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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

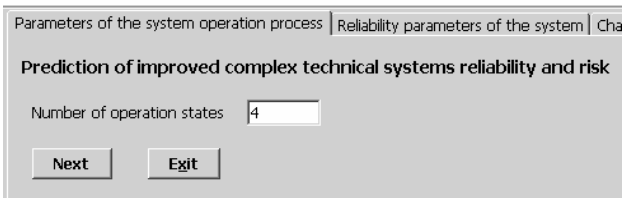
In Section 3 [5] there are presented the results of the system components reliability modeling from concerned with the fixed system reliability structures and their shape parameters and with the assumed the exponential models of the reliability functions of the system components in various operation 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]:

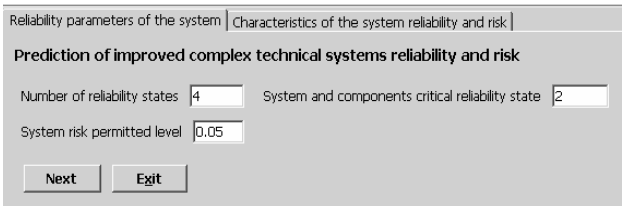
– the number of operation states states of the system operation process v,

– the transient probabilities in particular operation states p_1, p_2, …, p_ν, determined in Section 5 [6].

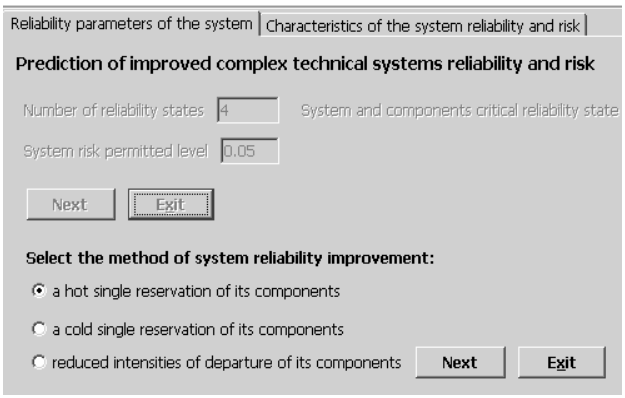


The second panel "Reliability parameters of the system" is served for reading input parameters of the system reliability model and method of improvement:

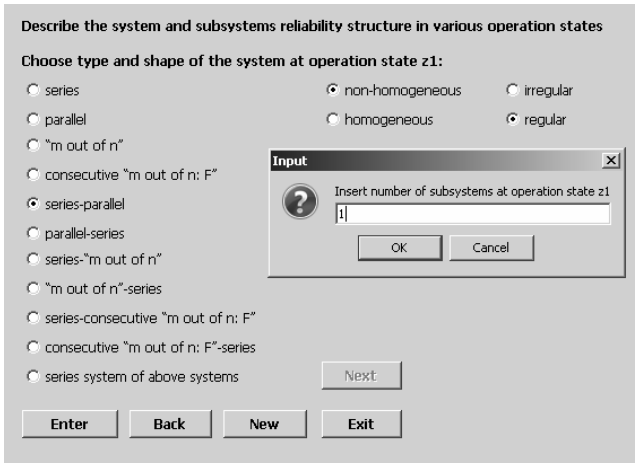
– the number of the system and components reliability states $z + 1$,
– the system and components critical reliability state r,
– the system risk permitted level δ,



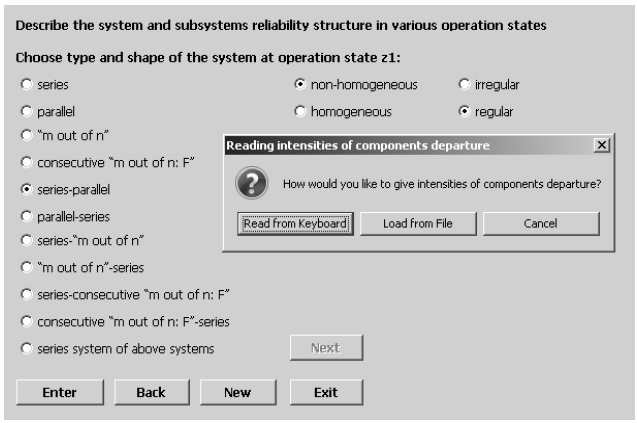
– the method of system reliability improvement [2]:
  - a hot single reservation of system components,
  - a cold single reservation of system components,
  - replacing the system components by improved components with reduced intensities of departure from the reliability state subsets,



– 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 $\{u, u+1, ..., z\}$, $u = 1,2,...,z$, at the operation state z_b, $b = 1,2,...,\nu$, assuming that the reliability functions of the system components are exponential, determined in Section 4 [5],



– the factor $\rho^{(b)}(u)$, $0 < \rho^{(b)}(u) \le 1$, (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 $\{u, u+1, ..., z\}$, $u = 1,2,...,z$, at the operation state z_b, $b = 1,2,...,\nu$, 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

$$\boldsymbol{R}(t,\cdot) = [1, \boldsymbol{R}(t,1), \ldots, \boldsymbol{R}(t,z)],$$

and after the system improvement

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

where $\boldsymbol{R}^{(1)}(t,\cdot)$ denotes the improved unconditional reliability function of the system with a hot single reservation of its components, $\boldsymbol{R}^{(2)}(t,\cdot)$ denotes the improved unconditional reliability function of the system with a cold single reservation of its components and $\boldsymbol{R}^{(3)}(t,\cdot)$ 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 $\{u, u+1, ..., z\}$ while the system is at the operational state z_b, $b = 1,2,...,v$, before the system improvement

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

and after the system improvement

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

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

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

and after the system improvement

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

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

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

and after the system improvement

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

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

$$\overline{\mu}(u), \quad u = 1,2,...,z,$$

and after the system improvement

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

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

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

and after the system improvement

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

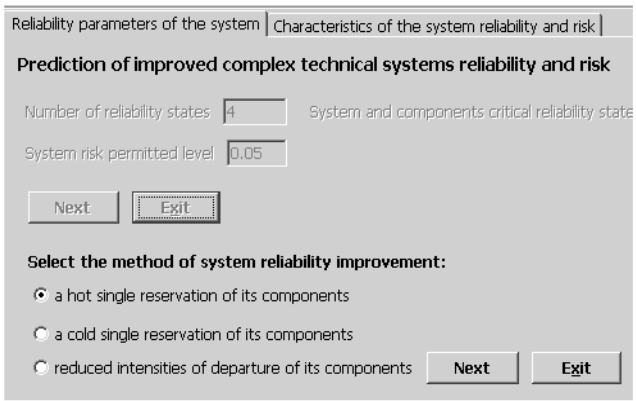
– the moment when the risk exceeds a permitted level δ before the system improvement

