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## **Integrated software tools supporting decision making on identification, prediction and optimization of complex technical systems operation, reliability and safety**

### **Part 5**

## **Integrated software tools application – Improved exemplary system operation and reliability characteristics prediction**

### **Keywords**

system improvement, reliability characteristics, availability, software tools

### **Abstract**

There is presented the application of the integrated software tools to the reliability of the improved exemplary complex technical system prediction. There are considered three ways of the exemplary system reliability improvement, i.e. a hot single reservation of its components, a cold single reservation of its components and replacing its components by the improved components with reduced intensities of departure from the reliability state subsets. Automatically obtained, using the computer program CP 8.16, the evaluations of these ways improved exemplary system unconditional multistate reliability function, the expected values and the standard deviations of its unconditional lifetimes in the reliability state subsets and the mean values of its lifetimes in the particular reliability states are presented. Moreover, in the case when the improved system is repairable, its renewal and availability characteristics are estimated using the computer program CP 8.8 with appropriately given data.

## **11. The improved exemplary system reliability modelling**

### **11.1. Reliability improvement of the exemplary system**

In Section 3 [5] there are presented the results of the system components reliability modeling from concerned with the fixed system reliability structures and their shape parameters and with the assumed the exponential models of the reliability functions of the system components in various operation states. Considering these results and the evaluations of the system components intensities of departures from the reliability state subsets from Section 4 [5], we may

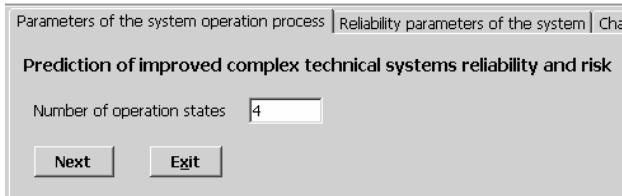
perform the improvement of the exemplary system reliability.

To determine the reliability characteristics of the system with hot and cold single reservation of its components and of the improved exemplary system with reduced intensities of departure from the reliability state subsets of its components [2] we use the computer program CP 8.16 “Prediction of improved system reliability and safety”.

The computer program is composed of three panels. The first panel “Parameters of the system operation process” is used for reading input parameters of the system operation process [3]:

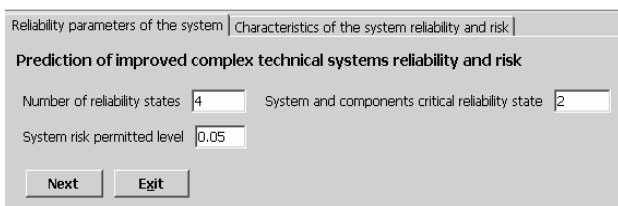
– the number of operation states states of the system operation process  $v$ ,

- the transient probabilities in particular operation states  $p_1, p_2, \dots, p_\nu$ , determined in Section 5 [6].

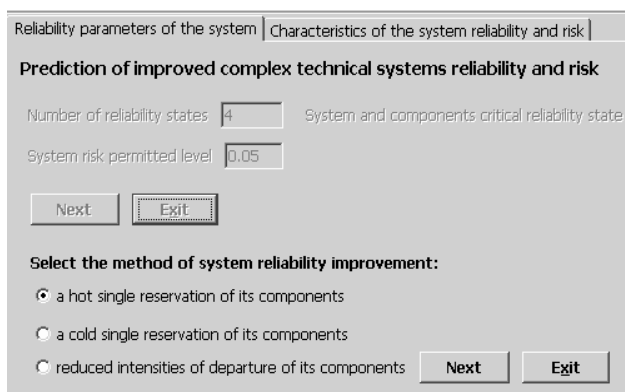


The second panel “Reliability parameters of the system” is served for reading input parameters of the system reliability model and method of improvement:

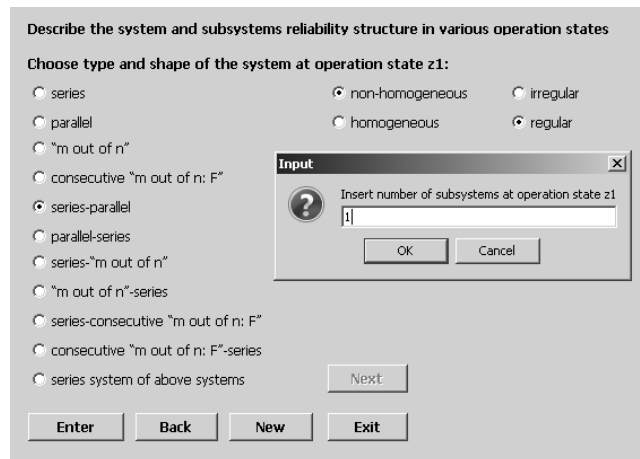
- the number of the system and components reliability states  $z + 1$ ,
- the system and components critical reliability state  $r$ ,
- the system risk permitted level  $\delta$ ,



