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Identification of complex technical system components safety models

Keywords

system safety, multistate system, statistical identification, maritime transport

Abstract

There is presented the contents of the training course addressed to industry. The curriculum of the course includes the methods, algorithms and procedures for identification of the safety models of components of the complex technical systems and their applications in practice. It is based on the theoretical backgrounds concerned with the semi-markov modeling of the complex technical systems operation processes, on the complex technical systems and their components multistate safety models and on the statistical methods of identification of the complex technical system components safety models. The illustration of the proposed methods and procedures practical application in maritime transportation is included.

1. Introduction

The training course is concerned with methods, algorithms and procedures of identification of the safety models the complex technical systems and their application in practice and it is based on the results given in [3] and [1]. The participants of the course are provided training materials and a disk with the computer program included in [4]. Presented at the training course example of practical applications is coming from [6].
The training course includes the following items:

- Theoretical backgrounds based on [3]: basic notions of the system multi-state safety analysis, definition of the conditional multi-state safety function of the system components, definition of the conditional multi-state exponential safety function of the system components, definition of the system components conditional intensities of departure from the safety states subsets;
- Methodology of fixing the subsystems and components of the complex technical systems in various operation states on [5] and [2]: defining the system operation states, fixing the subsystems of the system operating in various operation states, fixing and describing the components of the subsystems operating in various operation states;
- Methodology of defining the parameters of the system components multi-state safety models based on [3]: fixing the number of different safety states of the system components, defining the safety states of the system components, fixing the possible transitions between the system components safety states, fixing the set of unknown parameters of the system components safety models;
- Procedure of the system components safety data collection based on [1]: In the case of data coming from experts, fixing the approximate mean values of the system components lifetimes in the safety states subsets; In the case of data coming from the system components safety state changing processes, fixing the following experiment kinds: *Case 1*. Observations of the realizations of the component lifetimes up to the first departure from the safety states

subset on several experimental posts – Completed investigations, the same observation time on all experimental posts; *Case 2*. Observations of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, the same observation time on all experimental posts; *Case 3*. Observations of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, different observation times on particular experimental posts; *Case 4*. Observations of the realizations of the component simple renewal flow (stream) on one experimental post; *Case 5*. Observations of the realizations of the component simple renewal flows (streams) on several experimental posts – The same observation time on all experimental posts; *Case 6*. Observations of the realizations of the component simple renewal flows (streams) on several experimental posts – Different observation times on experimental posts; fixing the experiments duration times, fixing the realizations of the component lifetimes up to the first departure from the safety states subsets, fixing the numbers of the observed realizations of the component lifetimes up to the first departure from the safety states subsets in *Cases 1-6*;

- Procedure of evaluating the unknown system component conditional intensities of departures from the safety states subset based on [1]: *Case 1*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Completed investigations, the same observation time on all experimental posts; *Case 2*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, the same observation time on all experimental posts; *Case 3*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, different observation times on particular experimental posts; *Case 4*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flow (stream) on one experimental post; *Case 5*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – The same observation time on all experimental posts; *Case 6*. The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – Different observation times on experimental posts; The pessimistic estimations of the components intensities of departures from the safety states subsets in all *Cases 2-6*;
- Procedure of identifying the system components conditional multi-state exponential safety functions based on [1]: constructing and plotting the realization of the histogram of the system component conditional lifetime in the safety states subset, analyzing the realization of the histogram, comparing the histogram realization with the graph of the exponential density function and in the case of their good conformity formulating the hypothesis concerning the exponential form of the system component conditional multi-state safety function;

  - Procedure of applying the computer program for identification of system components reliability models based on [4];

  - Application of the procedures and computer program for identification of the safety models of the components of real complex technical systems operating in variable conditions: identification of the safety of the components of the technical system of the Stena Baltica ferry based on [6].

2. Theoretical backgrounds

In the multi-state safety analysis of non-repairable systems to define the system ageing (degrading) components we assume that:

– E is a component of a system,

- a components E has the safety state set $\{0,1,...,z\}$, $z \ge 1$,
- the safety states are ordered, the state 0 is the worst and the state z is the best,
- $T(u)$ is a random variable representing the lifetime of component E in the state subset $\{u,u+1,...,z\}$, while it was in the state z at the moment $t = 0$,
- the component safety states degrade with time t without repair,
- $e(t)$ is a component E state at the moment t, $t \in < 0, \infty)$, given that it was in the state z at the moment $t = 0$.

The above assumptions mean that the states of the system with degrading components may be changed in time only from better to worse (see: *Figure 1*).

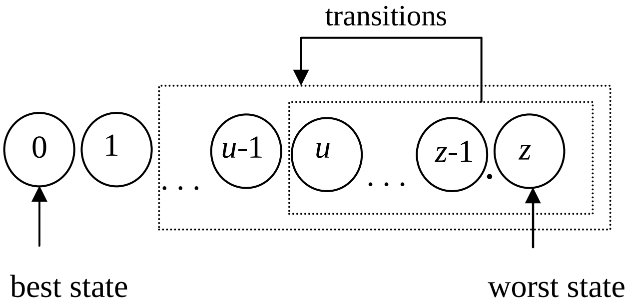

Figure 1. Illustration of safety states changing in system with ageing components

Under these assumption, a vector

$$s(t,\cdot) = [s(t,0), s(t,1), ..., s(t,z)],\ t \in < 0, \infty), \qquad (1)$$

where

$$s(t,u) = P(e(t) \ge u \mid e(0) = z)$$

$$= P(T(u) > t),\ t \in < 0, \infty),\ u = 0,1,...,z, \qquad (2)$$

is the probability that the component E is in the safety states subset $\{u, u+1, ..., z\}$ at the moment t, $t \in < 0, \infty)$, while it was in the safety state z at the moment $t = 0$, is called the multi-state safety function of a component E.

Particularly, for $u = 0$, in (1) and (2) we have

$$s(t,0) = P(e(t) \ge 0 \mid e(0) = z)$$

$$= P(T(0) > t) = 1,\ t \in < 0, \infty). \qquad (3)$$

We assume that the changes of operation states of the multistate system operation process $Z(t)$ have an influence on the safety functions of the system components and we mark by $T^{(b)}(u)$ the conditional lifetime $T^{(b)}(u)$ of the system component in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z$. Consequently, we mark the conditional multistate safety function of the system component when the system is in the operation state z_b, $b = 1,2,...,\nu$, by

$$[s(t,\cdot)]^{(b)} = [1,\ [s(t,1)]^{(b)},\ ...,\ [s(t,z)]^{(b)}], \qquad (4)$$

where

$$[s(t,u)]^{(b)} = P(T^{(b)}(u) > t \mid Z(t) = z_b) \qquad (5)$$

for $t \in < 0, \infty)$, $u = 1,2,...,z$, $b = 1,2,...,\nu$,

is the conditional safety function standing the probability that the conditional lifetime $T^{(b)}(u)$ of the system component in the safety states subset $\{u, u+1, ..., z\}$ is greater than t, while the system operation process $Z(t)$ is in the operation state z_b, $b = 1,2,...,\nu$.

Further, we assume that the coordinates of the vector of the conditional multistate safety function (4) are exponential safety functions of the form

$$[s(t,u)]^{(b)} = \exp[-[\lambda(u)]^{(b)} t] \qquad (6)$$

for $t \in < 0, \infty)$, $u = 1,2,...,z$, $b = 1,2,...,\nu$.

Te above assumptions mean that the density function of the system component conditional life time $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z$, at the operation state z_b, $b = 1,2,...,\nu$, is exponential of the form

$$[f(t,u)]^{(b)} = [\lambda(u)]^{(b)} \exp[-[\lambda(u)]^{(b)} t] \qquad (7)$$

for $t \in < 0, \infty)$,

where $[\lambda(u)]^{(b)}$, $[\lambda(u)]^{(b)} \ge 0$, is an unknown intensity of departure from this subset of the safety states.

3. Procedures of identification of complex technical system components safety models

3.1. Methodology of fixing the subsystems and components of the complex technical systems in various operation states

To fix the subsystems and components of the system in various operation states, firstly, we should analyze the system operation process and to fix or to define its following general parameters:

- the number of the operation states of the system operation process

ν,

- the operation states of the system operation process

$z_1, z_2, \ldots, z_\nu$.

Next, we should do the following steps:

i) to fixing the subsystems of the system operating in particular operation states;

ii) to fix, to describe and to mark the components of the subsystems operating in particular operation states.

3.2. Methodology of defining the parameters of the system components conditional multi-state safety models

To make the estimation of the unknown parameters of the system components conditional multistate safety functions the experiment delivering the necessary statistical data should be precisely planned.
Firstly, before the experiment, we should perform the following preliminary steps:

iii) to analyze the processes of safety states changing of all system components in different operation states;

iv) to fix or to define its following general parameters:

- the number of the safety states of the system components

z,

- the safety states of the system components

$0, 1, \ldots, z$;

v) to fix the possible transitions between the system components safety states;

iv) to fix the set of the unknown safety parameters of the system components.

3.3. Procedures of the system components safety data collection

3.3.1. Data coming from experts

On the basis of the expert opinions the approximate values

$$[\hat{\mu}(u)]^{(b)}, \ u = 1,2,\ldots,z, \ \ b = 1,2,\ldots,\nu,$$

of the mean values

$$[\mu(u)]^{(b)} = E[T(u)]^{(b)}, \ u = 1,2,\ldots,z, \ \ b = 1,2,\ldots,\nu,$$

of the system components lifetimes $[T(u)]^{(b)}$, $u = 1,2,\ldots,z,$ $b = 1,2,\ldots,\nu,$ in the safety states subsets $\{u, u+1,\ldots,z\}$, $u = 1,2,\ldots,z,$ while the system is operating in the operation state z_b, $b = 1,2,\ldots,\nu,$ should be fixed.

3.3.2. Data coming from components safety states changing processes

To estimate the unknown parameters of the system components multistate safety models, during the experiment, we should collect necessary statistical data performing the following steps:

i) to fix the experiment kinds subjected to the defined below *Cases 1-6;*

ii) to fix and to collect, in *Cases 1-6*, the following statistical data necessary to evaluating the unknown intensity of departure from the safety states subsets:

- the experiments duration times,

- the realizations of the component lifetimes up to the first departure from the safety states subsets,

- the numbers of the observed realizations of the component lifetimes up to the first departure from the safety states subsets.

The fixed kinds of the experiments and the collected statistical data are described below.

