining the distribution function of the optimal time until the successive exceeding the reliability critical state, the expected value and the variance of the optimal time until the successive exceeding the reliability critical state, the distribution of the optimal number of exceeding the reliability critical state up to a fixed moment of time, the expected value and variance of the optimal number of exceeding the reliability critical state up to a fixed moment of time, the distribution function of the optimal time until the successive renovation, the expected value and the variance of the optimal time until the successive renovation, the distributions of the optimal number of renovations up to a fixed moment of time, the expected value and variance of the optimal number of renovations up to a fixed moment of time, the optimal steady availability coefficient and the optimal availability coefficient in a fixed time interval for the considered system in the case when the system is repairable and the time of their renovation is non-ignored.

The computer program CP 8.12 is used for prediction of operation cost of complex technical systems. The aims of the program CP 8.12 are:

- determining the costs of the non-repairable and repairable complex technical systems before and after these systems operation processes optimization.

The computer program CP 8.13 is used for prediction of operation cost of improved complex technical systems. The aims of the program CP 8.13 are:

- determining the costs of the non-repairable and repairable improved complex technical systems with reserve and improved components before and after these systems operation processes optimization.

The computer program CP 8.14 is used for optimization of complex technical systems corrective and preventive maintenance policy maximizing their availability. The aims of the program CP 8.14 are:

- maximizing the availability of complex technical systems by optimization the corrective and preventive maintenance policy;
- determining the optimal value of the system preventive maintenance period of time that maximizes the availability coefficient of this system using the method of secants, in the case when such optimal value exists;
- determining the values of the system availability coefficient for the fixed values of the preventive maintenance period of time, in the case when there is no optimal value of the preventive

maintenance period of time that maximizes the system availability coefficient.

The computer program CP 8.15 is used for optimization of complex technical systems corrective and preventive maintenance policy minimizing their cost of renovation. The aims of the program CP 8.15 are:

- minimizing the cost of renovation of complex technical systems by optimization of the corrective and preventive maintenance policy;
- determining the optimal value of the system age at which the system successive preventive renovation is performed that minimizes the cost of the system renovation per unit of time using the method of secants, in the case when such optimal value exists;
- determining the values of the system operation cost for the selected fixed values of the system age at which the system successive preventive renovation is performed, in the case when there is no optimal value of the system age at which the system successive preventive renovation is performed that minimizes the cost of the system renovation per unit of time.

The computer program CP 8.16 is used for prediction of improved complex technical systems reliability and safety. The aims of the program CP 8.16 are:

- prediction of improved complex technical systems reliability: determining the reliability characteristics of the improved complex technical systems with hot and cold single reservation of their components and of the improved complex technical systems with reduced intensities of departure from the reliability state subsets of their components;
- determining the unconditional reliability function, the mean values and standard deviations of the unconditional lifetimes in the reliability state subsets and in particular reliability states, the system risk function and the moment when the system risk exceeds a permitted level of the complex technical systems before and after their improvement;
- using the presented computer program, it is also possible to perform the prediction the safety of the improved complex technical systems.

In the next parts of the paper, the software tools i.e. these programs are applied and tested in the maritime and coastal transportation industry to provide practically validated individual safety and reliability decision support systems for individual maritime transport sectors. The computer programs may be applied not only in maritime industry sectors but in other industry sectors as well.

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