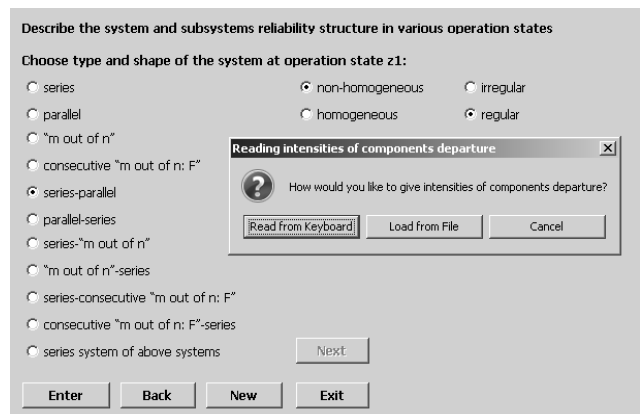
- the method of system reliability improvement [2]:
  - a hot single reservation of system components,
  - a cold single reservation of system components,
  - replacing the system components by improved components with reduced intensities of departure from the reliability state subsets,



- the parameters of a system reliability structure in various operation states, described in Section 3 [5],



- the intensities of components departure (equivalently  $[\lambda_i(u)]^{(b)}$  or  $[\lambda_{ij}(u)]^{(b)}$ ) from the reliability states subset  $\{u, u + 1, \dots, z\}$ ,  $u = 1, 2, \dots, z$ , at the operation state  $z_b$ ,  $b = 1, 2, \dots, \nu$ , assuming that the reliability functions of the system components are exponential, determined in Section 4 [5],



- the factor  $\rho^{(b)}(u)$ ,  $0 < \rho^{(b)}(u) \leq 1$ , (equivalently factors  $\rho_i^{(b)}(u)$  or  $\rho_{ij}^{(b)}(u)$ ), in a case of replacing the system components by improved components with reduced intensities of departure from the reliability state subsets  $\{u, u + 1, \dots, z\}$ ,  $u = 1, 2, \dots, z$ , at the operation state  $z_b$ ,  $b = 1, 2, \dots, \nu$ , by multiplying intensities by this factor fixed in [9].

After finishing giving data the computer program automatically comes to the third panel “Characteristics of the system reliability and risk” where are shown the results. Namely, there are given following reliability and risk characteristics of the system before and after system improvement [2]:

– the unconditional reliability function of the system (with plotting) before

$$\mathbf{R}(t, \cdot) = [1, \mathbf{R}(t, 1), \dots, \mathbf{R}(t, z)],$$

and after the system improvement

$$\mathbf{R}^{(k)}(t, \cdot) = [1, \mathbf{R}^{(k)}(t, 1), \dots, \mathbf{R}^{(k)}(t, z)], \quad k \in \{1, 2, 3\},$$

where  $\mathbf{R}^{(1)}(t, \cdot)$  denotes the improved unconditional reliability function of the system with a hot single reservation of its components,  $\mathbf{R}^{(2)}(t, \cdot)$  denotes the improved unconditional reliability function of the system with a cold single reservation of its components and  $\mathbf{R}^{(3)}(t, \cdot)$  denotes the improved unconditional reliability function of the system with reduced intensities of its components departure,

– the mean values of the system conditional lifetimes in the reliability state subsets  $\{u, u+1, \dots, z\}$  while the system is at the operational state  $z_b, b = 1, 2, \dots, v$ , before the system improvement

$$\mu_b(u) = \int_0^{\infty} [\mathbf{R}(t, u)]^{(b)} dt, \quad u = 1, 2, \dots, z,$$

and after the system improvement

$$\mu_b^{(k)}(u), \quad u = 1, 2, \dots, z, \quad k \in \{1, 2, 3\},$$

– the mean values of the system unconditional lifetimes in the reliability state subsets  $\{u, u+1, \dots, z\}$  before the system improvement