Case 1.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Completed

investigations, the same observation time on all experimental posts

We assume that during the time $\tau^{(b)}$, $\tau^{(b)} > 0$, we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z$, at the operation state z_b, $b = 1,2,...,\nu$, on $n^{(b)}$ identical experimental posts. Moreover, we assume that during the fixed observation time $\tau^{(b)}$ all components have left the safety states subset and we mark by $t_i^{(b)}(u) = t_i$, $i = 1,2,...,n^{(b)}$, (*Figure 2*) the moment of departure from the safety states subsets of the component on the $i-$th observational post, i.e. the realizations of the identical component lifetimes $T_i^{(b)}(u)$, $i = 1,2,...,n^{(b)}$, to the first departure from the safety states subsets, that are the independent random variables with the exponential distribution defined by the density function (7).

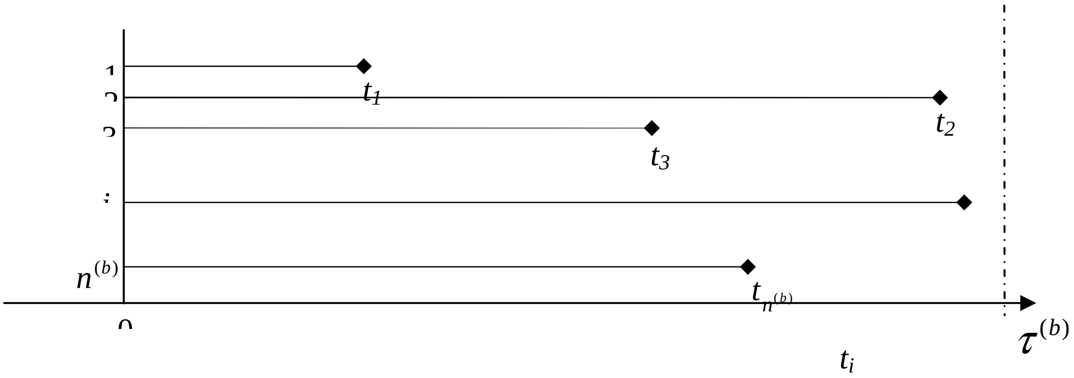

Figure 2. The scheme of the realizations of the component lifetimes up to the first departure from the safety states subset on $n^{(b)}$ observational posts (completed investigations, the same observation time on all experimental posts)

Case 2.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, the same observation time on all experimental posts

We assume that during the time $\tau^{(b)}$, $\tau^{(b)} > 0$, we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z$, at the operation state z_b, $b = 1,2,...,\nu$, on $n^{(b)}$ identical experimental posts. Moreover, we assume that during the fixed observation time $\tau^{(b)}$ not all components have left the safety states subset and we mark by $m_1^{(b)}(u) = m_1$, $m_1^{(b)}(u) < n^{(b)}$, the number of components that have left the safety states subset and by $t_i^{(b)}(u) = t_i$, $i = 1,2,...,m_1^{(b)}(u)$, (*Figure 3*) the moments of their departures from the safety states subsets, i.e. the realizations of the identical component lifetimes $T_i^{(b)}(u)$, $i = 1,2,...,m_1^{(b)}(u)$, to the first departure from the safety states subsets, that are the independent random variables with the exponential distribution defined by the density function (7).

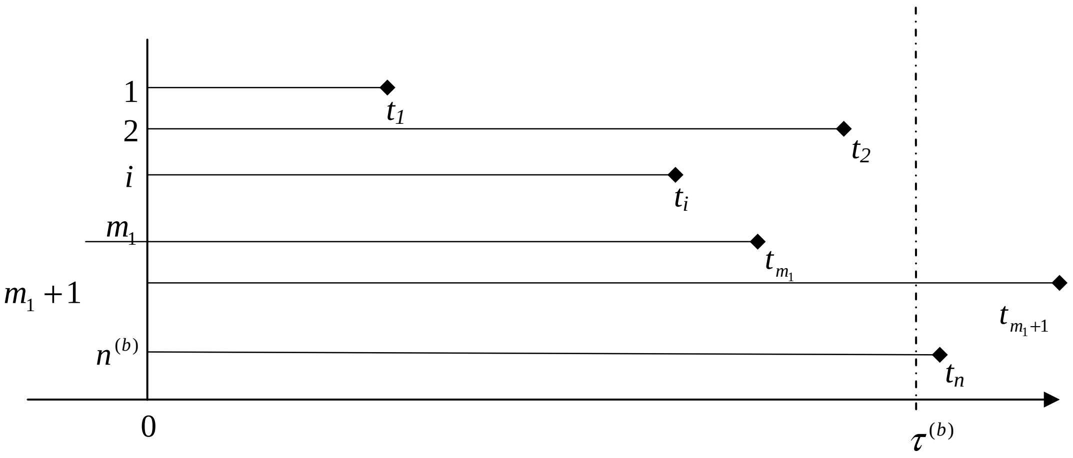

Figure 3. The scheme of the realizations of the component lifetimes up to the first departure from the safety states subset on $n^{(b)}$ observational posts (non-completed investigations, the same observation time on all experimental posts)

Case 3.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, different observation times on particular experimental posts

We assume that we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ at the operation state z_b, $b = 1,2,...,\nu$, on $n^{(b)}$ identical experimental posts. We assume that the observation times on particular experimental posts are different and we mark by $\tau_i^{(b)}$, $\tau_i^{(b)} > 0,$ $i = 1,2,...,n^{(b)}$, the observation time respectively on the *i*-th experimental post. Moreover, we assume that during the fixed observation times $\tau_i^{(b)}$ not all components have left the safety states subset and we mark by $m_1^{(b)}(u) = m_1$, $m_1^{(b)}(u) < n^{(b)}$, the number of components that have left the safety states subset and by $t_i^{(b)}(u) = t_i$, $i = 1,2,...,m_1^{(b)}(u),$ (*Figure 4*) the moments of their departures from the safety states subsets, i.e. the realizations of the identical component lifetimes $T_i^{(b)}(u)$, $i = 1,2,...,m_1^{(b)}(u),$ to the first departure from the safety states subsets, that are the independent random variables with the exponential distribution defined by the density function (7).

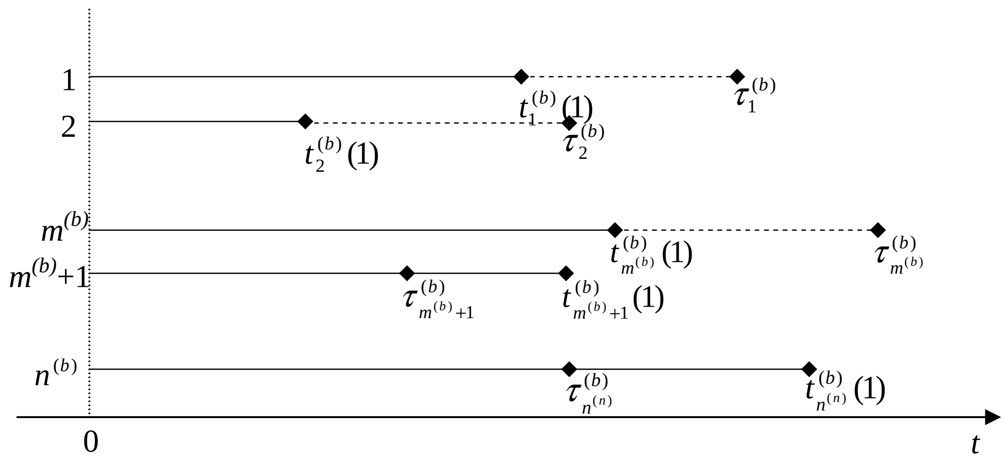

Figure 4. The scheme of the realizations of the component lifetimes up to the first departure from the safety states subset on $n^{(b)}$ observational posts (non-completed investigations, different observation times on all experimental posts)

Case 4.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flow (stream) on one experimental post

We assume that we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ at the operation state z_b, $b = 1,2,...,\nu$, on one experimental post. We assume that at the moment when the component is leaving the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ it is replaced at once by the same new component staying at the best safety state z. Moreover, we assume that the renewal process of the components is continuing during the observation time $\tau^{(b)}$, $\tau^{(b)} > 0,$ and that during this time $m_1^{(b)}(u) = m_1$, $m_1^{(b)}(u) < n^{(b)}$, components have left the safety states subset $\{u, u+1, ..., z\}$ and we mark by $t_i^{(b)}(u) = t_i$, $i = 1,2,..., m_1^{(b)}(u),$ (*Figure 5*) the moments of their departures from the safety states subsets, i.e. the realizations of the identical component lifetimes $T_i^{(b)}(u)$, $i = 1,2,..., m_1^{(b)}(u),$ to the first departure from the safety states subset $\{u, u+1, ..., z\}$, that are the independent random variables with the exponential distribution defined by the density function (7).

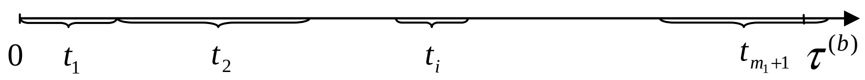

Figure 5. The scheme of the realizations of the component simple renewal flow (stream) on one experimental post

Case 5.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – The same observation time on all experimental posts

We assume that we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ at the operation state z_b, $b = 1,2,...,\nu$, on $n^{(b)}$ experimental posts. We assume that at the moment when the component is leaving the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ it is replaced at once by the same new component staying at the best reliability state z. Moreover, we assume that the renewal process of the components is continuing at all experimental posts during the same observation time $\tau^{(b)}$, $\tau^{(b)} > 0.$ We assume that during this time $m_k^{(b)}(u)$, $k = 1,2,..., n^{(b)}$, components at the *k*-th experimental post have left the safety states subset $\{u, u+1, ..., z\}$ and we mark by $[t_i^{(b)}(u)]^{(k)} = t_i^{(k)}$, $i = 1,2,..., m_k^{(b)}(u),$ (*Figure 6*) the moments of their departures from the safety states subsets, i.e. the realizations of the identical component lifetimes $[T_i^{(b)}(u)]^{(k)}$, $i = 1,2,..., m_k^{(b)}(u),$ to the first departure from the safety states subset $\{u, u+1, ..., z\}$, that are the independent random variables with the exponential distribution defined by the density function (7).