$$\tau,$$

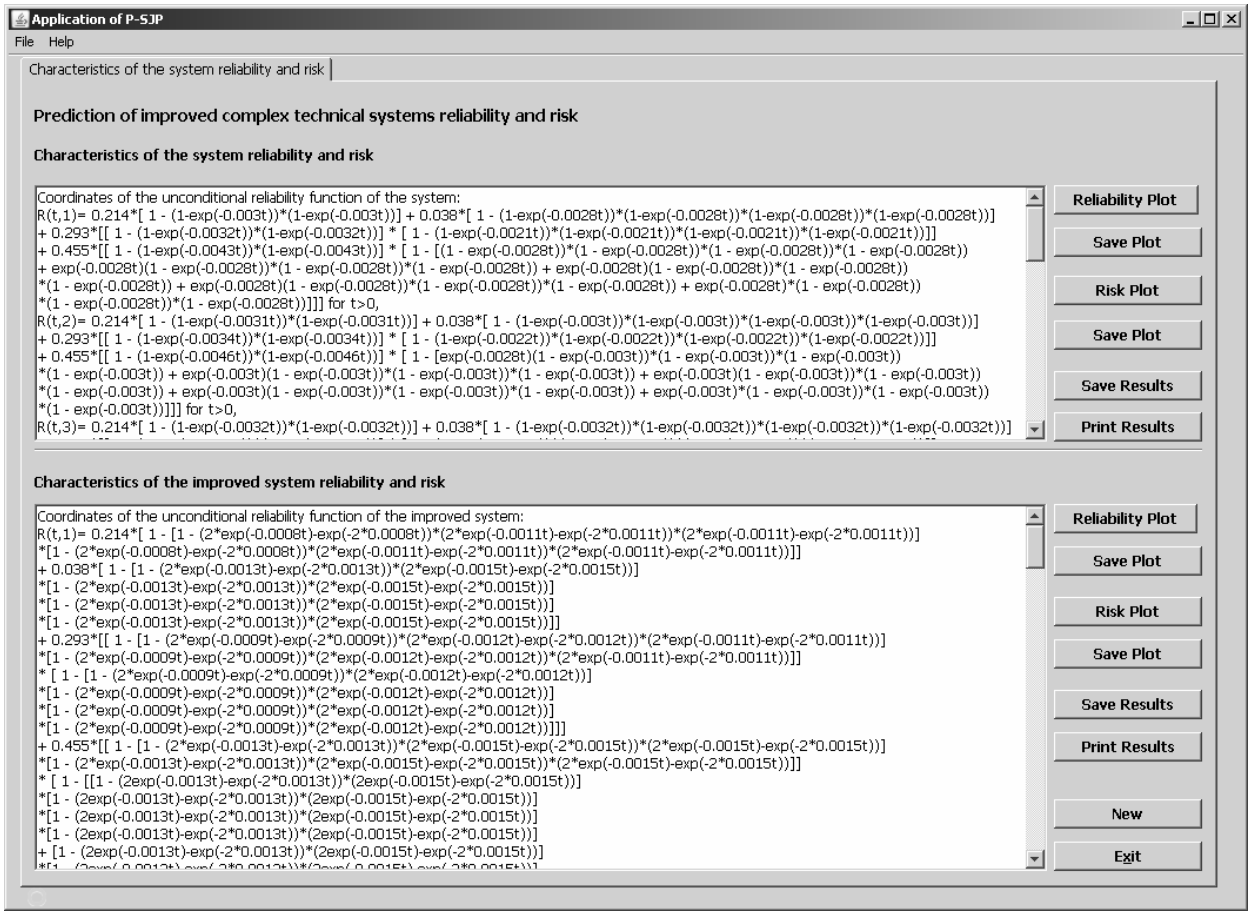
and after system improvement

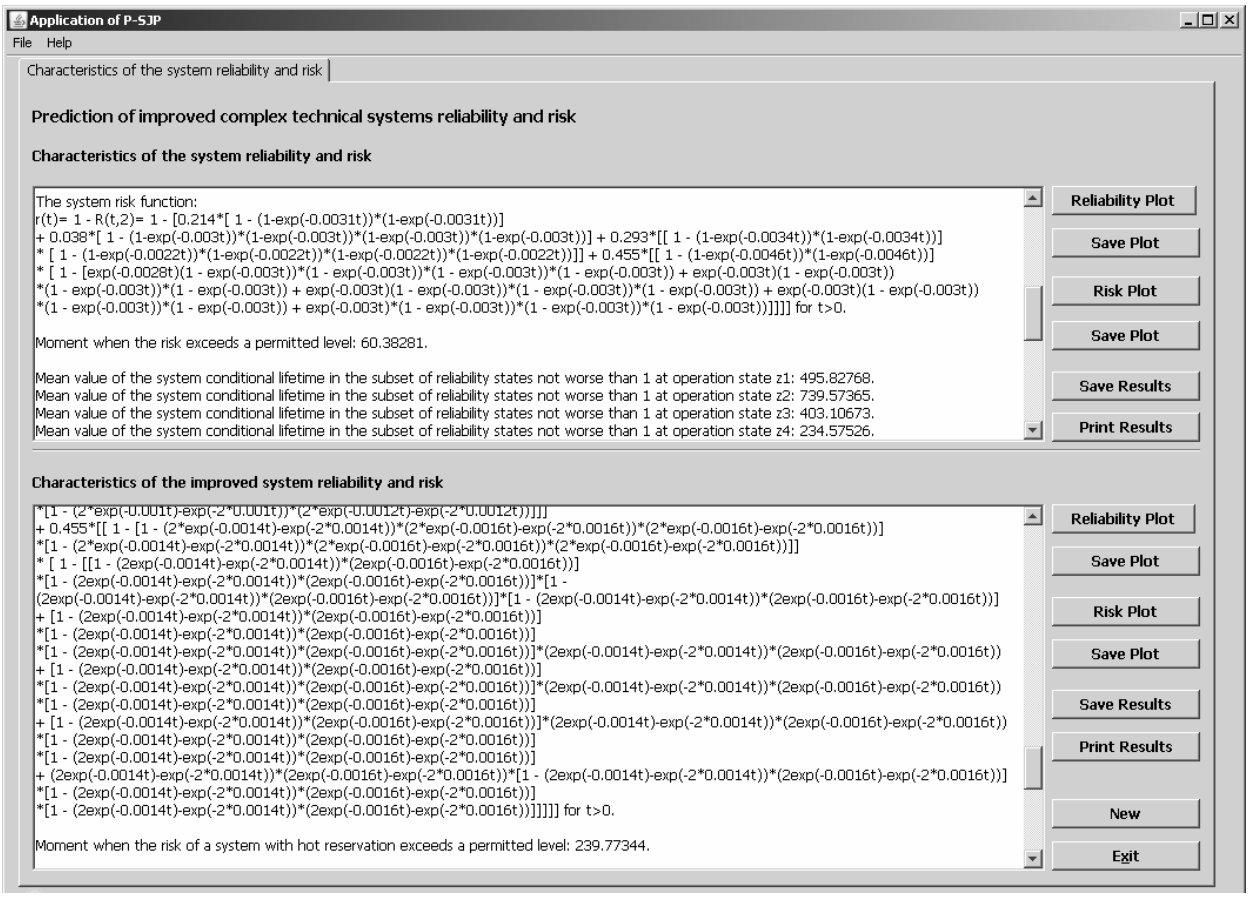
$$\tau^{(k)}, \quad k \in \{1,2,3\}.$$

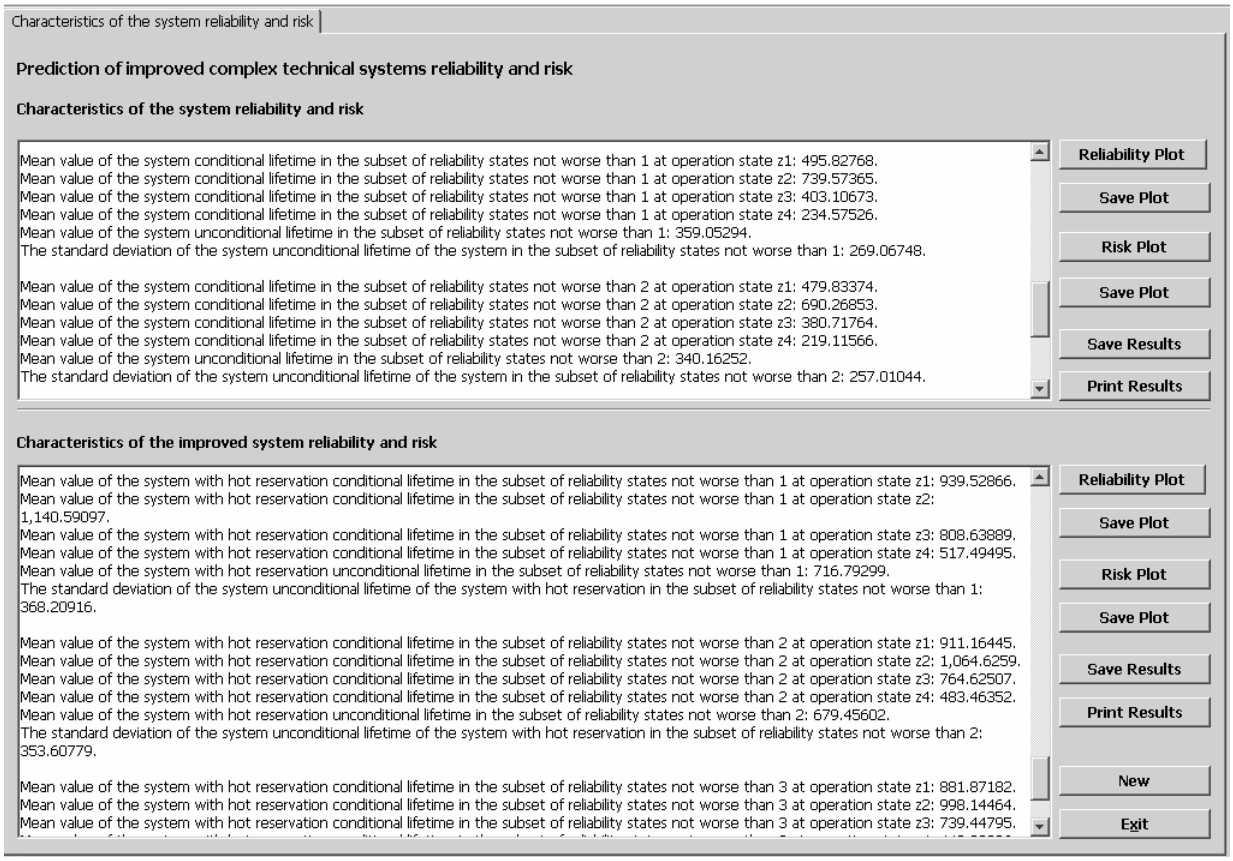
Below there are presented results for the exemplary system with a hot single reservation of its components.



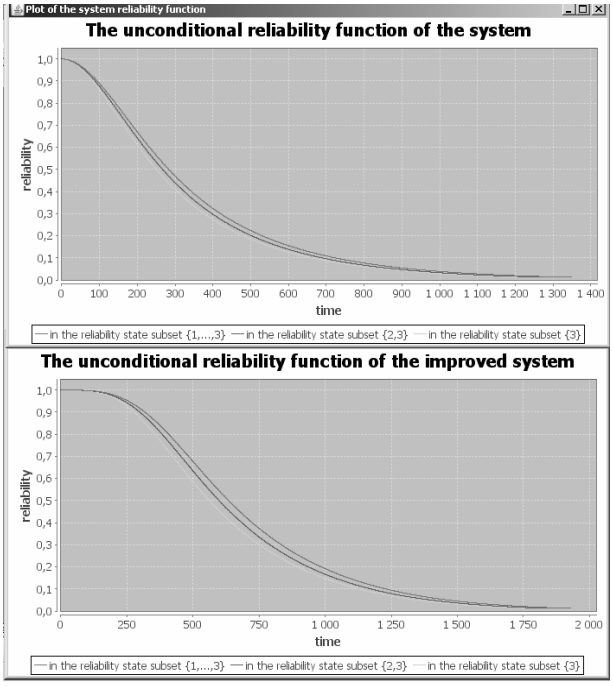
As a result there are given the reliability characteristics of the exemplary system in the first window before and in the second window after system improvement.