$$\mu(u), \quad u = 1, 2, \dots, z,$$

and after the system improvement

$$\mu^{(k)}(u), \quad u = 1, 2, \dots, z, \quad k \in \{1, 2, 3\},$$

– the standard deviations of the system unconditional lifetimes in the reliability state subsets  $\{u, u+1, \dots, z\}$  before the system improvement

$$\sigma(u), \quad u = 1, 2, \dots, z,$$

and after the system improvement

$$\sigma^{(k)}(u), \quad u = 1, 2, \dots, z, \quad k \in \{1, 2, 3\},$$

– the mean values of the system unconditional lifetimes in the particular reliability states before the system improvement

$$\bar{\mu}(u), \quad u = 1, 2, \dots, z,$$

and after the system improvement

$$\bar{\mu}^{(k)}(u), \quad u = 1, 2, \dots, z, \quad k \in \{1, 2, 3\},$$

– the system risk function (with plotting) before the system improvement

$$\mathbf{r}(t), \quad t \in < 0, \infty),$$

and after the system improvement

$$\mathbf{r}^{(k)}(t), \quad t \in < 0, \infty), \quad k \in \{1, 2, 3\},$$

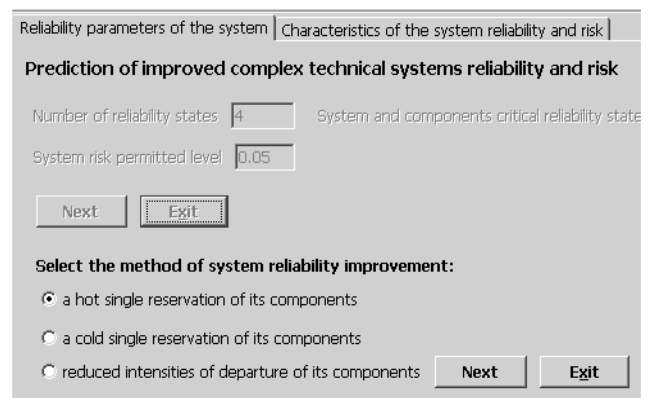
– the moment when the risk exceeds a permitted level  $\delta$  before the system improvement

$$\tau,$$

and after system improvement

$$\tau^{(k)}, \quad k \in \{1, 2, 3\}.$$

Below there are presented results for the exemplary system with a hot single reservation of its components.



As a result there are given the reliability characteristics of the exemplary system in the first window before and in the second window after system improvement.



Characteristics of the system reliability and risk

**Prediction of improved complex technical systems reliability and risk**

Characteristics of the system reliability and risk

Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 495.82768.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 739.57365.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 403.10673.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 234.57526.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 1: 359.05294.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 1: 269.06748.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 479.83374.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 690.26853.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 380.71764.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 219.11566.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 2: 340.16252.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 2: 257.01044.

Characteristics of the improved system reliability and risk

Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 939.52866.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 1,140.59097.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 808.63889.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 517.49495.  
 Mean value of the system with hot reservation unconditional lifetime in the subset of reliability states not worse than 1: 716.79299.  
 The standard deviation of the system unconditional lifetime of the system with hot reservation in the subset of reliability states not worse than 1: 368.20916.

Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 911.16445.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 1,064.62579.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 764.62507.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 483.46352.  
 Mean value of the system with hot reservation unconditional lifetime in the subset of reliability states not worse than 2: 679.45602.  
 The standard deviation of the system unconditional lifetime of the system with hot reservation in the subset of reliability states not worse than 2: 353.60779.