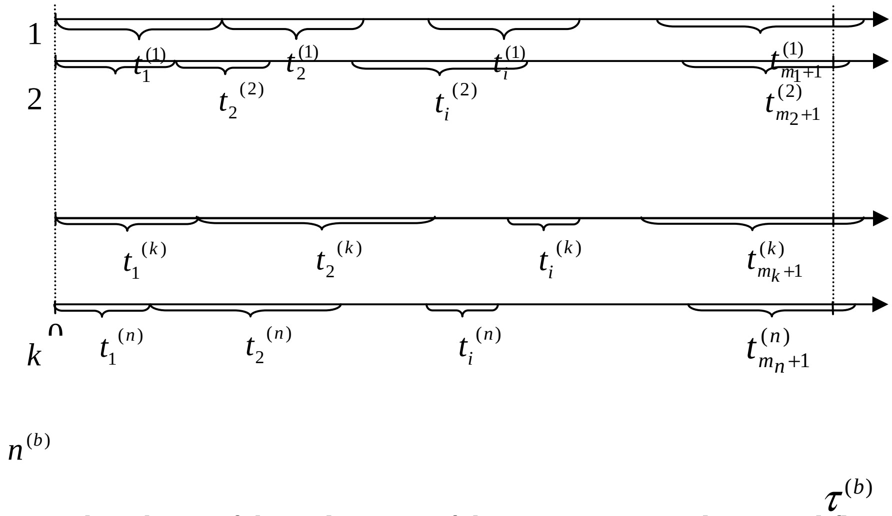

Figure 6. The scheme of the realizations of the component simple renewal flows (streams) on several experimental posts (the same observation time on all experimental posts)

Case 6.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – Different observation times on experimental posts

We assume that we are observing the realizations of the component lifetimes $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ at the operation state z_b, $b = 1,2,...,\nu$, on $n^{(b)}$ experimental posts. We assume that at the moment when the component is leaving the safety states subset $\{u, u+1, ..., z\}$, $u = 1,2,...,z,$ it is replaced at once by the same new component staying at the best safety state z. Moreover, we assume that the renewal process of the components is continuing at the *k*-th experimental post during the observation time $\tau_k^{(b)}$, $\tau_k^{(b)} > 0,$ $k = 1,2,...,n^{(b)}$. We assume that during this time $m_k^{(b)}(u)$, $k = 1,2,...,n^{(b)}$, components at the *k*-th experimental post have left the safety states subset $\{u, u+1, ..., z\}$ and we mark by $[t_i^{(b)}(u)]^{(k)} = t_i^{(k)}$, $i = 1,2,...,m_k^{(b)}(u),$ (*Figure 7*) the moments of their departures from the safety states subsets, i.e. the realizations of the identical component lifetimes $[T_i^{(b)}(u)]^{(k)}$, $i = 1,2,...,m_k^{(b)}(u),$ to the first departure from the safety states subset $\{u, u+1, ..., z\}$, that are the independent random variables with the exponential distribution defined by the density function (7).

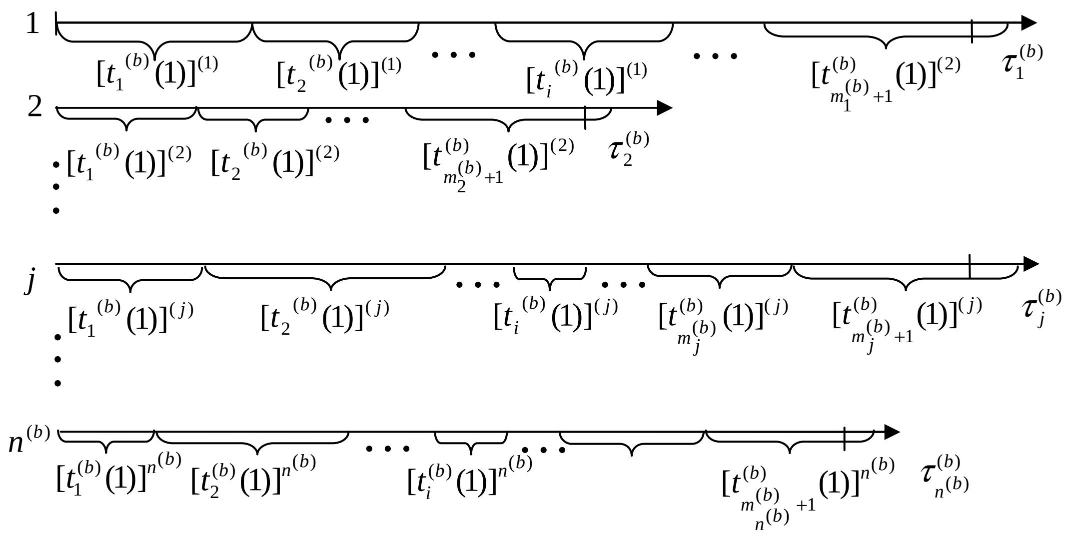

Figure 7. The scheme of the realizations of the component simple renewal flows (streams) on several experimental posts (different observation times on experimental posts)

3.4. Procedures of evaluating the system components unknown intensities of departure from the safety state subsets

3.4.1. Data coming from experts

On the basis of the approximate values

$$[\hat{\mu}(u)]^{(b)}, \; u = 1,2,...,z, \; b = 1,2,...,\nu,$$

of the mean values

$$[\mu(u)]^{(b)} = E[T(u)]^{(b)}, \; u = 1,2,...,z, \; b = 1,2,...,\nu,$$

of the system components lifetimes $[T(u)]^{(b)}$, $u = 1,2,...,z$, $b = 1,2,...,\nu$, in the safety states subsets $\{u, u+1,..., z\}$, $u = 1,2,...,z$, while the system is operating in the operation state z_b, $b = 1,2,...,\nu$, coming from experts and described in Section 3.3.1, we want to estimate the values $[\hat{\lambda}(u)]^{(b)}$ of the components unknown intensities $[\lambda(u)]^{(b)}$ of departure from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$, while the system is operating in the operation state z_b, $b = 1,2,...,\nu$. The formula for all system components is given by the following approximate equation

$$[\lambda(u)]^{(b)} \cong [\hat{\lambda}(u)]^{(b)} = \frac{1}{[\hat{\mu}(u)]^{(b)}}, \; u = 1,2,...,z, \quad (8)$$

$b = 1,2,...,\nu$.

3.4.2. Data coming from components safety states changing processes

On the basis of statistical data described in Section 3.3.2, we want to estimate the value of this unknown intensity of departure $[\hat{\lambda}(u)]^{(b)}$ from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$. The formulae for all considered kinds of experiments are presented below.

Case 1.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Completed investigations, the same observation time on all experimental posts

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{n^{(b)}}{\sum_{i=1}^{n^{(b)}} t_i^{(b)}(u)}, \; u = 1,2,...,z. \quad (9)$$

Case 2.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed

investigations, the same observation time on all experimental posts

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{m^{(b)}(u)}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + \tau^{(b)}[n^{(b)} - m^{(b)}(u)]}, \quad (10)$$

$u = 1,2,...,z.$

Assuming the observation time $\tau^{(b)}$ as the moment of departure from the safety states subset of the components that have not left this safety states subset we get so called a pessimistic evaluation of the intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset of the form

$$[\hat{\lambda}(u)]^{(b)} = \frac{n^{(b)}}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + \tau^{(b)}[n^{(b)} - m^{(b)}(u)]}, \quad (11)$$

$u = 1,2,...,z.$

Case 3.

The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component lifetimes up to the first departure from the safety states subset on several experimental posts – Non-completed investigations, different observation times on particular experimental posts

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{m^{(b)}(u)}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + \sum_{i=m^{(b)}(u)+1}^{n^{(b)}} \tau_i^{(b)}}, \quad (12)$$

$u = 1,2,...,z.$

Assuming the observation times $\tau_i^{(b)}$, $i = m_1^{(b)}(u), m_1^{(b)}(u)+1,...,n^{(b)}$, as the moment of departure from the safety states subset of the components that have not left this safety states subset we get so called a pessimistic evaluation of the intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset of the form

$$[\hat{\lambda}(u)]^{(b)} = \frac{n^{(b)}}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + \sum_{i=m^{(b)}(u)+1}^{n^{(b)}} \tau_i^{(b)}}, \quad (13)$$

$u = 1,2,...,z.$

Case 4.

The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flow (stream) on one experimental post

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{m^{(b)}(u)}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + d^{(b)}(u)}, \; u = 1,2,...,z, \quad (14)$$

where

$$d^{(b)}(u) = \\ = \begin{cases} \tau^{(b)} - \sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(1) & if \;\; m^{(b)}(u) = m^{(b)} \\ 0 \quad if \;\; m^{(b)}(u) = m^{(b)} + 1, & u = 1,2,...,z. \end{cases} \quad (15)$$

In the case if $m^{(b)}(u) = m^{(b)}$, $u = 1,2,...,z,$ after assuming the observation time $\tau^{(b)}$ as the moment of departure from the safety states subset $\{u, u+1,...,z\}$, $u = 1,2,...,z,$ of the last component that has not left this safety states subset we get so called a pessimistic evaluation of the intensity of departure $[\lambda(u)]^{(b)}$ from the afety states subset $\{u, u+1,...,z\}$, $u = 1,2,...,z,$ of the form

$$[\hat{\lambda}(u)]^{(b)} = \frac{m^{(b)} + 1}{\sum_{i=1}^{m^{(b)}(u)} t_i^{(b)}(u) + d^{(b)}(u)}, \; u = 1,2,...,z. \quad (16)$$

Case 5.

The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – The same observation time on all experimental posts

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{\sum_{j=1}^{n^{(b)}} m_j^{(b)}(u)}{\sum_{j=1}^{n^{(b)}} \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(u)]^j + \sum_{j=1}^{n^{(b)}} d_j^{(b)}(u)}, \quad (17)$$

$u = 1,2,...,z,$

where for $j = 1,2,...,n^{(b)}$

$$d_j^{(b)}(u) = \begin{cases} \tau^{(b)} - \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(1)]^{(j)} & if \ m_j^{(b)}(u) = m_j^{(b)} \\ 0 \quad if \ m_j^{(b)}(u) = m_j^{(b)} + 1, \ u = 1,2,...,z. \end{cases} \quad (18)$$

In the case if there exist j, $j \in \{1,2,...,n^{(b)}\}$, such that $m_j^{(b)}(u) = m_j^{(b)}$, $u = 1,2,...,z$, assuming the observation time $\tau^{(b)}$ as the moment of departures from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$, of the last components on all experimental posts that have not left this safety states subset we get so called pessimistic evaluation of the intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$, of the form

$$[\hat{\lambda}(u)]^{(b)} = \frac{\sum_{j=1}^{n^{(b)}} m_j^{(b)} + n^{(b)}}{\sum_{j=1}^{n^{(b)}} \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(u)]^j + \sum_{j=1}^{n^{(b)}} d_j^{(b)}(u)}, \quad (19)$$

Case 6.
The estimation of the component intensity of departure from the safety states subset on the basis of the realizations of the component simple renewal flows (streams) on several experimental posts – Different observation times on experimental posts

In this case, the maximum likelihood evaluation of the unknown component intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset is

$$[\hat{\lambda}(u)]^{(b)} = \frac{\sum_{j=1}^{n^{(b)}} m_j^{(b)}(u)}{\sum_{j=1}^{n^{(b)}} \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(u)]^j + \sum_{j=1}^{n^{(b)}} \bar{d}_j^{(b)}(u)}, \quad (20)$$