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
Coordinates of the unconditional reliability function of the system:
R(t,1)= 0.214*[1 - (1-exp(-0.003t))*(1-exp(-0.003t))] + 0.038*[1 - (1-exp(-0.0028t))*(1-exp(-0.0028t))*(1-exp(-0.0028t))*(1-exp(-0.0028t))]
+ 0.293*[[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))] * [1 - (1-exp(-0.0021t))*(1-exp(-0.0021t))*(1-exp(-0.0021t))*(1-exp(-0.0021t))]]
+ 0.455*[[1 - (1-exp(-0.0043t))*(1-exp(-0.0043t))] * [1 - [(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t))
+ exp(-0.0028t)(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t)) + exp(-0.0028t)(1 - exp(-0.0028t))*(1 - exp(-0.0028t))
(1 - exp(-0.0028t)) + exp(-0.0028t)(1 - exp(-0.0028t))(1 - exp(-0.0028t))*(1 - exp(-0.0028t)) + exp(-0.0028t)*(1 - exp(-0.0028t))
(1 - exp(-0.0028t))(1 - exp(-0.0028t))]]] for t>0,
R(t,2)= 0.214*[1 - (1-exp(-0.0031t))*(1-exp(-0.0031t))] + 0.038*[1 - (1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))]
+ 0.293*[[1 - (1-exp(-0.0034t))*(1-exp(-0.0034t))] * [1 - (1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))]]
+ 0.455*[[1 - (1-exp(-0.0046t))*(1-exp(-0.0046t))] * [1 - [exp(-0.0028t)(1 - exp(-0.003t))*(1 - exp(-0.003t))*(1 - exp(-0.003t))
(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))*(1 - exp(-0.003t))
(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)*(1 - exp(-0.003t))*(1 - exp(-0.003t))
*(1 - exp(-0.003t))]]] for t>0,
R(t,3)= 0.214*[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))] + 0.038*[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))*(1-exp(-0.0032t))*(1-exp(-0.0032t))]
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
Characteristics of the improved system reliability and risk
Coordinates of the unconditional reliability function of the improved system:
R(t,1)= 0.214*[1 - [1 - (2*exp(-0.0008t)-exp(-2*0.0008t))*(2*exp(-0.0011t)-exp(-2*0.0011t))*(2*exp(-0.0011t)-exp(-2*0.0011t))]
*[1 - (2*exp(-0.0008t)-exp(-2*0.0008t))*(2*exp(-0.0011t)-exp(-2*0.0011t))*(2*exp(-0.0011t)-exp(-2*0.0011t))]]
+ 0.038*[1 - [1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]]
+ 0.293*[[1 - [1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))*(2*exp(-0.0011t)-exp(-2*0.0011t))]
*[1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))*(2*exp(-0.0011t)-exp(-2*0.0011t))]]
* [1 - [1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))]
*[1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))]
*[1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))]
*[1 - (2*exp(-0.0009t)-exp(-2*0.0009t))*(2*exp(-0.0012t)-exp(-2*0.0012t))]]]
+ 0.455*[[1 - [1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2*exp(-0.0013t)-exp(-2*0.0013t))*(2*exp(-0.0015t)-exp(-2*0.0015t))*(2*exp(-0.0015t)-exp(-2*0.0015t))]]
* [1 - [[1 - (2exp(-0.0013t)-exp(-2*0.0013t))*(2exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2exp(-0.0013t)-exp(-2*0.0013t))*(2exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2exp(-0.0013t)-exp(-2*0.0013t))*(2exp(-0.0015t)-exp(-2*0.0015t))]
*[1 - (2exp(-0.0013t)-exp(-2*0.0013t))*(2exp(-0.0015t)-exp(-2*0.0015t))]
+ [1 - (2exp(-0.0013t)-exp(-2*0.0013t))*(2exp(-0.0015t)-exp(-2*0.0015t))]
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
New
Exit

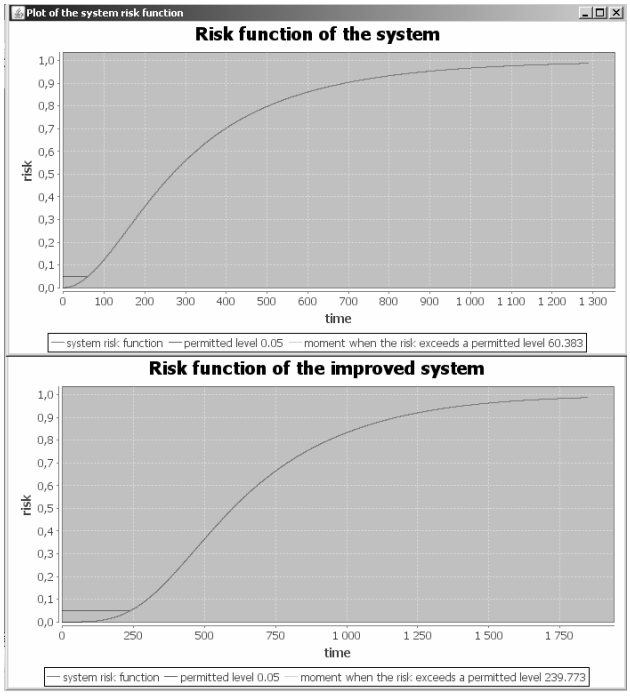

Application of P-SJP
File Help
Characteristics of the system reliability and risk
Prediction of improved complex technical systems reliability and risk
Characteristics of the system reliability and risk
The system risk function:
r(t)= 1 - R(t,2)= 1 - [0.214*[1 - (1-exp(-0.0031t))*(1-exp(-0.0031t))]
+ 0.038*[1 - (1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))] + 0.293*[[1 - (1-exp(-0.0034t))*(1-exp(-0.0034t))]
* [1 - (1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))]] + 0.455*[[1 - (1-exp(-0.0046t))*(1-exp(-0.0046t))]
* [1 - [exp(-0.0028t)(1 - exp(-0.003t))*(1 - exp(-0.003t))*(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))
(1 - exp(-0.003t))(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))
(1 - exp(-0.003t))(1 - exp(-0.003t)) + exp(-0.003t)*(1 - exp(-0.003t))*(1 - exp(-0.003t))*(1 - exp(-0.003t))]]]] for t>0.
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.
Characteristics of the improved system reliability and risk
*[1 - (2*exp(-0.001t)-exp(-2*0.001t))*(2*exp(-0.0012t)-exp(-2*0.0012t))]]]
+ 0.455*[[1 - [1 - (2*exp(-0.0014t)-exp(-2*0.0014t))*(2*exp(-0.0016t)-exp(-2*0.0016t))*(2*exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2*exp(-0.0014t)-exp(-2*0.0014t))*(2*exp(-0.0016t)-exp(-2*0.0016t))*(2*exp(-0.0016t)-exp(-2*0.0016t))]]
* [1 - [[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]*[1 -
(2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
+ [1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]*(2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))
+ [1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]*(2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
+ [1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]*(2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
+ (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]
*[1 - (2exp(-0.0014t)-exp(-2*0.0014t))*(2exp(-0.0016t)-exp(-2*0.0016t))]]]]] for t>0.
Moment when the risk of a system with hot reservation exceeds a permitted level: 239.77344.
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
New
Exit



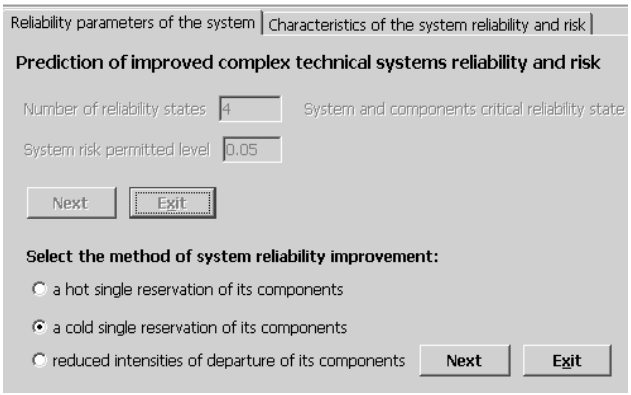
The program gives possibility of showing the plot of the coordinates of the system unconditional reliability function in the reliability state subset by pressing the button "Reliability Plot" for both widows i.e. for the system before and after improvement. Then the following window with the plot appears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