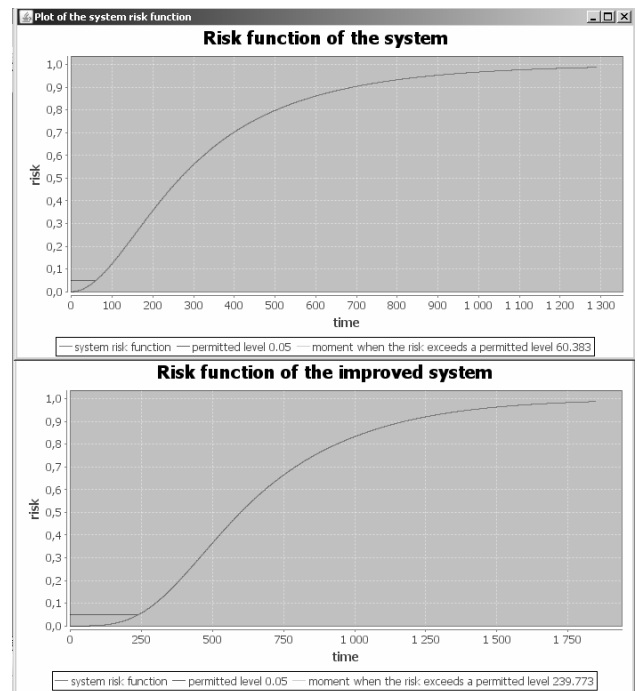
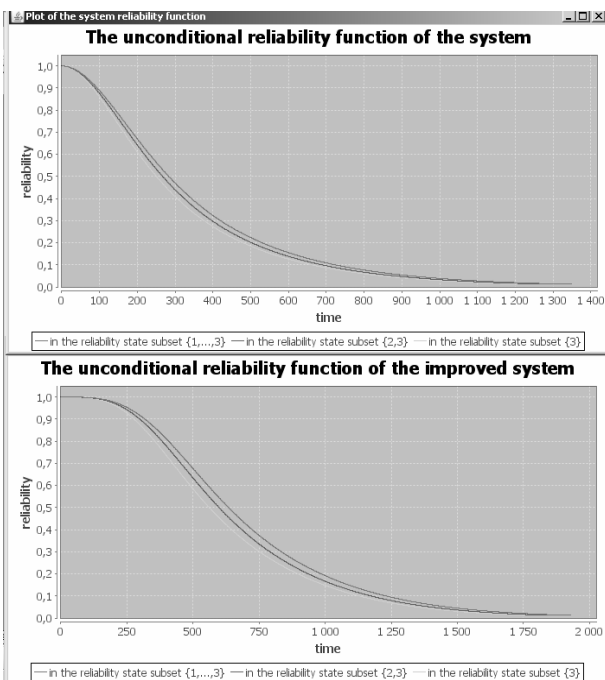
Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z1: 881.87182.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z2: 998.14464.  
 Mean value of the system with hot reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z3: 739.44795.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results  
 New  
 Exit

The program gives possibility of showing the plot of the coordinates of the system unconditional reliability function in the reliability state subset by pressing the button “Reliability Plot” for both widows i.e. for the system before and after improvement. Then the following window with the plot appears on the screen.

It is also possible to obtain the plot of the system risk function with marked moment when the risk exceeds a permitted level by pressing the button “Risk Plot”.



For the exemplary system with a cold single reservation of its components we obtain following results.



Application of P-SJP

File Help

Characteristics of the system reliability and risk

**Prediction of improved complex technical systems reliability and risk**

**Characteristics of the system reliability and risk**

Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 495.82768.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 739.57365.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 403.10673.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 234.57526.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 1: 359.05294.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 1: 269.06748.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 479.83374.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 690.26853.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 380.71764.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 219.11566.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 2: 340.16252.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 2: 257.01044.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results

**Characteristics of the improved system reliability and risk**

Moment when the risk of a system with cold reservation exceeds a permitted level: 335.80469.

Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 1,265.89583.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 1,534.67108.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 1,111.18455.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 714.61824.  
 Mean value of the system with cold reservation unconditional lifetime in the subset of reliability states not worse than 1: 984.22758.  
 The standard deviation of the system unconditional lifetime of the system with cold reservation in the subset of reliability states not worse than 1: 493.41163.

Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 1,247.57923.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 1,432.50529.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 1,050.95381.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 667.63539.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results  
 New  
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Application of P-SJP

File Help

Characteristics of the system reliability and risk

**Prediction of improved complex technical systems reliability and risk**

**Characteristics of the system reliability and risk**

Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 219.11566.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 2: 340.16252.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 2: 257.01044.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z1: 464.83904.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z2: 647.12772.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z3: 368.42992.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z4: 200.44004.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 3: 323.21659.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 3: 248.12587.

Mean value of the system unconditional lifetime in the particular reliability state 1: 18.89042.  
 Mean value of the system unconditional lifetime in the particular reliability state 2: 16,94593.  
 Mean value of the system unconditional lifetime in the particular reliability state 3: 323.21659.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results

**Characteristics of the improved system reliability and risk**

Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 1,050.95381.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 667.63539.  
 Mean value of the system with cold reservation unconditional lifetime in the subset of reliability states not worse than 2: 933.12073.  
 The standard deviation of the system unconditional lifetime of the system with cold reservation in the subset of reliability states not worse than 2: 474.22116.

Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z1: 1,207.24538.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z2: 1,343.08431.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z3: 1,016.18902.  
 Mean value of the system with cold reservation conditional lifetime in the subset of reliability states not worse than 3 at operation state z4: 610.46101.  
 Mean value of the system with cold reservation unconditional lifetime in the subset of reliability states not worse than 3: 884.89086.  
 The standard deviation of the system unconditional lifetime of the system with cold reservation in the subset of reliability states not worse than 3: 461.95479.

Mean value of the system unconditional lifetime in the particular reliability state 1: 51.10685.  
 Mean value of the system unconditional lifetime in the particular reliability state 2: 48.22987.  
 Mean value of the system unconditional lifetime in the particular reliability state 3: 884.89086.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results  
 New  
 Exit





Application of P-SJP

File Help

Characteristics of the system reliability and risk

**Prediction of improved complex technical systems reliability and risk**

**Characteristics of the system reliability and risk**

Moment when the risk exceeds a permitted level: 60.38281.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 495.82768.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 739.57365.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 403.10673.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 234.57526.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 1: 359.05294.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 1: 269.06748.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 479.83374.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 690.26853.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 380.71764.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 219.11566.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 2: 340.16252.

**Characteristics of the improved system reliability and risk**

Moment when the risk of a system with reduced intensities exceeds a permitted level: 68.14844.

Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 1 at operation state z1: 557.11014.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 1 at operation state z2: 873.75811.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 1 at operation state z3: 457.41247.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 1 at operation state z4: 268.92629.  
 Mean value of the system with reduced intensities unconditional lifetime in the subset of reliability states not worse than 1: 408.8077.  
 The standard deviation of the system unconditional lifetime of the system with reduced intensities in the subset of reliability states not worse than 1: 306.90397.

Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 2 at operation state z1: 536.99734.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 2 at operation state z2: 815.2785.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 2 at operation state z3: 431.45701.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results  
 New  
 Exit

Application of P-SJP

File Help

Characteristics of the system reliability and risk

**Prediction of improved complex technical systems reliability and risk**

**Characteristics of the system reliability and risk**

Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 219.11566.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 2: 340.16252.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 2: 257.01044.

Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z1: 464.83904.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z2: 647.12772.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z3: 368.42992.  
 Mean value of the system conditional lifetime in the subset of reliability states not worse than 3 at operation state z4: 200.44004.  
 Mean value of the system unconditional lifetime in the subset of reliability states not worse than 3: 323.21659.  
 The standard deviation of the system unconditional lifetime of the system in the subset of reliability states not worse than 3: 248.12587.

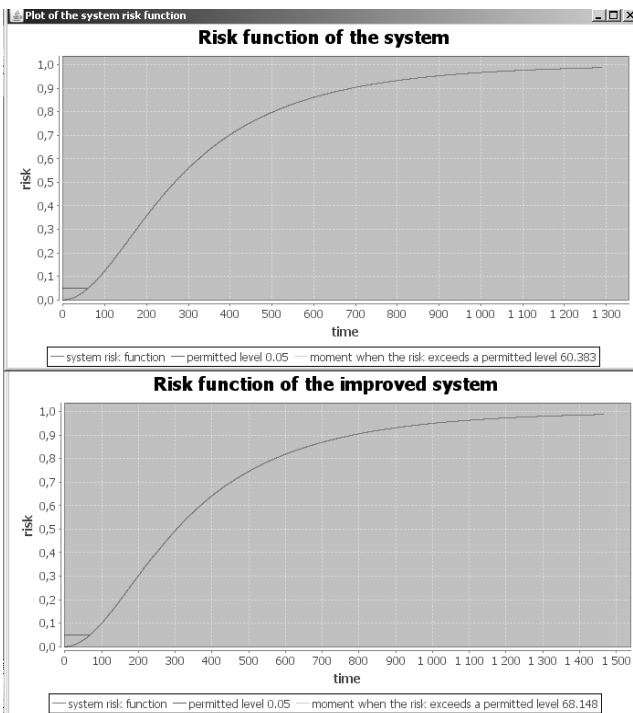
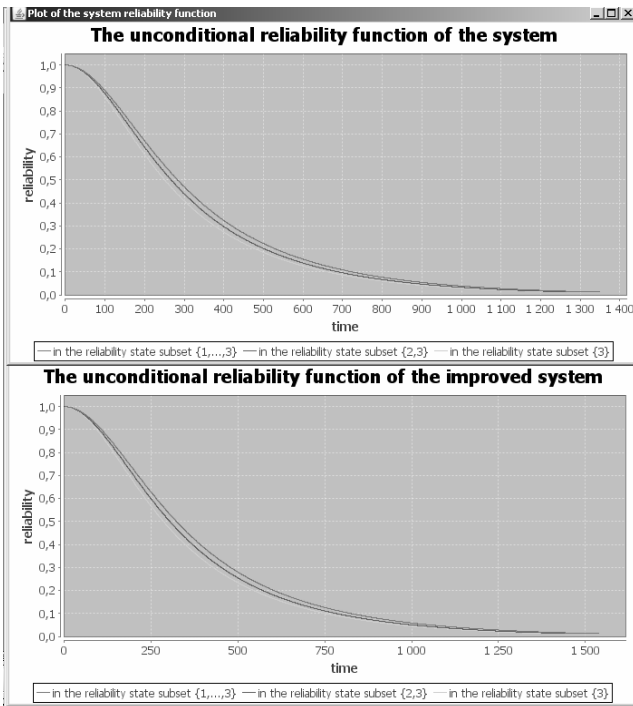
Mean value of the system unconditional lifetime in the particular reliability state 1: 18.89042.  
 Mean value of the system unconditional lifetime in the particular reliability state 2: 16.94593.  
 Mean value of the system unconditional lifetime in the particular reliability state 3: 323.21659.