$u = 1,2,...,z,$

where for $j = 1,2,...,n^{(b)}$

$$\bar{d}_j^{(b)}(u) = \begin{cases} \tau_j^{(b)} - \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(1)]^{(j)} & if \ m_j^{(b)}(u) = m_j^{(b)} \\ 0 \quad if \ m_j^{(b)}(u) = m_j^{(b)} + 1, \ u = 1,2,...,z. \end{cases} \quad (21)$$

In the case if there exist j, $j \in \{1,2,...,n^{(b)}\}$, such that $m_j^{(b)}(u) = m_j^{(b)}$, $u = 1,2,...,z$, assuming the observation times $\tau_j^{(b)}$, $j = 1,2,...,n^{(b)}$, as the moments of departures from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$, of the last components on experimental posts that have not left this safety states subset we get so called a pessimistic evaluation of the intensity of departure $[\lambda(u)]^{(b)}$ from the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,...,z$, of the form

$$[\hat{\lambda}(u)]^{(b)} = \frac{\sum_{j=1}^{n^{(b)}} m_j^{(b)} + n^{(b)}}{\sum_{j=1}^{n^{(b)}} \sum_{i=1}^{m_j^{(b)}(u)} [t_i^{(b)}(u)]^j + \sum_{j=1}^{n^{(b)}} \bar{d}_j^{(b)}(u)}, \quad (22)$$

$u = 1,2,...,z.$

3.5. Procedure of identifying the system components conditional multistate exponential safety functions

To formulate and next to verify the non-parametric hypothesis concerning the exponential form of the coordinate

$$[s(t,u)]^{(b)} = \exp[-[\lambda(u)]^{(b)} t] \text{ for } t \in <0, \infty),$$

$u = 1,2,...,z, \ b = 1,2,...,v.$

of the vector

$$[s(t, \cdot)]^{(b)} = [1, [s(t,1)]^{(b)}, ..., [s(t,z)]^{(b)}],$$

of the conditional multistate safety function of the system component when the system is at the operation state z_b, $b = 1,2,...,v$, it is necessary to act according to the scheme below:

- to fix the numbers $n^{(b)}$ of realizations of the system component conditional lifetimes $T^{(b)}(u)$, $b = 1,2,...,v$, in the saety states subsets $\{u, u+1,..., z\}$, $u = 1,2,...,z$,
- to fix the realizations $t_1^{(b)}(u)$, $t_2^{(b)}(u)$, …, $t_n^{(b)}(u)$, $u = 1,2,...,z$, of the system component conditional

lifetimes $T^{(b)}(u)$, $b = 1,2,...,\nu$, in the safety states subsets $\{u, u+1,..., z\}$, $u = 1,2,..., z$,

- to determine the number $\bar{r}^{(b)}$ of the disjoint intervals $I_j^{(b)} =< x_j^{(b)}, y_j^{(b)})$, $j = 1,2,...,\bar{r}^{(b)}$, that include the realizations $t_1^{(b)}(u),\ t_2^{(b)}(u),\ \ldots,\ t_n^{(b)}(u)$ of the system component conditional lifetimes $T^{(b)}(u)$ in the safety states subset, according to the formula

$$\bar{r}^{(b)} \cong \sqrt{n^{(b)}},$$

- to determine the length $d^{(b)}$ of the intervals $I_j^{(b)} =< x_j^{(b)}, y_j^{(b)})$, $j = 1,2,...,\bar{r}^{(b)}$, according to the formula

$$d^{(b)} = \frac{\bar{R}^{(b)}}{\bar{r}^{(b)} - 1},$$

where

$$\bar{R}^{(b)} = \max_{1 \le i \le n} t_i^{(b)}(u) - \min_{1 \le i \le n} t_i^{(b)}(u),$$

- to determine the ends $x_j^{(b)}$, $y_j^{(b)}$, of the intervals $I_j^{(b)} =< x_j^{(b)}, y_j^{(b)})$, $j = 1,2,...,\bar{r}^{(b)}$, according to the formulae

$$x_1^{(b)} = \max\{\min_{1 \le i \le n} t_i^{(b)}(u) - \frac{d^{(b)}}{2}, 0\},$$

$$y_j^{(b)} = x_1^{(b)} + jd^{(b)}, \quad j = 1,2,...,\bar{r}^{(b)},$$

$$x_j^{(b)} = y_{j-1}^{(b)}, \quad j = 2,3,...,\bar{r}^{(b)},$$

in the way such that

$$I_1^{(b)} \cup I_2^{(b)} \cup ... \cup I_{\bar{r}}^{(b)} =< x_1^{(b)}, y_{\bar{r}^{(b)}}^{(b)}),$$

and

$$I_i^{(b)} \cap I_j^{(b)} = \emptyset \text{ for all } i \neq j,\ i, j \in \{1,2,...,\bar{r}^{(b)}\},$$

- to determine the numbers of realizations $n_j^{(b)}$ in particular intervals $I_j^{(b)}$, $j = 1,2,...,\bar{r}^{(b)}$, according to the formula

$$n_j^{(b)} = \#\ \{i : t_i^{(b)}(u) \in I_j^{(b)}, i \in \{1,2,...,n\}\},$$

$$j = 1,2,...,\bar{r}^{(b)},$$

where

$$\sum_{j=1}^{\bar{r}} n_j^{(b)} = n^{(b)},$$

whereas the symbol # means the number of elements of a set,

- to evaluate the value of the unknown intensity of the component departure $\lambda^{(b)}(u)$, from the safety states subset, applying suitable formula from Section 3.4.2,

- to construct and to plot the realization of the histogram of the conditional system component lifetime $T^{(b)}(u)$, $b = 1,2,...,\nu$, in the safety states subset $\{u, u+1,..., z\}$, $u = 1,2,..., z$, at the system operation state z_b, $b = 1,2,...,\nu$,

$$\bar{f}_n^{(b)}(t,u) = \frac{n_j^{(b)}}{n^{(b)}} \text{ for } t \in I_j^{(b)},$$

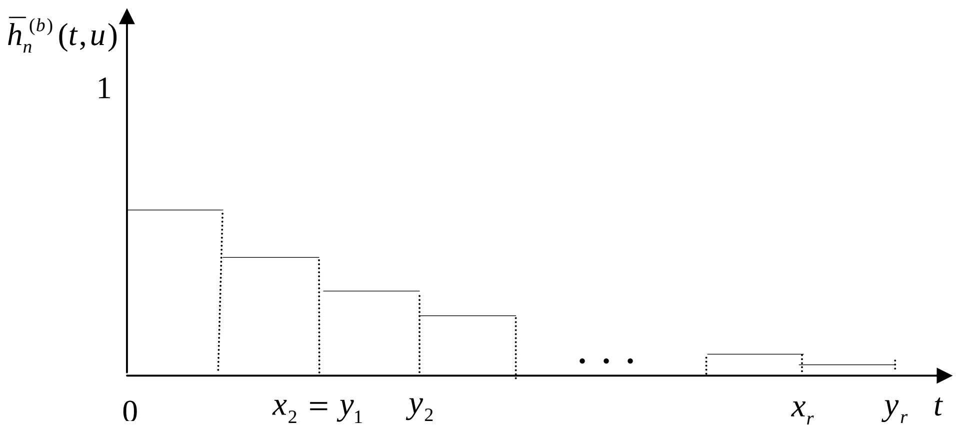

Figure 8. The realization of the histogram of the conditional system component lifetime in the safety states subset

- to analyze the realization of the histogram, comparing it with the graph of the exponential density function

$$[f(t,u)]^{(b)} = [\lambda(u)]^{(b)} \exp[-[\lambda(u)]^{(b)} t]$$

for $t \in <0, \infty)$,

of the system component lifetime $T^{(b)}(u)$ in the safety states subset $\{u, u+1, ..., z\}$ at the operation state z_b, corresponding the safety function coordinate (20) of the vector of the conditional multistate safety function of the system component (21) and to formulate the null hypothesis H_0 and the alternative hypothesis H_A, concerned with the form of the component multistate safety $[s(t,\cdot)]^{(b)}$ in the following form:

H_0 : The conditional multistate safety function of the system component

$$[s(t,\cdot)]^{(b)} = [1, [s(t,1)]^{(b)}, ..., [s(t,z)]^{(b)}],$$

has the exponential safety functions coordinates of the form

$$[s(t,u)]^{(b)} = \exp[-[\lambda(u)]^{(b)} t] \text{ for } t \in <0, \infty),$$

H_A : The conditional multistate safety function of the system component has different from the exponential safety functions coordinates,

- to join each of the intervals $I_j^{(b)}$, that has the number $n_j^{(b)}$ of realizations less than 4 either with the neighbor interval $I_{j+1}^{(b)}$ or with the neighbor interval $I_{j-1}^{(b)}$, this way that the numbers of realizations in all intervals are not less than 4,

- to fix a new number of intervals

$$\bar{\bar{r}}^{(b)},$$

- to determine new intervals

$$\bar{I}_j^{(b)} = <\bar{x}_j^{(b)}, \bar{y}_j^{(b)}), \quad j = 1,2,..,\bar{\bar{r}}^{(b)},$$

- to fix the numbers $\bar{n}_j^{(b)}$ of realizations in new intervals $\bar{I}_j^{(b)}$, $j = 1,2,..,\bar{\bar{r}}^{(b)}$,

- to calculate the hypothetical probabilities that the variable $T^{(b)}(u)$ takes values from the interval $\bar{I}_j^{(b)}$, under the assumption that the hypothesis H_0 is true, i.e. the probabilities

$$p_j^{(b)} = P(T^{(b)}(u) \in \bar{I}_j^{(b)}) = P(\bar{x}_j^{(b)} \le T^{(b)}(u) < \bar{y}_j^{(b)})$$

$$= s^{(b)}(\bar{x}_j, u) - s^{(b)}(\bar{y}_j, u), \quad j = 1,2,...,\bar{\bar{r}}^{(b)},$$

where $s^{(b)}(\bar{x}_j, u)$ and $s^{(b)}(\bar{y}_j, u)$ are the values of the coordinate safety function $s^{(b)}(t,u)$ of the multistate safety function defined in the null hypothesis H_0,

- to calculate the realization of the χ^2 (*chi-square*)-Pearson's statistics U_n, according to the formula

$$u_n^{(b)} = \sum_{j=1}^{\bar{\bar{r}}} \frac{(\bar{n}_j^{(b)} - n^{(b)} p_j^{(b)})^2}{n^{(b)} p_j^{(b)}},$$