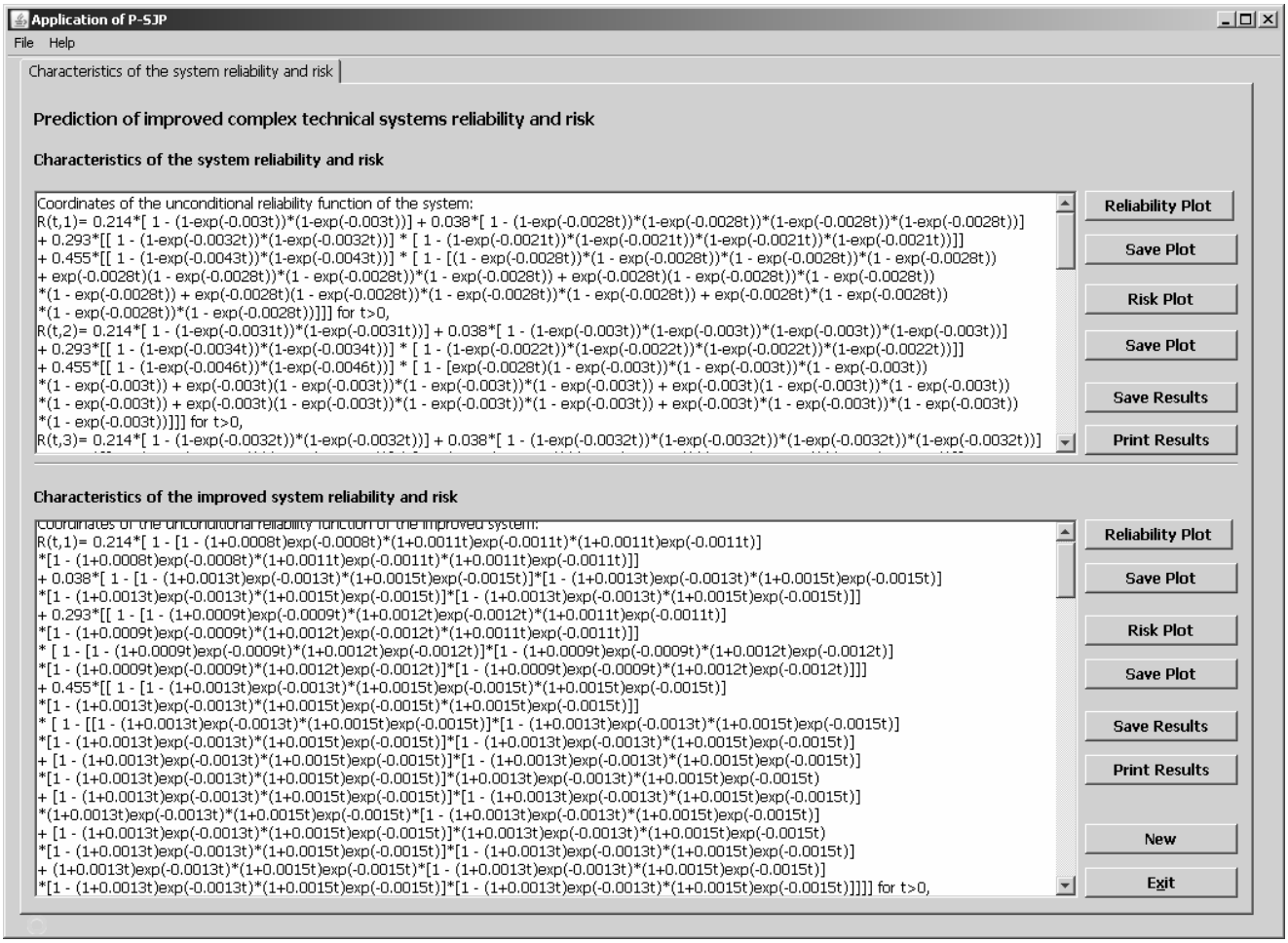


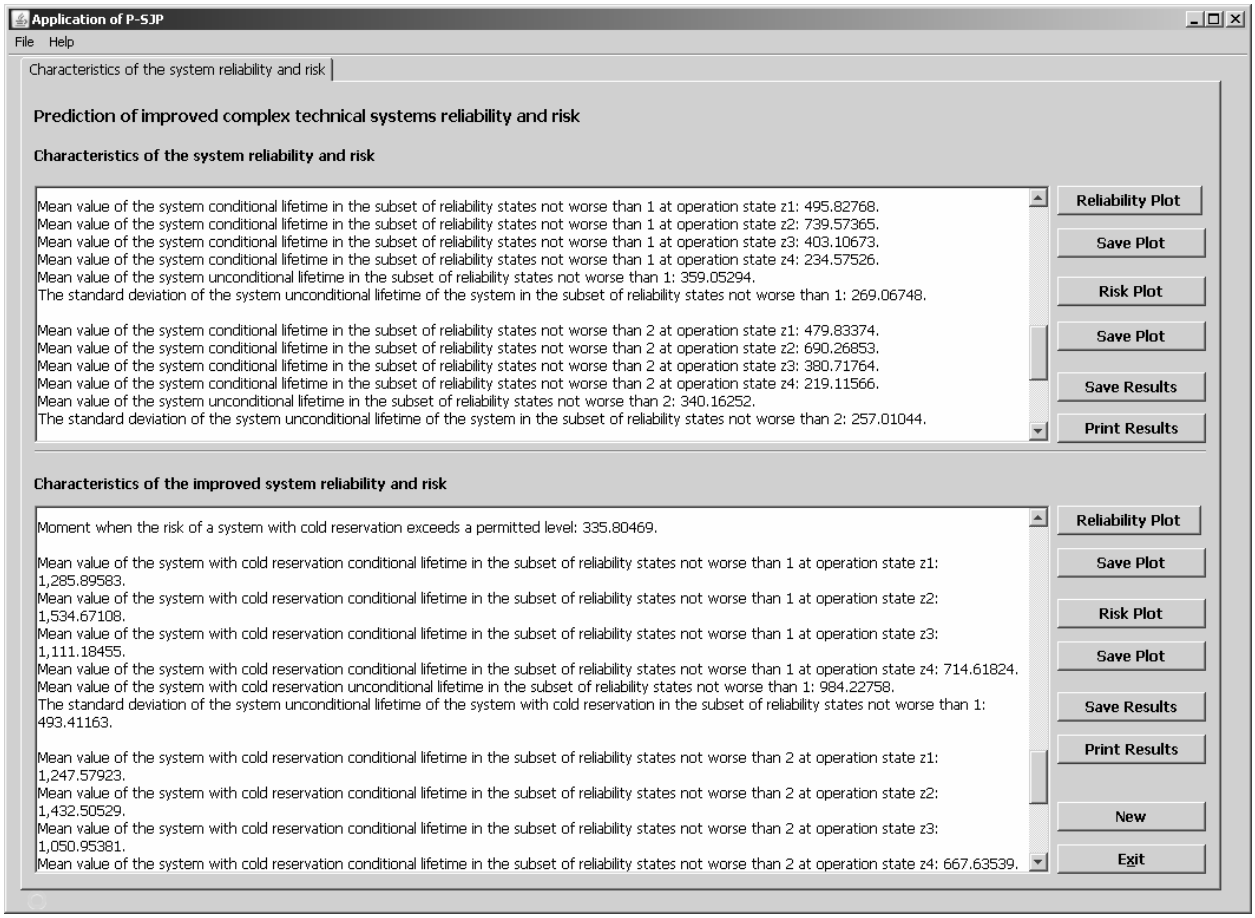
It is also possible to obtain the plot of the system risk function with marked moment when the risk exceeds a permitted level by pressing the button "Risk Plot".

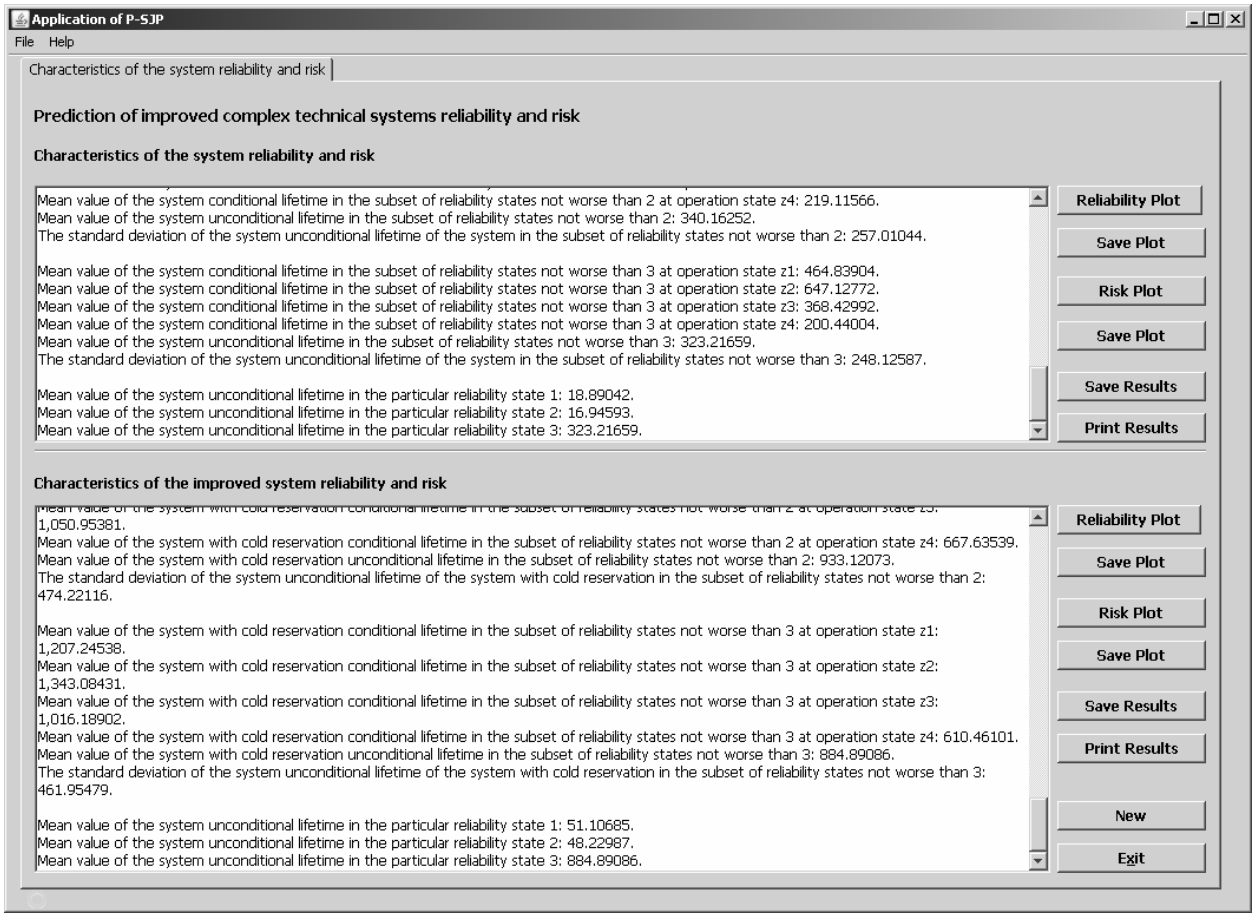


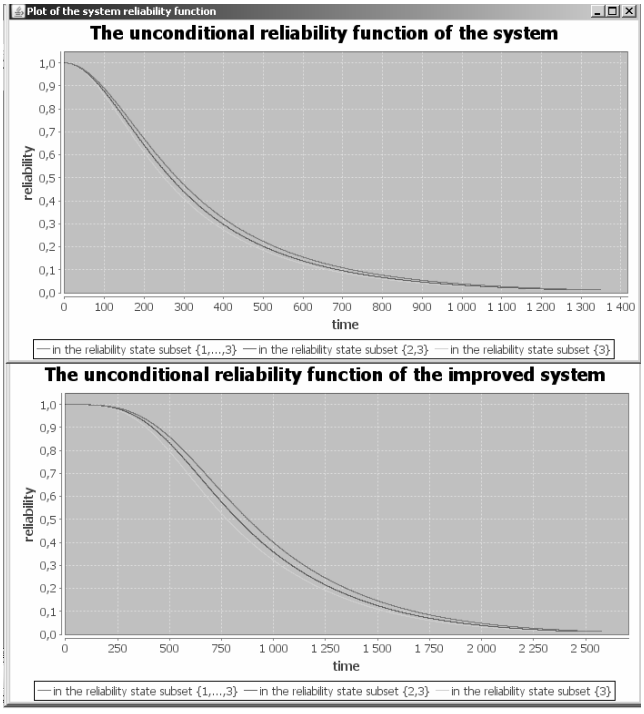
For the exemplary system with a cold single reservation of its components we obtain following results.