**Characteristics of the improved system reliability and risk**

Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 2 at operation state z4: 251.13222.  
 Mean value of the system with reduced intensities unconditional lifetime in the subset of reliability states not worse than 2: 386.58008.  
 The standard deviation of the system unconditional lifetime of the system with reduced intensities in the subset of reliability states not worse than 2: 292.26003.

Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 3 at operation state z1: 520.09879.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 3 at operation state z2: 764.13528.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 3 at operation state z3: 417.81186.  
 Mean value of the system with reduced intensities conditional lifetime in the subset of reliability states not worse than 3 at operation state z4: 229.88853.  
 Mean value of the system with reduced intensities unconditional lifetime in the subset of reliability states not worse than 3: 367.35644.  
 The standard deviation of the system unconditional lifetime of the system with reduced intensities in the subset of reliability states not worse than 3: 282.04964.  
 Mean value of the system unconditional lifetime in the particular reliability state 1: 22.22762.  
 Mean value of the system unconditional lifetime in the particular reliability state 2: 19.22364.  
 Mean value of the system unconditional lifetime in the particular reliability state 3: 367.35644.

Reliability Plot  
 Save Plot  
 Risk Plot  
 Save Plot  
 Save Results  
 Print Results  
 New  
 Exit



## 11.2. Renewal and availability characteristics of the improved exemplary system

To determine the renewal and availability characteristics of the improved exemplary system, we use the results of the system reliability characteristics evaluation performed in Sections 11.1 and the results of the Section 12.3.1. of IS&RDSS 12 [7].

If components of the repairable improved exemplary system with ignored time of renovation have

exponential reliability functions at the operation states  $z_b$ ,  $b = 1, 2, \dots, v$ , with the coordinates fixed in Sections 11.1 and the system reliability critical state is  $r = 2$ , using the computer program CP 8.8 [4] with appropriately given data from Sections 11.1, we determine following characteristics: the distribution, the expected value and the variance of the time until the  $N$ th 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.

For the exemplary system with a hot single reservation of its components we obtain following results.

Choose the renovation type: Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored time

Renovation with ignored time  
 Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system and components reliability critical state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

Choose the renovation type: Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored time

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system reliability state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

number of system exceeding:   
 system renewal process duration time:

Choose the renovation type: Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored time

RESULTS:

the distribution of the time until the  $N$ th exceeding of reliability critical state  $r$  of this system:   
 the expected value:  and the variance of the time:   
 the distribution of the number of exceeding the reliability critical state  $r$  of this system:  
 the expected value:  and the variance of the number:

For the exemplary system with a cold single reservation of its components we get.

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time |

Renovation with ignored time  
 Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system and components reliability critical state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignore - non-ignored |

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system reliability state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

number of system exceeding   
 system renewal process duration time

Choose the renovation type | Ignored time | Non-ignored time | Results - ignore - non-ignored |

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system reliability state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

number of system exceeding   
 system renewal process duration time

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored time |

RESULTS:

the distribution of the time until the Nth exceeding of reliability critical state r of this system:   
 the expected value:  and the variance of the time:   
 the distribution of the number of exceeding the reliability critical state r of this system:  
 the expected value  and the variance of the number:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored time |

RESULTS:

the distribution of the time until the Nth exceeding of reliability critical state r of this system:   
 the expected value:  and the variance of the time:   
 the distribution of the number of exceeding the reliability critical state r of this system:  
 the expected value  and the variance of the number:

For the exemplary system with reduced rates of departure of its components the computer program is predicting the renewal and availability characteristics in the following way.