- to assume the significance level α ($\alpha = 0.01$, $\alpha = 0.02$, $\alpha = 0.05$ or $\alpha = 0.10$) of the test,

- to fix the number $\bar{\bar{r}}^{(b)} - l - 1$ of degrees of freedom, substituting $l = 1$,

- to read from the Tables of the χ^2 – Pearson's distribution the value u_α for the fixed values of the significance level α and the number of degrees of freedom $\bar{\bar{r}} - l - 1$ such that the following equality holds

$$P(U_n > u_\alpha) = 1 - \alpha,$$

and next to determine the critical domain in the form of the interval $(u_\alpha, +\infty)$ and the acceptance domain in the form of the interval $< 0, u_\alpha >$,

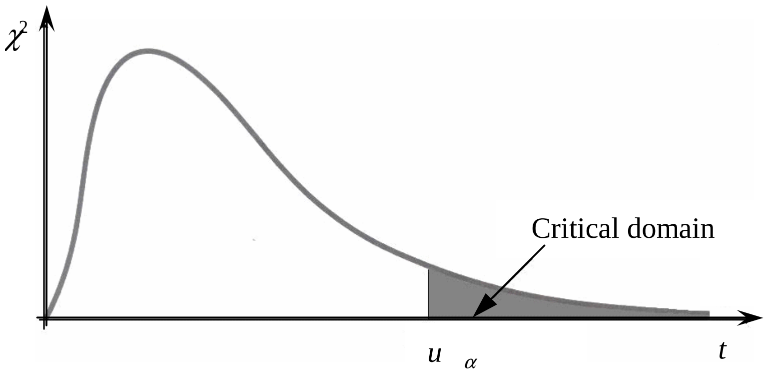

Figure 9. The graphical interpretation of the critical interval and the acceptance interval for the chi-square goodness-of-fit test

- to compare the obtained value u_n of the realization of the statistics U_n with the read from the Tables critical value u_α of the chi-square random variable and to verify previously formulated the null hypothesis H_0 in the following way: if the value u_n does not belong to the critical domain, i.e. when $u_n \le u_\alpha$, then we do not reject the hypothesis H_0, otherwise if the value u_n belongs to the critical domain, i.e. when $u_n > u_\alpha$, then we reject the hypothesis H_0 in favor of the hypothesis H_A.

4. Procedure of applying the computer program for identification of the system components safety models

Training material is given in [4].

5. Identification of the components safety models of real complex technical systems – using procedures

5.1. Statistical identification of the Stena Baltic ferry technical system components safety models

5.1.1. The subsystems and components of the Stena Baltic ferry technical system in various operation states

We assume that the ship is composed of a number of main subsystems having an essential influence on its safety. These subsystems are illustrated in *Figure10* and *Figure11*.

On the scheme of the ship presented in *Figure 10*, there are distinguished her following subsystems:

S_1 - a navigational subsystem,

S_2 - a propulsion and controlling subsystem,

S_3 - a loading and unloading subsystem,

S_4 - a hull subsystem,

S_5 - an anchoring and mooring subsystem,

S_6 - a protection and rescue subsystem,

S_7 - a social subsystem.

In our further ship safety analysis we will omit the protection and rescue subsystem S_6 and the social subsystem S_7 and we will consider its strictly technical subsystems S_1, S_2, S_3, S_4 and S_5 only.

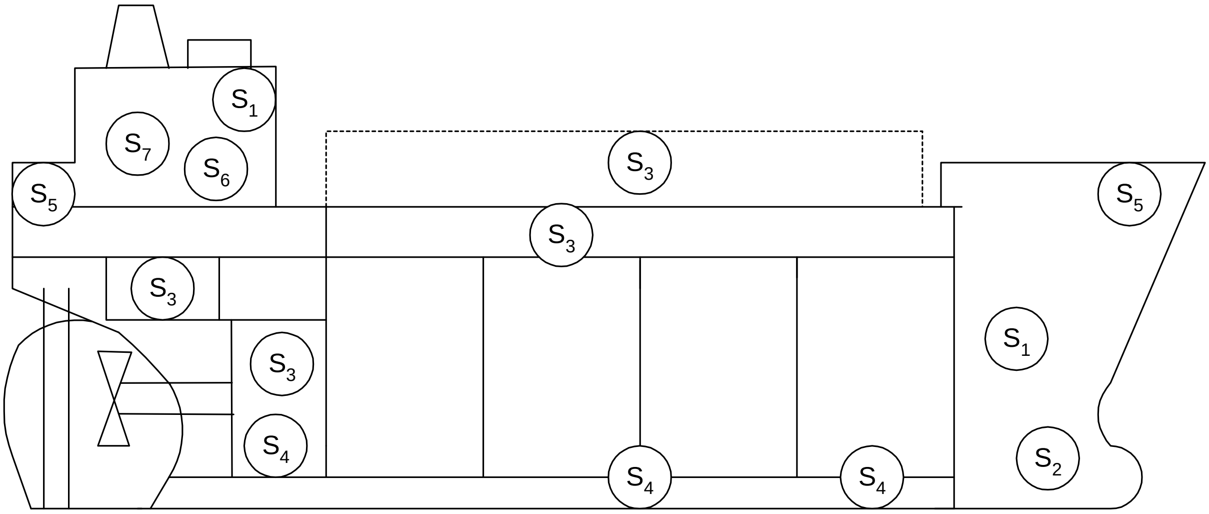

Figure 10. Subsystems having an essential influence on ship safety

The navigational subsystem S_1 is equipment of: GPS, AIS, speed log, gyrocompass, magnetic compass, echo sounding system, paper and electronic charts, radar, ARPA, communication system and other subsystems according to SOLAS-V convention, and is denoted by

$$E_{ij}^{(1)}, \ i=1, \ \ j=1.$$

The propulsion and controlling subsystem S_2 is composed of :

- subsystem S_{21} which consist of 4 main engines,
- subsystem S_{22} which consist of 3 thrusts,
- subsystem S_{23} which consist of twin patch propellers,
- subsystem S_{24} which consist of twin directional rudders,

and elements of subsystem S_2 are denoted respectively by

$$E_{ij_i}^{(2)}, \ i=1,2,3,4,5,6,7,$$

$$j_1=4, \ j_2=2, \ j_3=1, \ j_4=1, \ j_5=1, \ j_6=1, \ j_7=1.$$

The loading and unloading subsystem S_3 is composed of :

- subsystem S_{31} which consist of 2 remote upper trailer decks to main deck,
- subsystem S_{32} which consist of 1 remote fore car deck to main deck,
- subsystem S_{33} which consist of passenger gangway to Gdynia Terminal,
- subsystem S_{34} which consist of passenger gangway to Karlskrona Terminal,

and elements of subsystem S_3 are denoted respectively by

$$E_{ij}^{(3)}, \ i=1,2,3,4,5, \ \ j=1.$$

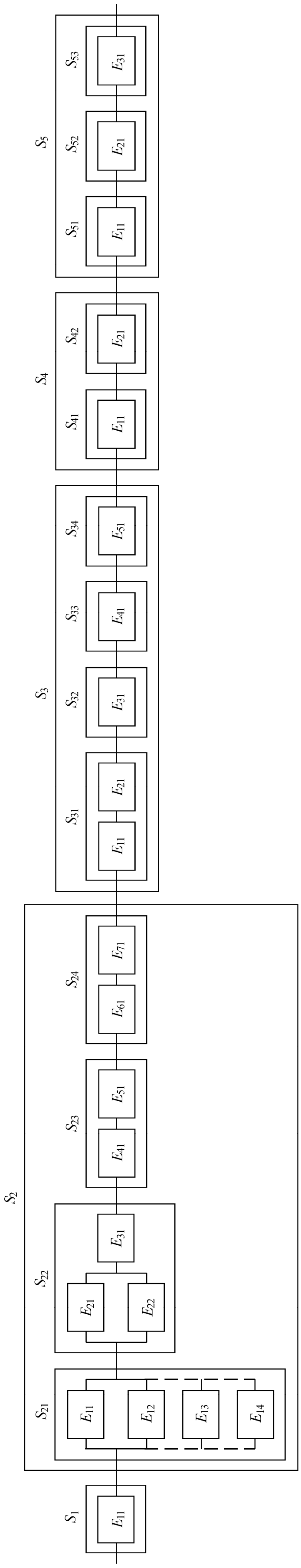

Figure 11. Detailed scheme of ship safety structure

The hull subsystem S_4 is composed of :

- subsystem S_{41} which consist of an anti-heeling system, which is used in port during loading operations,
- subsystem S_{42} which consist of an anti-heeling system, which is used at sea to stabilizing ships rolling

and elements of subsystem S_4 are denoted respectively by

$$E_{ij}^{(4)}, \; i = 1,2, \;\; j = 1.$$

The anchoring and mooring subsystem S_5 is composed of :

- subsystem S_{51} which consist of aft mooring winches,
- subsystem S_{52} which consist of fore mooring and anchor winches,
- subsystem S_{53} which consist of fore mooring winches,

and elements of subsystem S_5 are denoted respectively by

$$E_{ij}^{(5)}, \; i = 1,2,3, \;\; j = 1.$$

The subsystems S_1, S_2, S_3, S_4, S_5, indicated in *Figure 10* are forming a general system structures presented in *Figure 12.*

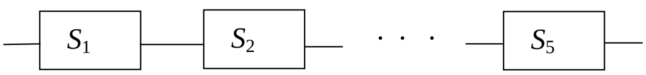

Figure 12. General scheme of ship safety structure

However, the Stena Baltica ferry structure and the subsystems and components safety depend on its changing in time operation states.

Taking into account the expert opinion on the operation process of the considered Stena Baltica ferry we fix the number of the ferry operation process states $\nu = 18$ and we distinguish the following as its eighteen operation states:

- an operation state z_1 – loading at Gdynia Port,
- an operation state z_2 – unmooring operations at Gdynia Port,
- an operation state z_3 – leaving Gdynia Port and navigation to “GD” buoy,
- an operation state z_4 – navigation at restricted waters from “GD” buoy to the end of Traffic Separation Scheme,
- an operation state z_5 – navigation at open waters from the end of Traffic Separation Scheme to “Angoring” buoy,
- an operation state z_6 – navigation at restricted waters from “Angoring” buoy to “Verko” Berth at Karlskrona,
- an operation state z_7 – mooring operations at Karlskrona Port,
- an operation state z_8 – unloading at Karlskrona Port,
- an operation state z_9 – loading at Karlskrona Port,
- an operation state z_{10} – unmooring operations at Karlskrona Port,
- an operation state z_{11} – ship turning at Karlskrona Port,
- an operation state z_{12} – leaving Karlskrona Port and navigation at restricted waters to “Angoring” buoy,
- an operation state z_{13} – navigation at open waters from “Angoring” buoy to the entering Traffic Separation Scheme,
- an operation state z_{14} – navigation at restricted waters from the entering Traffic Separation Scheme to “GD” buoy,
- an operation state z_{15} – navigation from “GD” buoy to turning area,
- an operation state z_{16} – ship turning at Gdynia Port,
- an operation state z_{17} – mooring operations at Gdynia Port,
- an operation state z_{18} – unloading at Gdynia Port.