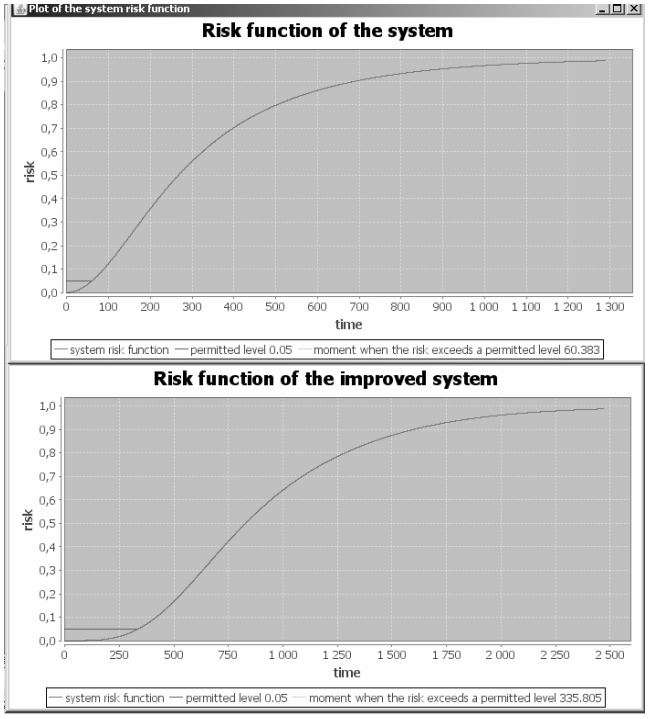

Reliability parameters of the system
Characteristics of the system reliability and risk
Prediction of improved complex technical systems reliability and risk
Number of reliability states
4
System and components critical reliability state
System risk permitted level
0.05
Next
Exit
Select the method of system reliability improvement:
a hot single reservation of its components
a cold single reservation of its components
reduced intensities of departure of its components
Next
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
Coordinates of the unconditional reliability function of the system:
R(t,1)= 0.214*[1 - (1-exp(-0.003t))*(1-exp(-0.003t))] + 0.038*[1 - (1-exp(-0.0028t))*(1-exp(-0.0028t))*(1-exp(-0.0028t))*(1-exp(-0.0028t))]
+ 0.293*[[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))] * [1 - (1-exp(-0.0021t))*(1-exp(-0.0021t))*(1-exp(-0.0021t))*(1-exp(-0.0021t))]]
+ 0.455*[[1 - (1-exp(-0.0043t))*(1-exp(-0.0043t))] * [1 - [(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t))
+ exp(-0.0028t)(1 - exp(-0.0028t))*(1 - exp(-0.0028t))*(1 - exp(-0.0028t)) + exp(-0.0028t)(1 - exp(-0.0028t))*(1 - exp(-0.0028t))
(1 - exp(-0.0028t)) + exp(-0.0028t)(1 - exp(-0.0028t))(1 - exp(-0.0028t))*(1 - exp(-0.0028t)) + exp(-0.0028t)*(1 - exp(-0.0028t))
(1 - exp(-0.0028t))(1 - exp(-0.0028t))]]] for t>0,
R(t,2)= 0.214*[1 - (1-exp(-0.0031t))*(1-exp(-0.0031t))] + 0.038*[1 - (1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))*(1-exp(-0.003t))]
+ 0.293*[[1 - (1-exp(-0.0034t))*(1-exp(-0.0034t))] * [1 - (1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))*(1-exp(-0.0022t))]]
+ 0.455*[[1 - (1-exp(-0.0046t))*(1-exp(-0.0046t))] * [1 - [exp(-0.0028t)(1 - exp(-0.003t))*(1 - exp(-0.003t))*(1 - exp(-0.003t))
(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))*(1 - exp(-0.003t))
(1 - exp(-0.003t)) + exp(-0.003t)(1 - exp(-0.003t))(1 - exp(-0.003t))*(1 - exp(-0.003t)) + exp(-0.003t)*(1 - exp(-0.003t))*(1 - exp(-0.003t))
*(1 - exp(-0.003t))]]] for t>0,
R(t,3)= 0.214*[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))] + 0.038*[1 - (1-exp(-0.0032t))*(1-exp(-0.0032t))*(1-exp(-0.0032t))*(1-exp(-0.0032t))]
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
Characteristics of the improved system reliability and risk
Coordinates of the unconditional reliability function of the improved system:
R(t,1)= 0.214*[1 - [1 - (1+0.0008t)exp(-0.0008t)*(1+0.0011t)exp(-0.0011t)*(1+0.0011t)exp(-0.0011t)]
[1 - (1+0.0008t)exp(-0.0008t)(1+0.0011t)exp(-0.0011t)*(1+0.0011t)exp(-0.0011t)]]
+ 0.038*[1 - [1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]]
+ 0.293*[[1 - [1 - (1+0.0009t)exp(-0.0009t)*(1+0.0012t)exp(-0.0012t)*(1+0.0011t)exp(-0.0011t)]
[1 - (1+0.0009t)exp(-0.0009t)(1+0.0012t)exp(-0.0012t)*(1+0.0011t)exp(-0.0011t)]]
* [1 - [1 - (1+0.0009t)exp(-0.0009t)*(1+0.0012t)exp(-0.0012t)]*[1 - (1+0.0009t)exp(-0.0009t)*(1+0.0012t)exp(-0.0012t)]
[1 - (1+0.0009t)exp(-0.0009t)(1+0.0012t)exp(-0.0012t)]*[1 - (1+0.0009t)exp(-0.0009t)*(1+0.0012t)exp(-0.0012t)]]]
+ 0.455*[[1 - [1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)*(1+0.0015t)exp(-0.0015t)]
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)*(1+0.0015t)exp(-0.0015t)]]
* [1 - [[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
+ [1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
(1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
+ [1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]*(1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
+ (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]
[1 - (1+0.0013t)exp(-0.0013t)(1+0.0015t)exp(-0.0015t)]*[1 - (1+0.0013t)exp(-0.0013t)*(1+0.0015t)exp(-0.0015t)]]]] for t>0,
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
New
Exit

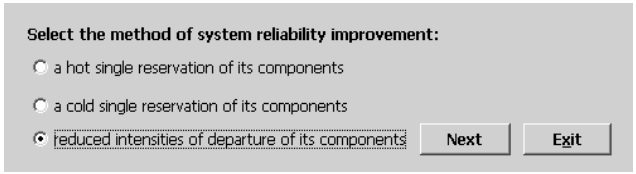

Application of P-SJP
File Help
Characteristics of the system reliability and risk
Prediction of improved complex technical systems reliability and risk
Characteristics of the system reliability and risk
Mean value of the system conditional lifetime in the subset of reliability states not worse than 1 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: 1,285.89583.
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
Exit

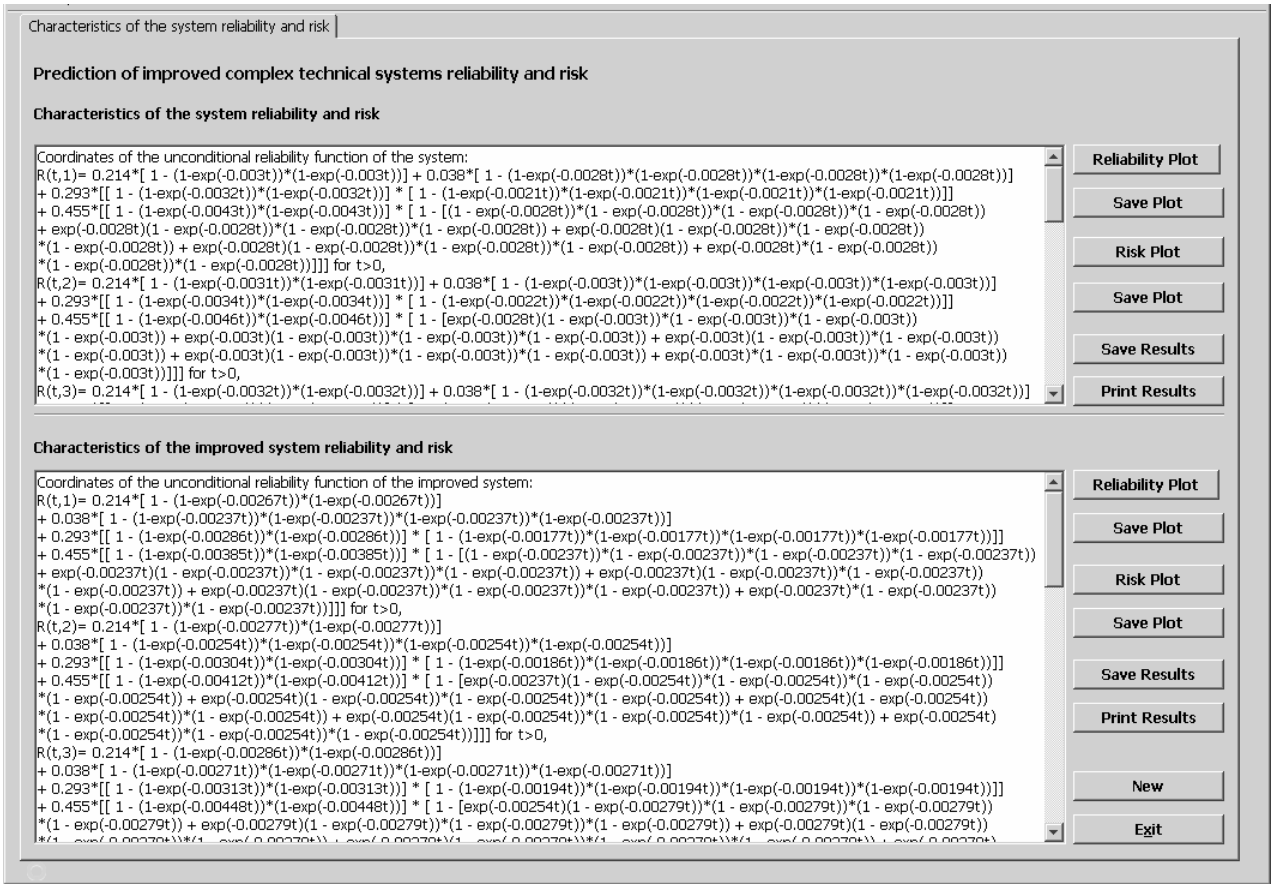

Application of P-SJP
File Help
Characteristics of the system reliability and risk
Prediction of improved complex technical systems reliability and risk
Characteristics of the system reliability and risk
Mean value of the system conditional lifetime in the subset of reliability states not worse than 2 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.
Reliability Plot
Save Plot
Risk Plot
Save Plot
Save Results
Print Results
Characteristics of the improved system reliability and risk
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