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time |

Renovation with ignored time  
 Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
 the system and components reliability critical state:   
 the mean value of unconditional lifetime:   
 the standard deviation of unconditional lifetime:

To make the estimation of the renewal and availability of the improved exemplary system in the case when the time of renovation is non-ignored, we assume the mean value of the system renovation time is equal  $\mu_0(2) = 10$  years and the standard deviation of the system renovation time amounts  $\sigma_0(2) = 5$  years. If components of the repairable improved exemplary system have exponential reliability functions at the operation states  $z_b$ ,  $b = 1, 2, \dots, v$ , with the coordinates fixed in Section 11.1 and the system reliability critical state is  $r = 2$ , using the computer program CP 8.8 with appropriately given values  $\mu^{(k)}(2)$  and  $\sigma^{(k)}(2)$ ,  $k = 1, 2, 3$ , from Section 11.1, we determine its renewal and availability characteristics. Namely, the computer program is predicting following characteristics: the distribution function, the expected 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. Finally, in this type of renovation, the computer program predict the availability coefficient of the system at the particular moment and in the time interval.

For the exemplary system with a hot single reservation of its components we get.

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time

Renovation with ignored time  
 Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
the system and components reliability critical state:   
the mean value of unconditional lifetime:   
the standard deviation of unconditional lifetime:

| t                   | Values           |
|---------------------|------------------|
| 0.0                 | 0.00000000014968 |
| 142.40200000000002  | 0.00000000015062 |
| 284.80400000000003  | 0.00000000015156 |
| 427.20599999999996  | 0.00000000015252 |
| 569.60800000000001  | 0.00000000015347 |
| 712.01000000000001  | 0.00000000015444 |
| 854.41199999999999  | 0.00000000015541 |
| 996.814             | 0.00000000015638 |
| 1139.21600000000001 | 0.00000000015736 |
| 1281.61800000000002 | 0.00000000015835 |
| 1424.02000000000002 | 0.00000000015934 |
| 1566.422            | 0.00000000016034 |
| 1708.82399999999998 | 0.00000000016135 |
| 1851.22599999999999 | 0.00000000016236 |
| 1993.628            | 0.00000000016338 |
| 2136.03             | 0.00000000016444 |
| 2278.43200000000002 | 0.00000000016543 |
| 2420.83400000000003 | 0.00000000016647 |
| 2563.23600000000003 | 0.00000000016751 |

For the exemplary system with a cold single reservation of its components the results are presented below.

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - r

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
the system and components reliability critical state:   
the mean value of unconditional lifetime:   
the standard deviation of unconditional lifetime:

Input reliability function

**INPUT PARAMETERS OF THE SYST**

mean value of system renovation time:   
standard deviation of system renovat:   
number of system exceeding the critic:   
renewal process duration time:   
length of system availability interval:

Calculate

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | R

Renovation with ignored time  
 Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
the system and components reliability critical state:   
the mean value of unconditional lifetime:   
the standard deviation of unconditional lifetime:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | R

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
the system and components reliability critical state:   
the mean value of unconditional lifetime:   
the standard deviation of unconditional lifetime:

Input reliability function

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

mean value of system renovation time:   
standard deviation of system renovation time:   
number of system exceeding the critical reliability state:   
renewal process duration time:   
length of system availability interval:

Calculate

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - r

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:   
the system and components reliability critical state:   
the mean value of unconditional lifetime:   
the standard deviation of unconditional lifetime:

Input reliability function

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

mean value of system renovation time:   
standard deviation of system renovati:   
number of system exceeding the critic:   
renewal process duration time:   
length of system availability interval:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

the distribution function of the time until the Nth exceeding the reliability critical state:  $f(7,210.1, 1,084.73)$   
the expected value  and the variance of the time   
the distribution of the number of exceeding the reliability critical state - table  
the expected value  and the variance  of the optimal number of exceeding the re  
the distribution function of the time until the Nth system's renovation  $f(7,220.1, 1,084.74)$   
the expected value  and the variance  of the time until the Nth syste  
the distribution of the number of system's renovations  
the expected value  and the variance of the optimal number of system's renovations   
the availability coefficient of the system at the moment t  in the time interval