At the operation states z_1, i.e. at the cargo loading and un-loading state the ferry is built of $n_1 = 2$ subsystems S_3 and S_4 forming a series structure shown in *Figure 13*.

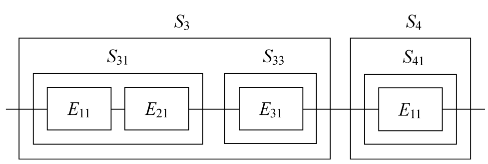

Figure 13. The scheme of the ferry structure at the operation state z_1

At the operation states z_2, i.e. at the unmooring operations state the ferry is built of $n_2 = 3$ subsystems S_1, S_2 and S_5 forming a series structure shown in *Figure 14*.

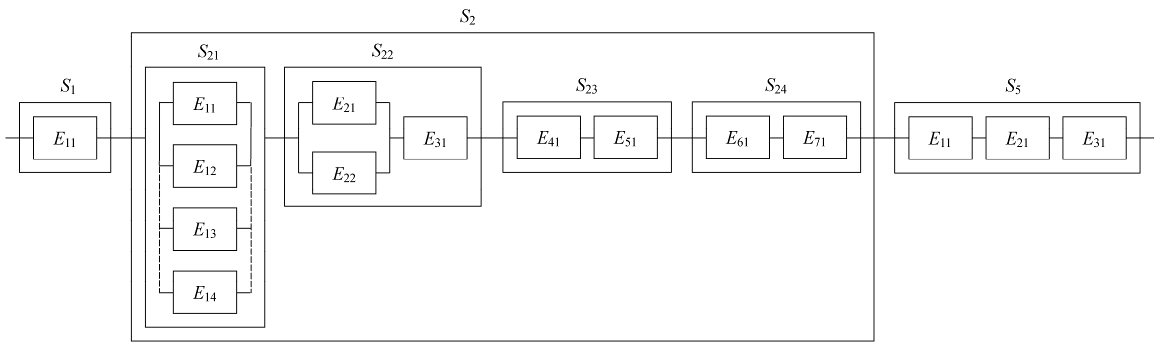

Figure 14. The scheme of the ferry structure at the operation state z_2

At the operation states z_3, i.e. at the leaving Gdynia Port state the ferry is built of $n_3 = 2$ subsystems S_1 and S_2 forming a series structure shown in *Figure 15*.

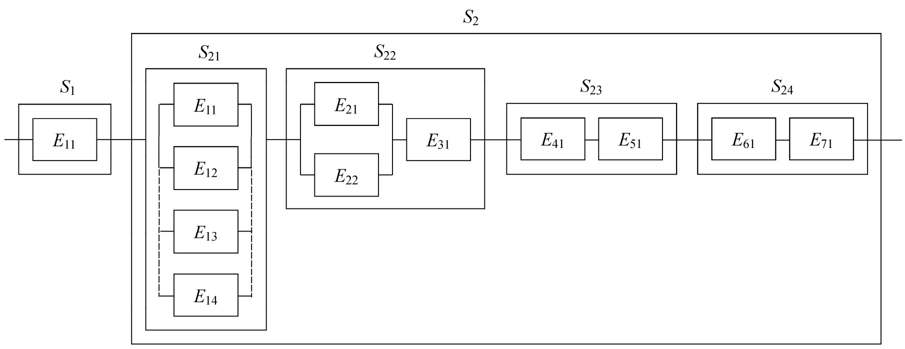

Figure 15. The scheme of the ferry structure at the operation state z_3

At the operation states z_4, i.e. at the navigation at restricted waters state the ferry is built of $n_4 = 3$ subsystems S_1, S_2 and S_4 forming a series structure shown in *Figure 16*.

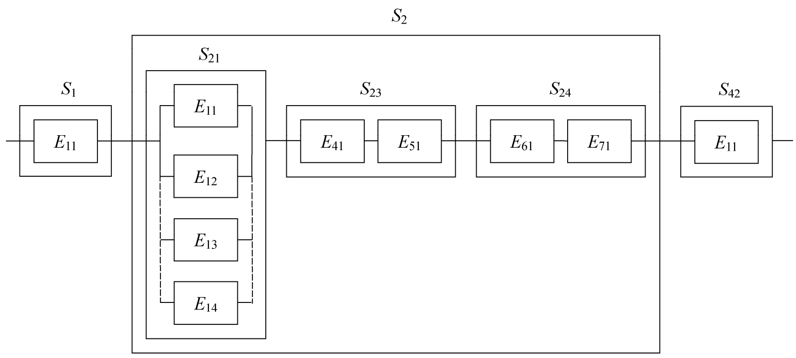

Figure 16. The scheme of the ferry structure at the operation state z_4

At the operation state z_5, i.e. at the navigation at open waters state the ferry is built of $n_5 = 3$ subsystems S_1, S_2 and S_4 forming a series-parallel structure shown in *Figure 17*.

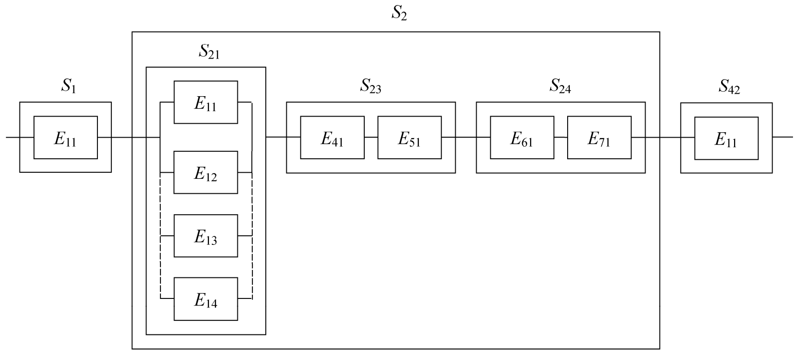

Figure 17. The scheme of the ferry structure at the operation state z_5

At the operation state z_6, i.e. at the navigation at restricted waters state the ferry is built of $n_6 = 3$ subsystems S_1, S_2 and S_4 forming a series structure shown in *Figure 18*.

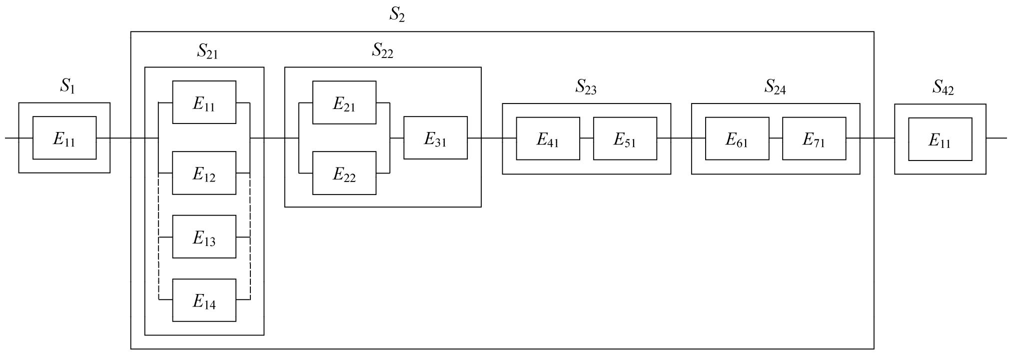

Figure 18. The scheme of the ferry structure at the operation state z_6

At the operation state z_7, i.e. at the mooring operations state the ferry is built of $n_7 = 3$ subsystems S_1, S_2 and S_5 forming a series structure shown in *Figure 19*.

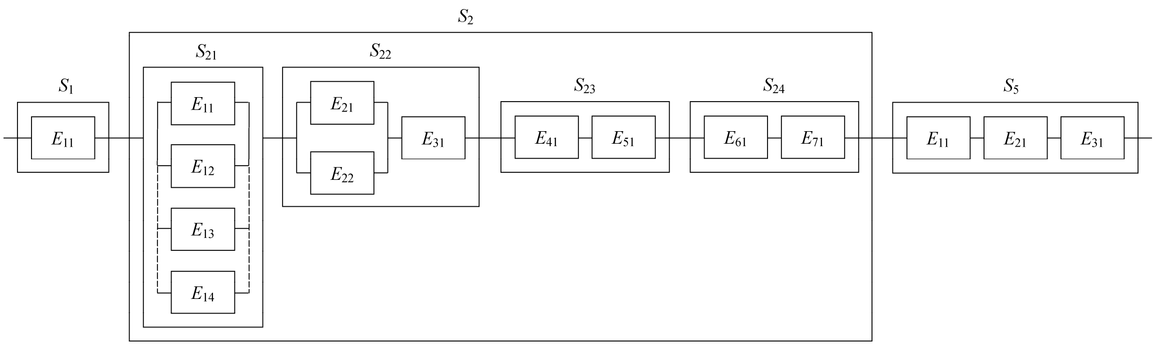

Figure 19. The scheme of the ferry structure at the operation state z_7

At the operation state z_8, i.e. at the unloading at Karlskrona Port state the ferry is built of $n_8 = 2$ subsystems S_3 and S_4 forming a series structure shown in *Figure 20.*

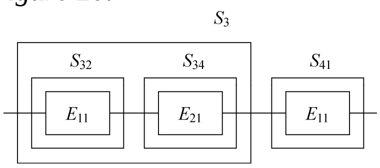

Figure 20. The scheme of the ferry structure at the operation state z_8

At the operation state z_9, i.e. at the unloading at Karlskrona Port state the ferry is built of $n_9 = 2$ subsystems S_3 and S_4 forming a series structure shown in *Figure 21*.

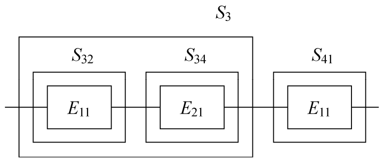

Figure 21. The scheme of the ship structure at the operation state z_9

At the operation state z_{10}, i.e. at the unmooring operations state the ferry is built of $n_{10} = 3$ subsystems S_1, S_2 and S_5 forming a series structure shown in *Figure 22*.