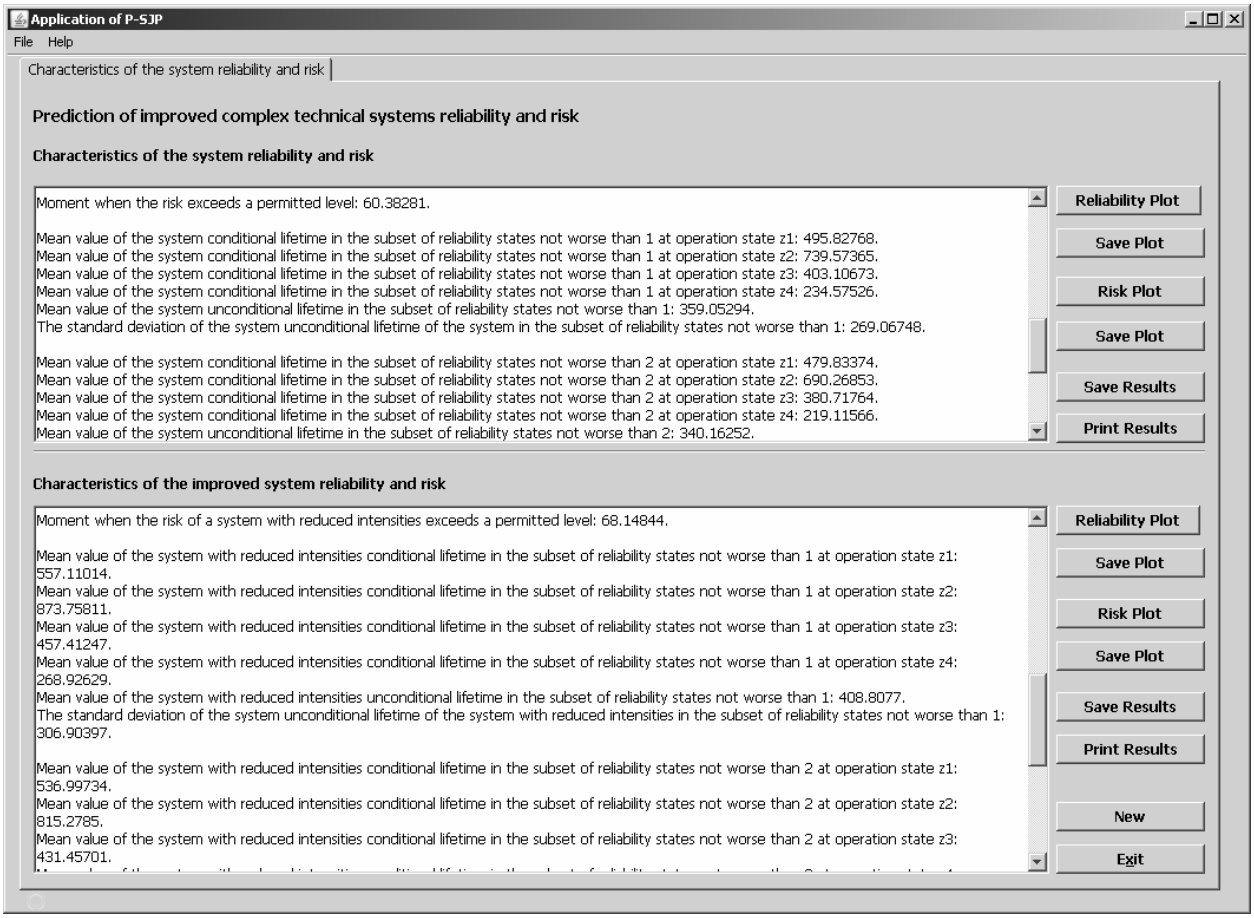


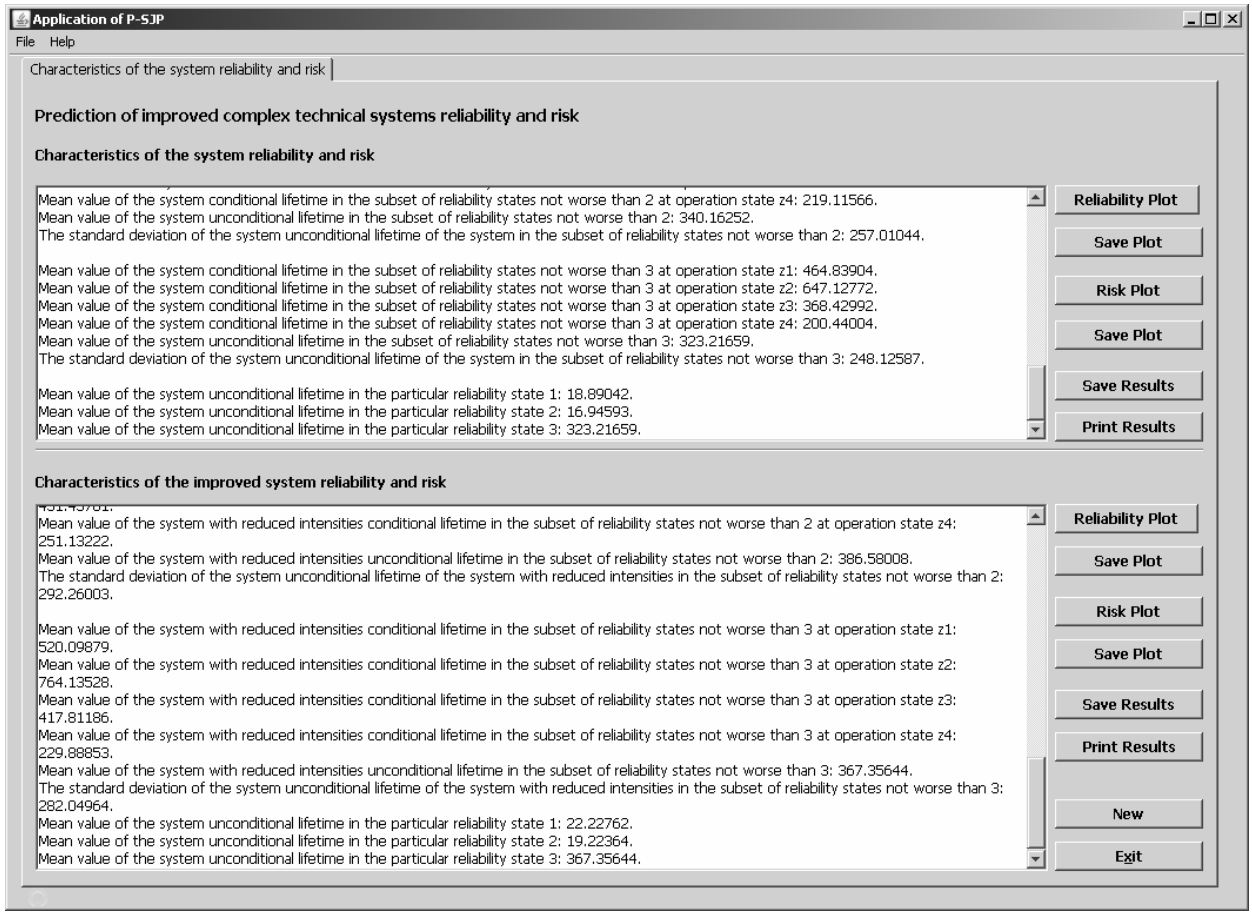


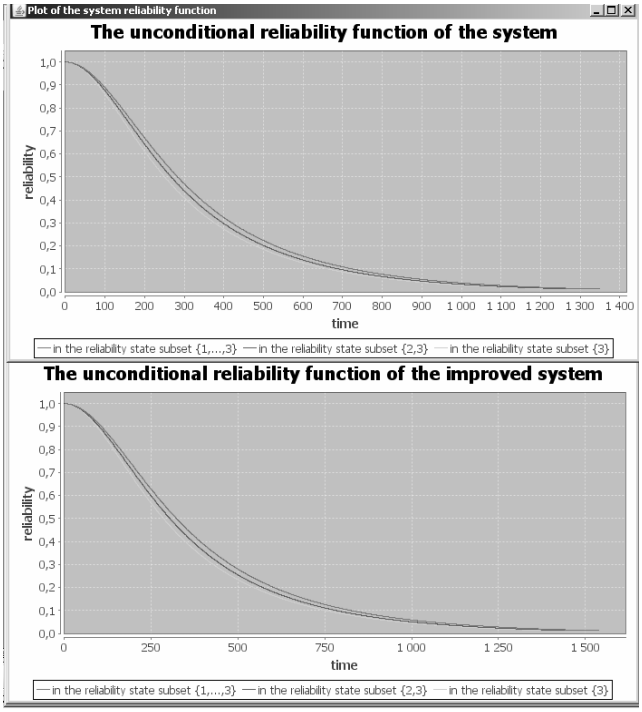
The results of the computer program CP 8.16 for the exemplary system with reduced intensities of departure of its components are presented below.

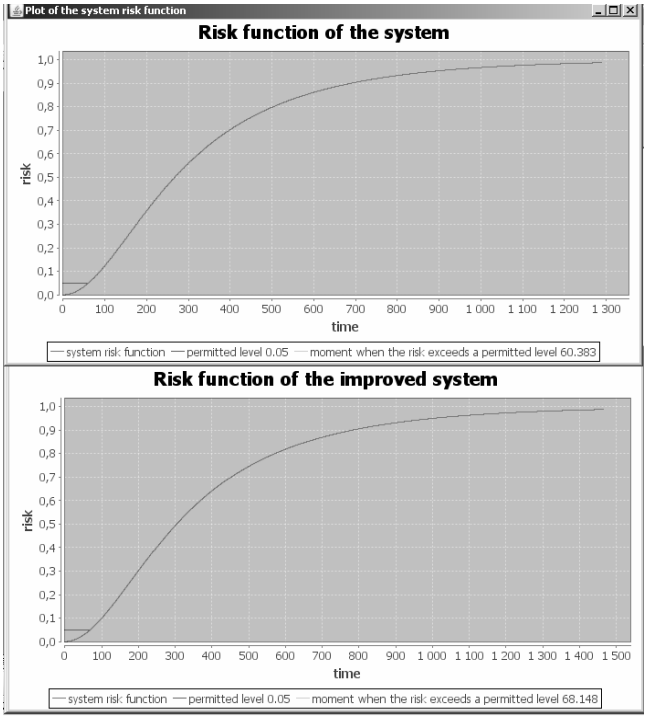





Application of P-SJP
File Help
Characteristics of the system reliability and risk
Prediction of improved complex technical systems reliability and risk
Characteristics of the system reliability and risk
Moment when the risk exceeds a permitted level: 60.38281.
Mean value of the system conditional lifetime 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.
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 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.
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 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



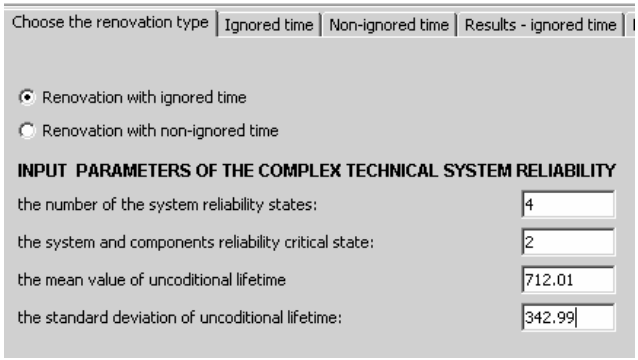


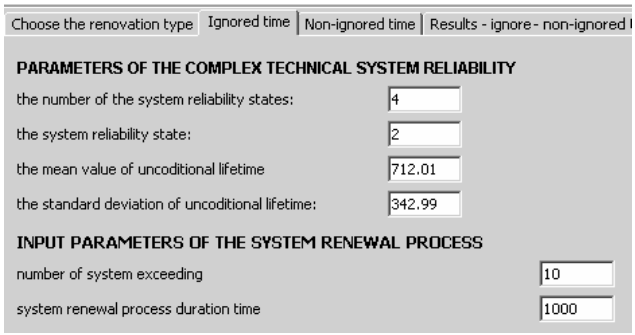
11.2. Renewal and availability characteristics of the improved exemplary system

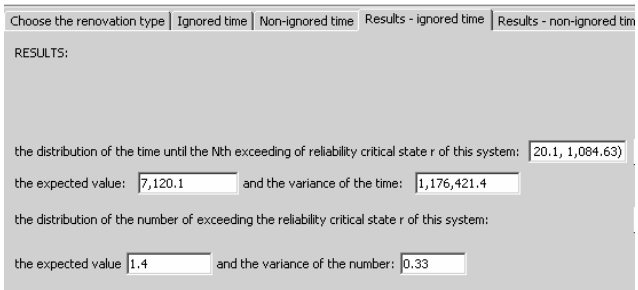
To determine the renewal and availability characteristics of the improved exemplary system, we use the results of the system reliability characteristics evaluation performed in Sections 11.1 and the results of the Section 12.3.1. of IS&RDSS 12 [7].