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:

the system and components reliability critical state:

the mean value of unconditional lifetime:

the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

mean value of system renovation time:

standard deviation of system renovation time:

number of system exceeding the critical reliability state:

renewal process duration time:

length of system availability interval:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

Renovation with ignored time

Renovation with non-ignored time

**INPUT PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:

the system and components reliability critical state:

the mean value of unconditional lifetime:

the standard deviation of unconditional lifetime:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

the distribution function of the time until the Nth exceeding the reliability critical state:

the expected value  and the variance of the time

the distribution of the number of exceeding the reliability critical state - table

the expected value  and the variance  of the optimal number of exceeding the re

the distribution function of the time until the Nth system's renovation

the expected value  and the variance  of the time until the Nth syste

the distribution of the number of system's renovations

the expected value  and the variance of the optimal number of system's renovations

the availability coefficient of the system at the moment t  in the time interval

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:

the system and components reliability critical state:

the mean value of unconditional lifetime:

the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

mean value of system renovation time:

standard deviation of system renovation time:

number of system exceeding the critical reliability state:

renewal process duration time:

length of system availability interval:

**Input**

Give  $R(t, 2)[1]$

| t                 | Values            |
|-------------------|-------------------|
| 0.0               | 0.000000000005367 |
| 195.574           | 0.000000000005393 |
| 391.148           | 0.000000000005418 |
| 586.722000000001  | 0.000000000005444 |
| 782.296           | 0.00000000000547  |
| 977.870000000001  | 0.000000000005497 |
| 1173.444000000002 | 0.000000000005523 |
| 1369.018          | 0.000000000005549 |
| 1564.592          | 0.000000000005576 |
| 1760.166000000002 | 0.000000000005603 |
| 1955.740000000002 | 0.000000000005629 |
| 2151.314          | 0.000000000005656 |
| 2346.888000000004 | 0.000000000005683 |
| 2542.462          | 0.000000000005711 |
| 2738.036          | 0.000000000005738 |
| 2933.61           | 0.000000000005765 |
| 3129.184          | 0.000000000005793 |
| 3324.758000000003 | 0.000000000005821 |
| 3520.332000000003 | 0.000000000005848 |
| 3715.906          | 0.000000000005876 |

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

**PARAMETERS OF THE COMPLEX TECHNICAL SYSTEM RELIABILITY**

the number of the system reliability states:

the system and components reliability critical state:

the mean value of unconditional lifetime:

the standard deviation of unconditional lifetime:

**INPUT PARAMETERS OF THE SYSTEM RENEWAL PROCESS**

mean value of system renovation time:

standard deviation of system renovation time:

number of system exceeding the critical reliability state:

renewal process duration time:

length of system availability interval:

Choose the renovation type | Ignored time | Non-ignored time | Results - ignored time | Results - non-ignored

the distribution function of the time until the Nth exceeding the reliability critical state:

the expected value  and the variance of the time

the distribution of the number of exceeding the reliability critical state - table

the expected value  and the variance  of the optimal number of exceeding the re

the distribution function of the time until the Nth system's renovation

the expected value  and the variance  of the time until the Nth syste

the distribution of the number of system's renovations

the expected value  and the variance of the optimal number of system's renovations

the availability coefficient of the system at the moment t  in the time interval

For the exemplary system with reduced rates of departure of its components the computer program is predicting the renewal and availability characteristics in the following way.

| t                    | Values            |
|----------------------|-------------------|
| 0.0                  | 0.000003199925065 |
| 80.98                | 0.000003216421024 |
| 161.96               | 0.000003232998326 |
| 242.93999999999997   | 0.000003249657353 |
| 323.92               | 0.000003266398488 |
| 404.900000000000003  | 0.000003283222116 |
| 485.879999999999994  | 0.000003300128623 |
| 566.86               | 0.000003317118398 |
| 647.84               | 0.00000333419183  |
| 728.82               | 0.00000335134931  |
| 809.800000000000001  | 0.000003368591232 |
| 890.78               | 0.000003385917991 |
| 971.759999999999999  | 0.00000340329984  |
| 1052.74              | 0.000003420827608 |
| 1133.72              | 0.000003438411265 |
| 1214.7               | 0.000003456081356 |
| 1295.68              | 0.000003473838286 |
| 1376.659999999999999 | 0.000003491682459 |
| 1457.64              | 0.000003509614283 |
| 1538.62              | 0.000003527634167 |

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