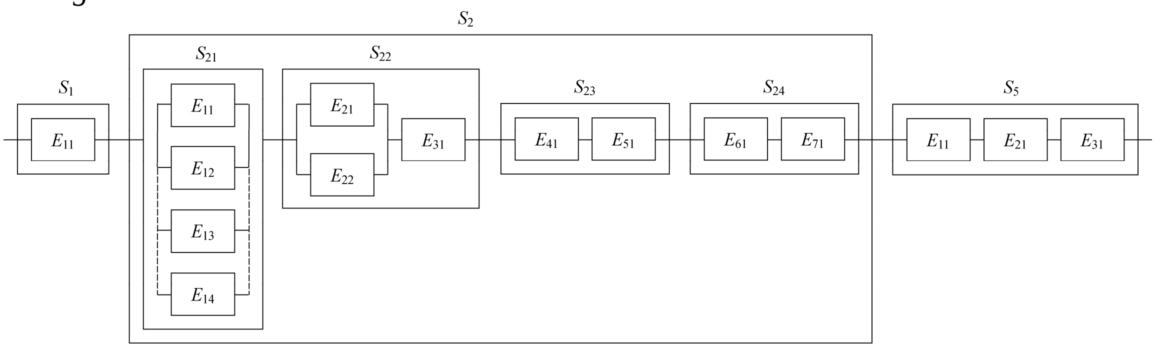

Figure 22. The scheme of the ferry structure at the operation state z_{10}

At the operation states z_{11}, i.e. at the ship turning state the ferry is built of $n_{11} = 2$ subsystems S_1 and S_2 forming a series structure shown in *Figure 23*.

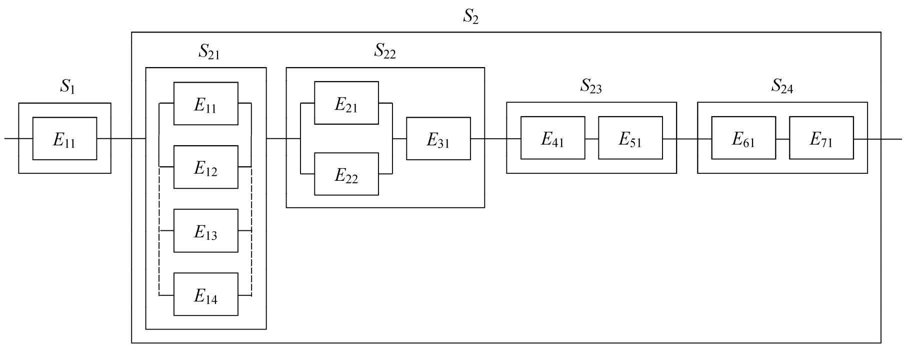

Figure 23. The scheme of the ferry structure at the operation state z_{11}

At the operation states z_{12}, i.e. at the leaving Karlskrona Port state the ferry is built of $n_{12} = 3$ subsystems S_1, S_2 and S_4 forming a series-parallel structure shown in *Figure 24*.

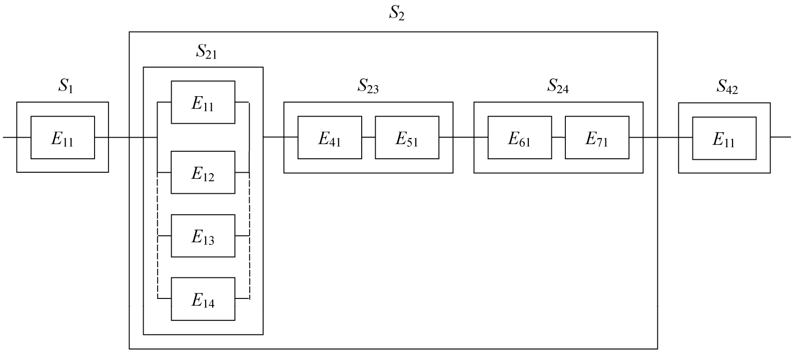

Figure 24. The scheme of the ferry structure at the operation state z_{12}

At the operation states z_{13}, i.e. at the navigation at open waters state the ferry is built of $n_{13} = 3$ subsystems S_1, S_2 and S_4 forming a series structure shown in *Figure 25*.

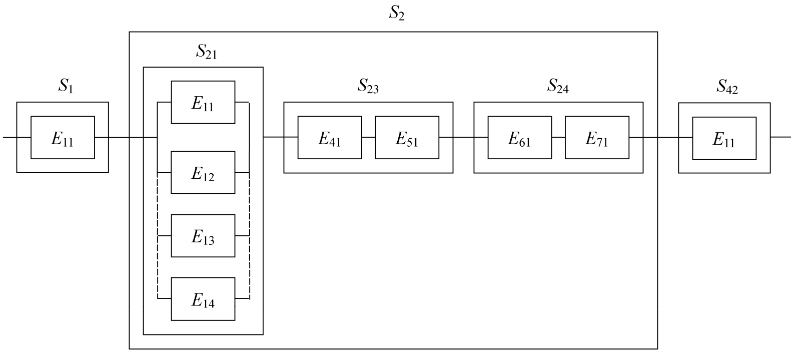

Figure 25. The scheme of the ferry structure at the operation state z_{13}

At the operation states z_{14}, i.e. at the navigation at restricted waters state the ferry is built of $n_{14} = 3$ subsystems S_1, S_2 and S_4 forming a series-parallel structure shown in *Figure 26*.

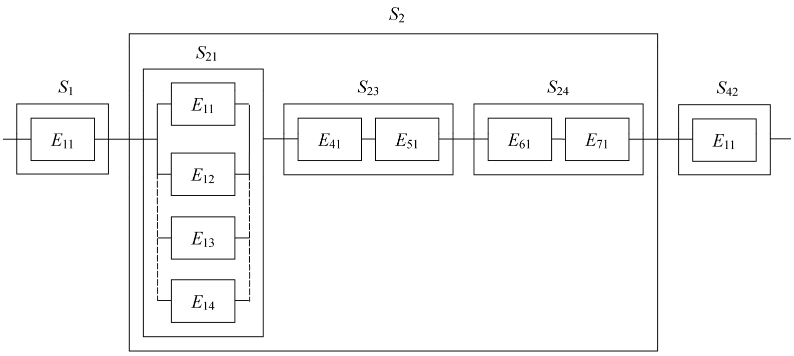

Figure 26. The scheme of the ferry structure at the operation state z_{14}

At the operation states z_{15}, i.e. at the navigation to turning area state the ferry is built of $n_{15} = 2$ subsystems S_1 and S_2 forming a series structure shown in *Figure 27*.

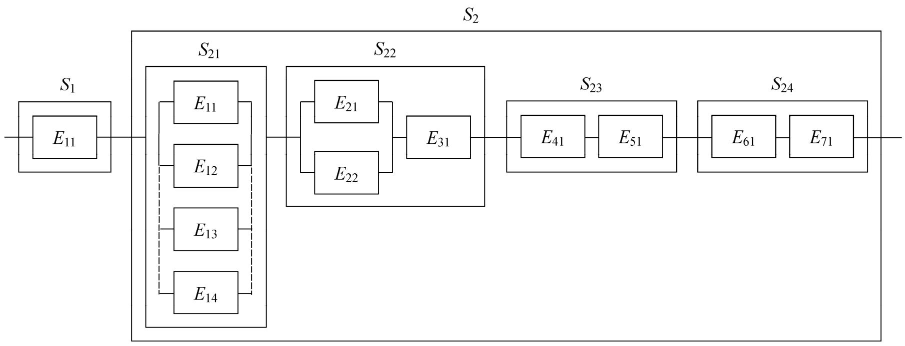

Figure 27. The scheme of the ferry structure at the operation state z_{15}

At the operation states z_{16}, i.e. at the ship turning state the ferry is built of $n_{16} = 2$ subsystems S_1 and S_2 forming a series structure shown in *Figure 28.*

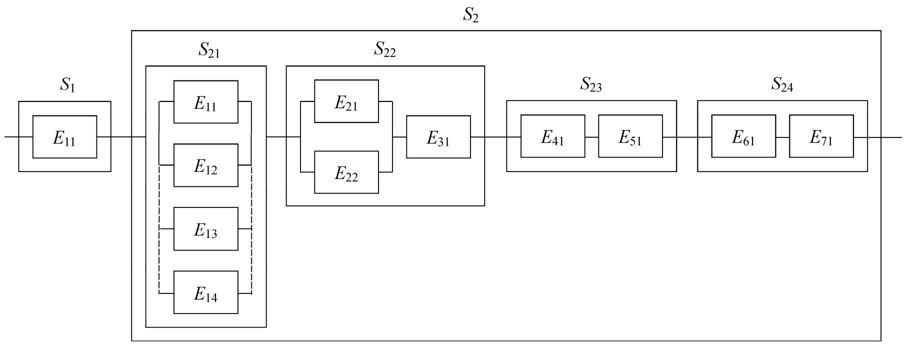

Figure 28. The scheme of the ferry structure at the operation state z_{16}

At the operation states z_{17}, i.e. at the mooring operations state the ferry is built of $n_{17} = 3$ subsystems S_1, S_2 and S_5 forming a series structure shown in *Figure 29*.

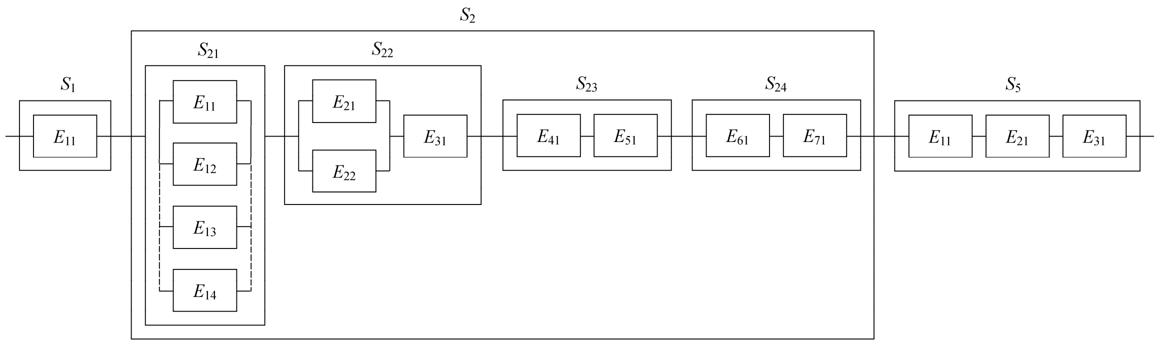

Figure 29. The scheme of the ferry structure at the operation state z_{17}

At the operation states z_{18}, i.e. at the unloading state the ferry is built of $n_{18} = 2$ subsystems S_3 and S_4 forming a series structure shown in *Figure 30.*

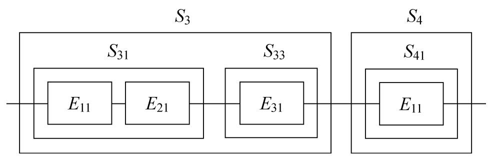

Figure 30. The scheme of the ferry structure at the operation state z_{18}

5.1.2. The parameters of the Stena Baltica ferry technical system components multi-state safety models

After discussion with experts, taking into account the safety of the operation of the Stena Baltica ferry, in all operation states z_b, $b = 1,2,...,18$, we distinguish the following five safety states ($z = 4$) of the ferry and her components:

- a safety state 4 – the ferry operation is fully safe,
- a safety state 3 – the ferry operation is less safe and more dangerous because of the possibility of environment pollution,
- a safety state 2 – the ferry operation is less safe and more dangerous because of the possibility of environment pollution and causing small accidents,
- a safety state 1 - the ferry operation is much less safe and much more dangerous because of the possibility of serious environment pollution and causing extensive accidents,
- a safety state 0 – ferry is destroyed.