If components of the repairable improved exemplary system with ignored time of renovation have exponential reliability functions at the operation states z_b, $b = 1,2,...,v$, 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 *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.

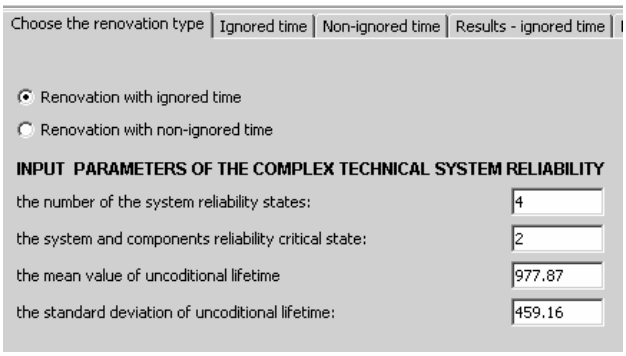
For the exemplary system with a hot single reservation of its components we obtain following results.

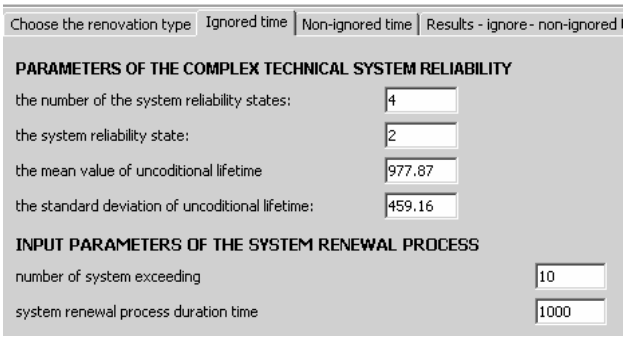


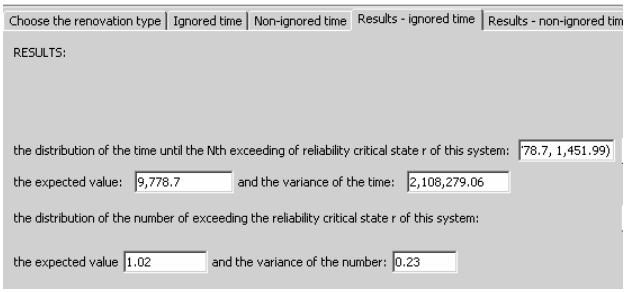




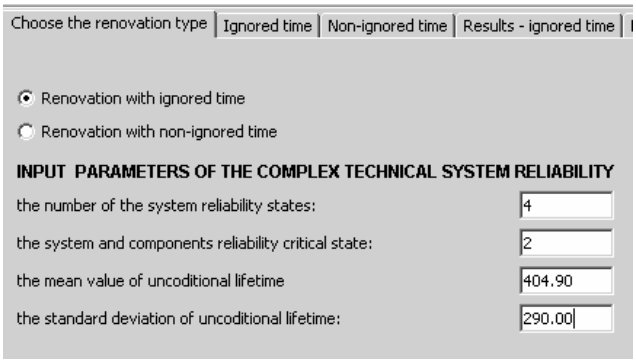
For the exemplary system with a cold single reservation of its components we get.

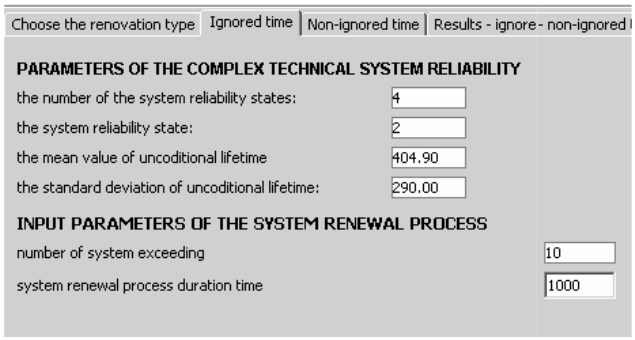


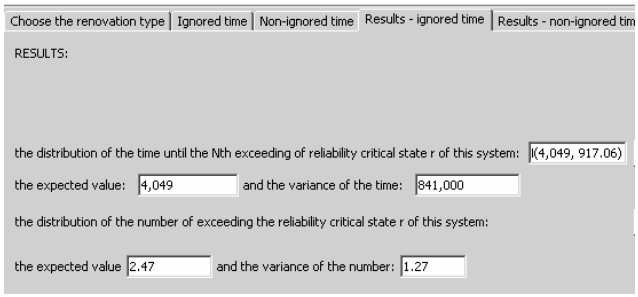




For the exemplary system with reduced rates of departure of its components the computer program is predicting the renewal and availability characteristics in the following way.

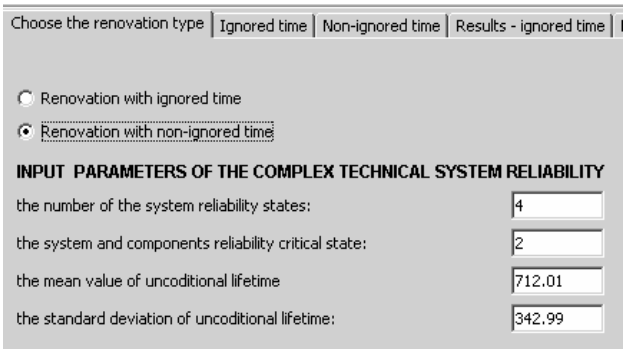


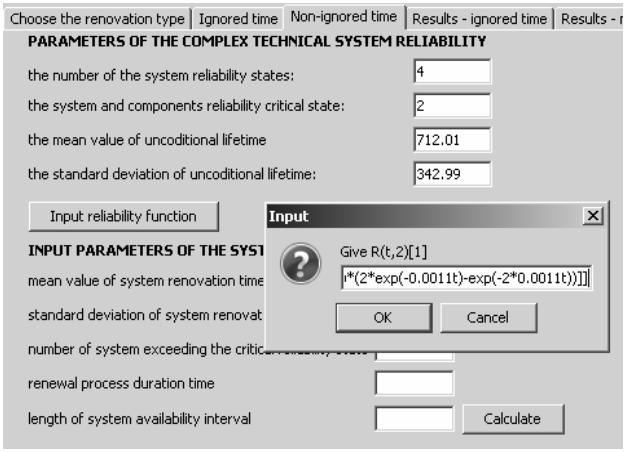


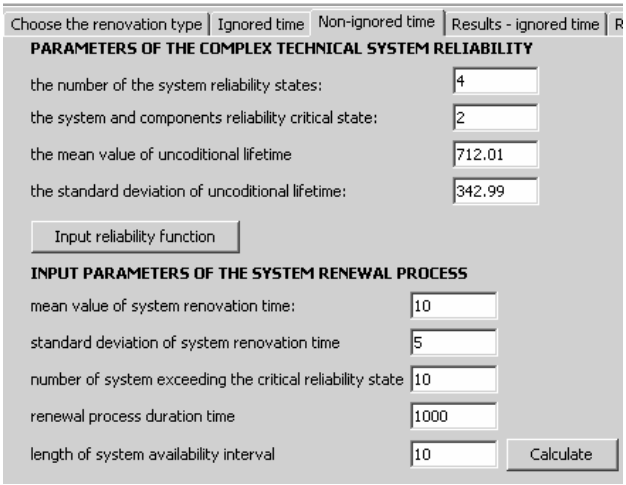


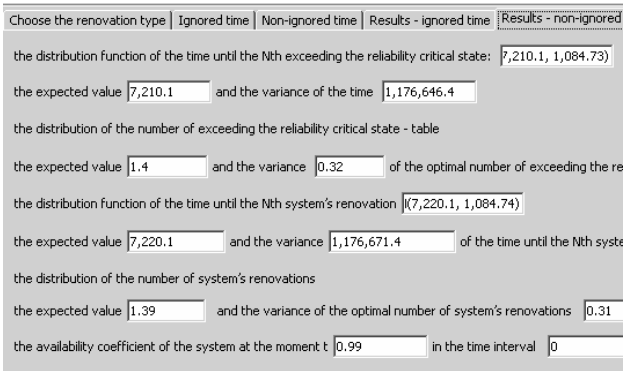
To make the estimation of the renewal and availability of the improved exemplary system in the case when the time of renovation is non-ignored, we assume the mean value of the system renovation time is equal $\mu_0(2)=10$ years and the standard deviation of the system renovation time amounts $\sigma_0(2)=5$ years. If components of the repairable improved exemplary system have exponential reliability functions at the operation states z_b, $b=1,2,...,v$, 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.

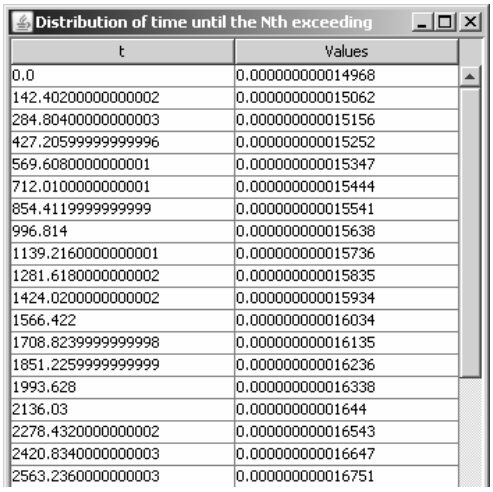
For the exemplary system with a hot single reservation of its components we get.





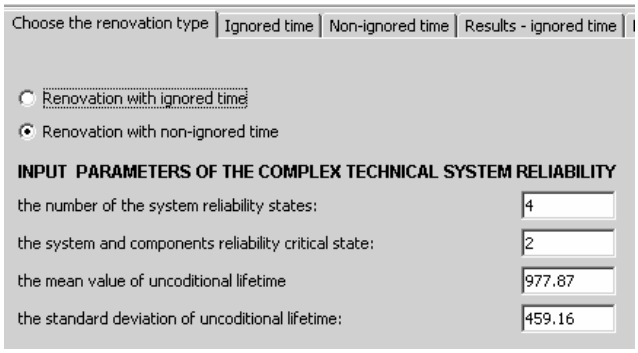


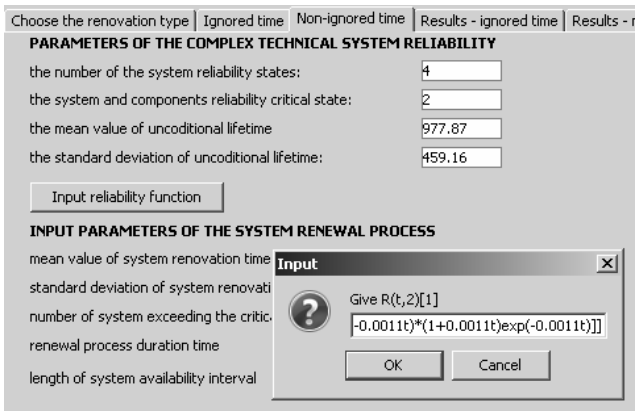


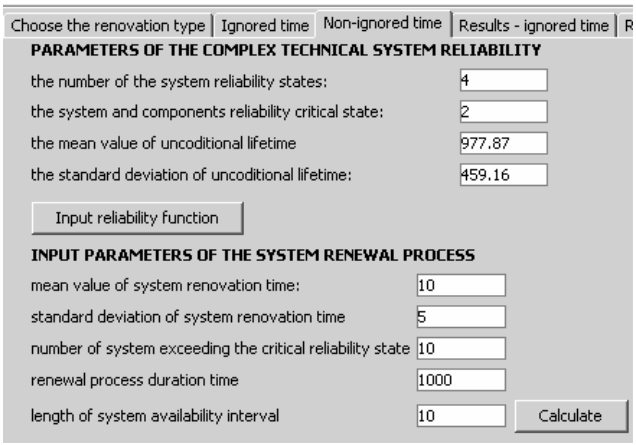


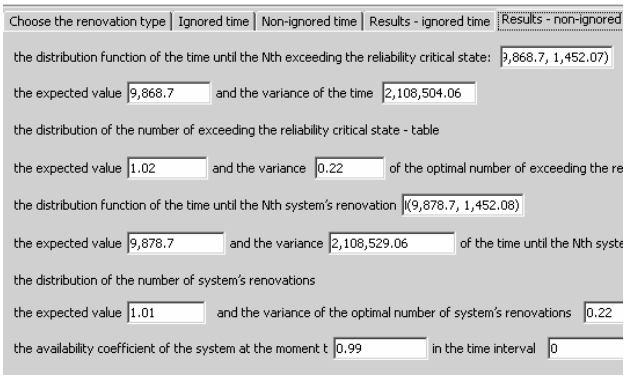
t	Values
0.0	0.000000000014968
142.40200000000002	0.000000000015062
284.80400000000003	0.000000000015156
427.20599999999996	0.000000000015252
569.6080000000001	0.000000000015347
712.0100000000001	0.000000000015444
854.4119999999999	0.000000000015541
996.814	0.000000000015638
1139.2160000000001	0.000000000015736
1281.6180000000002	0.000000000015835
1424.0200000000002	0.000000000015934
1566.422	0.000000000016034
1708.8239999999998	0.000000000016135
1851.2259999999999	0.000000000016236
1993.628	0.000000000016338
2136.03	0.00000000001644
2278.4320000000002	0.000000000016543
2420.8340000000003	0.000000000016647
2563.2360000000003	0.000000000016751

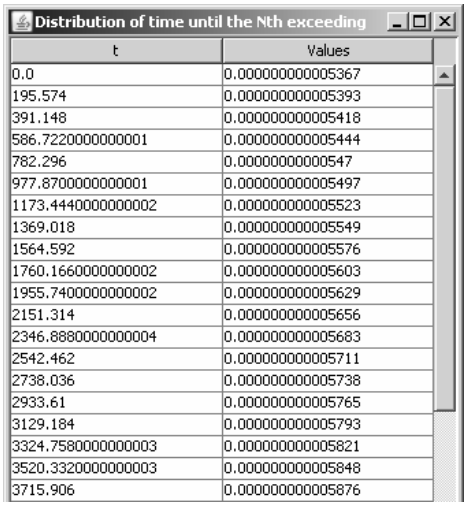
For the exemplary system with a cold single reservation of its components the results are presented below.



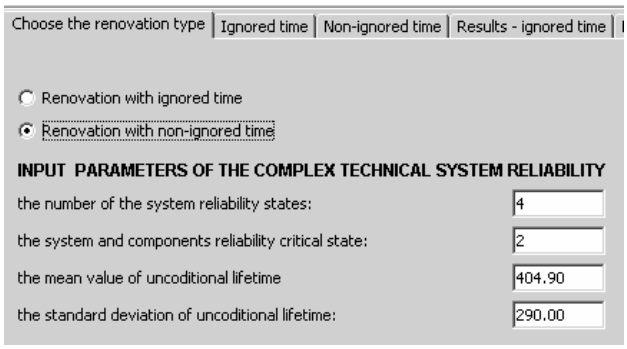


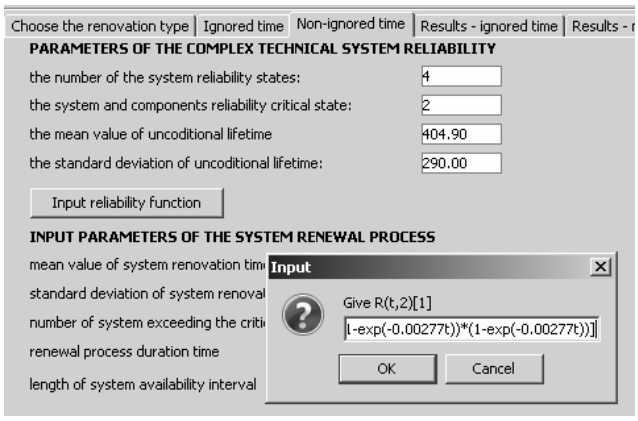


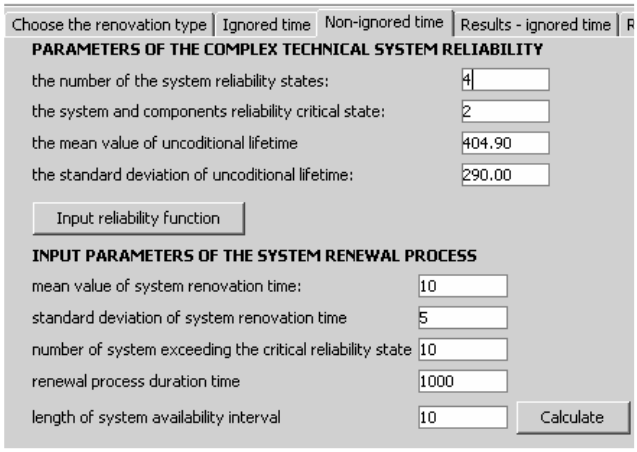


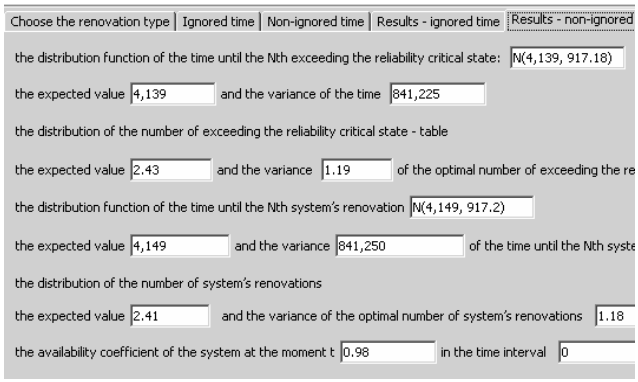


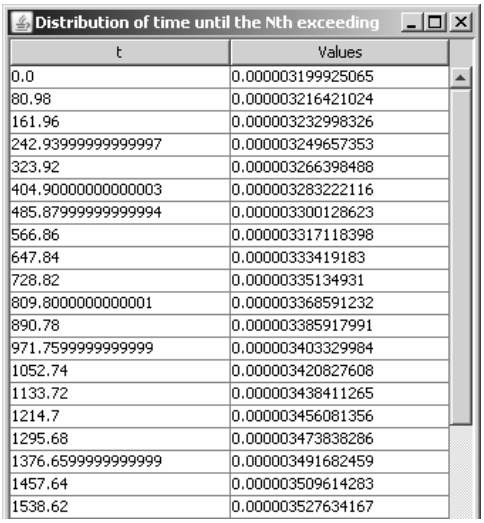
For the exemplary system with reduced rates of departure of its components the computer program is predicting the renewal and availability characteristics in the following way.











Distribution of time until the Nth exceeding

t	Values
0.0	0.000003199925065
80.98	0.000003216421024
161.96	0.000003232998326
242.93999999999997	0.000003249657353
323.92	0.000003266398488
404.90000000000003	0.000003283222116
485.87999999999994	0.000003300128623
566.86	0.000003317118398
647.84	0.00000333419183
728.82	0.00000335134931
809.8000000000001	0.000003368591232
890.78	0.000003385917991
971.7599999999999	0.000003403329984
1052.74	0.000003420827608
1133.72	0.000003438411265
1214.7	0.000003456081356
1295.68	0.000003473838286
1376.6599999999999	0.000003491682459
1457.64	0.000003509614283
1538.62	0.000003527634167

Acknowledgements

The paper describes the work in the Poland-Singapore Joint Research Project titled “Safety and Reliability of Complex Industrial Systems and Processes” supported by grants from the Poland’s Ministry of Science and Higher Education (MSHE grant No. 63/N-Singapore/2007/0) and the Agency for Science, Technology and Research of Singapore (A*STAR SERC grant No. 072 1340050).

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