Moreover, we fix that there are possible the transitions between the components safety states only from better to worse ones.

From the above, the ferry subsystems S_k, $k = 1,2,...,5$, are compoed of five-state i.e. z = 4, components, $E_{ij}^{(k)}$, $k = 1,2,3,4,5$, with the conditional multi-state safety functions

$$[s_{ij}^{(k)}(t,\cdot)]^{(b)} = [1, [s_{ij}^{(k)}(t,1)]^{(b)}, [s_{ij}^{(k)}(t,2)]^{(b)}, [s_{ij}^{(k)}(t,3)]^{(b)}, [s_{ij}^{(k)}(t,4)]^{(b)}], \ b = 1,2,...,18,$$

with exponential co-ordinates $[s_{ij}^{(k)}(t,1)]^{(b)}$, $[s_{ij}^{(k)}(t,2)]^{(b)}$, $[s_{ij}^{(k)}(t,3)]^{(b)}$ and $[R_{ij}^{(k)}(t,4)]^{(b)}$ different in various operation states z_b, $b = 1,2,...,18$.

More precisely, from the performed in Section 3.4.2 analysis, the unknown safety parameters of the system components safety models in various system operation states are:

i) at the system operation states z_1:

- the reliability functions of the subsystem S_3 components

for component $E_{11}^{(3)}$

$$[s_{11}^{(3)}(t,\cdot)]^{(1)} = [1, [s_{11}^{(3)}(t,1)]^{(1)}, [s_{11}^{(3)}(t,2)]^{(1)}, [s_{11}^{(3)}(t,3)]^{(1)}, [s_{11}^{(3)}(t,4)]^{(1)}],$$

coordinates

$$[s_{11}^{(3)}(t,1)]^{(1)} = \exp[-[\lambda_{11}^{(3)}(1)]^{(1)} t],$$

$$[s_{11}^{(3)}(t,2)]^{(1)} = \exp[-[\lambda_{11}^{(3)}(2)]^{(1)} t],$$

$$[s_{11}^{(3)}(t,3)]^{(1)} = \exp[-[\lambda_{11}^{(3)}(3)]^{(1)} t],$$

$$[s_{11}^{(3)}(t,4)]^{(1)} = \exp[-[\lambda_{11}^{(3)}(4)]^{(1)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(3)}(1)]^{(1)}, \ [\lambda_{11}^{(3)}(2)]^{(1)}, \ [\lambda_{11}^{(3)}(3)]^{(1)}, \ [\lambda_{11}^{(3)}(4)]^{(1)},$$

for component $E_{21}^{(3)}$

$$[s_{21}^{(3)}(t,\cdot)]^{(1)} = [1, [s_{21}^{(3)}(t,1)]^{(1)}, [s_{21}^{(3)}(t,2)]^{(1)}, [s_{21}^{(3)}(t,3)]^{(1)}, [s_{21}^{(3)}(t,4)]^{(1)}]$$

coordinates

$$[s_{21}^{(3)}(t,1)]^{(1)} = \exp[-[\lambda_{21}^{(3)}(1)]^{(1)} t],$$

$$[s_{21}^{(3)}(t,2)]^{(1)} = \exp[-[\lambda_{21}^{(3)}(2)]^{(1)} t],$$

$$[s_{21}^{(3)}(t,3)]^{(1)} = \exp[-[\lambda_{21}^{(3)}(3)]^{(1)} t],$$

$$[s_{21}^{(3)}(t,4)]^{(1)} = \exp[-[\lambda_{21}^{(3)}(4)]^{(1)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{21}^{(3)}(1)]^{(1)}, \ [\lambda_{21}^{(3)}(2)]^{(1)}, \ [\lambda_{21}^{(3)}(3)]^{(1)}, \ [\lambda_{21}^{(3)}(4)]^{(1)},$$

for component $E_{31}^{(3)}$

$$[s_{31}^{(3)}(t,\cdot)]^{(1)} = [1, [s_{31}^{(3)}(t,1)]^{(1)}, [s_{31}^{(3)}(t,2)]^{(1)}, [s_{31}^{(3)}(t,3)]^{(1)}, [s_{31}^{(3)}(t,4)]^{(1)}]$$

coordinates

$$[s_{31}^{(3)}(t,1)]^{(1)} = \exp[-[\lambda_{31}^{(3)}(1)]^{(1)} t],$$

$$[s_{31}^{(3)}(t,2)]^{(1)} = \exp[-[\lambda_{31}^{(3)}(2)]^{(1)} t],$$

$$[s_{31}^{(3)}(t,3)]^{(1)} = \exp[-[\lambda_{31}^{(3)}(3)]^{(1)} t],$$

$$[s_{31}^{(3)}(t,4)]^{(1)} = \exp[-[\lambda_{31}^{(3)}(4)]^{(1)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{31}^{(3)}(1)]^{(1)}$, $[\lambda_{31}^{(3)}(2)]^{(1)}$, $[\lambda_{31}^{(3)}(3)]^{(1)}$, $[\lambda_{31}^{(3)}(4)]^{(1)}$,

- the reliability functions of the subsystem S_4 components

for component $E_{11}^{(4)}$

$$[s_{11}^{(4)}(t,\cdot)]^{(1)} = [1, [s_{11}^{(4)}(t,1)]^{(1)}, [s_{11}^{(4)}(t,2)]^{(1)}, [s_{11}^{(4)}(t,3)]^{(1)}, [s_{11}^{(4)}(t,4)]^{(1)}]$$

coordinates

$$[s_{11}^{(4)}(t,1)]^{(1)} = \exp[-[\lambda_{11}^{(4)}(1)]^{(1)} t],$$

$$[s_{11}^{(4)}(t,2)]^{(1)} = \exp[-[\lambda_{11}^{(4)}(2)]^{(1)} t],$$

$$[s_{11}^{(4)}(t,3)]^{(1)} = \exp[-[\lambda_{11}^{(4)}(3)]^{(1)} t],$$

$$[s_{11}^{(4)}(t,4)]^{(1)} = \exp[-[\lambda_{11}^{(4)}(4)]^{(1)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(4)}(1)]^{(1)}$, $[\lambda_{11}^{(4)}(2)]^{(1)}$, $[\lambda_{11}^{(4)}(3)]^{(1)}$, $[\lambda_{11}^{(4)}(4)]^{(1)}$,

ii) at the system operation states z_2:

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(2)} = [1, [s_{11}^{(1)}(t,1)]^{(2)}, [s_{11}^{(1)}(t,2)]^{(2)}, [s_{11}^{(1)}(t,3)]^{(2)}, [s_{11}^{(1)}(t,4)]^{(2)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(2)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(2)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(2)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(2)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(2)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(2)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(2)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(1)}(1)]^{(2)}$, $[\lambda_{11}^{(1)}(2)]^{(2)}$, $[\lambda_{11}^{(1)}(3)]^{(2)}$, $[\lambda_{11}^{(1)}(4)]^{(2)}$,

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{11}^{(2)}(t,1)]^{(2)}, [s_{11}^{(2)}(t,2)]^{(2)}, [s_{11}^{(2)}(t,3)]^{(2)}, [s_{11}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(2)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(2)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(2)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(2)}(1)]^{(2)}$, $[\lambda_{11}^{(2)}(2)]^{(2)}$, $[\lambda_{11}^{(2)}(3)]^{(2)}$, $[\lambda_{11}^{(2)}(4)]^{(2)}$,

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{12}^{(2)}(t,1)]^{(2)}, [s_{12}^{(2)}(t,2)]^{(2)}, [s_{12}^{(2)}(t,3)]^{(2)}, [s_{12}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{12}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(2)} t],$$

$$[s_{12}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(2)} t],$$

$$[s_{12}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(2)} t],$$

$$[s_{12}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{12}^{(2)}(1)]^{(2)}$, $[\lambda_{12}^{(2)}(2)]^{(2)}$, $[\lambda_{12}^{(2)}(3)]^{(2)}$, $[\lambda_{12}^{(2)}(4)]^{(2)}$,

for component $E_{13}^{(2)}$

$$[s_{13}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{13}^{(2)}(t,1)]^{(2)}, [s_{13}^{(2)}(t,2)]^{(2)}, [s_{13}^{(2)}(t,3)]^{(2)}, [s_{13}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{13}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(2)} t],$$

$$[s_{13}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(2)} t],$$

$$[s_{13}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(2)} t],$$

$$[s_{13}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{13}^{(2)}(1)]^{(2)},\ [\lambda_{13}^{(2)}(2)]^{(2)},\ [\lambda_{13}^{(2)}(3)]^{(2)},\ [\lambda_{13}^{(2)}(4)]^{(2)},$$

for component $E_{14}^{(2)}$

$$[s_{14}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{14}^{(2)}(t,1)]^{(2)}, [s_{14}^{(2)}(t,2)]^{(2)}, [s_{14}^{(2)}(t,3)]^{(2)}, [s_{14}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{14}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(2)} t],$$

$$[s_{14}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(2)} t],$$

$$[s_{14}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(2)} t],$$

$$[s_{14}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{14}^{(2)}(1)]^{(2)},\ [\lambda_{14}^{(2)}(2)]^{(2)},\ [\lambda_{14}^{(2)}(3)]^{(2)},\ [\lambda_{14}^{(2)}(4)]^{(2)},$$

for component $E_{21}^{(2)}$

$$[s_{21}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{21}^{(2)}(t,1)]^{(2)}, [s_{21}^{(2)}(t,2)]^{(2)}, [s_{21}^{(2)}(t,3)]^{(2)}, [s_{21}^{(2)}(t,4)]^{(2)}]$$

coordinates

$$[s_{21}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{21}^{(2)}(1)]^{(2)} t],$$

$$[s_{21}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{21}^{(2)}(2)]^{(2)} t],$$

$$[s_{21}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{21}^{(2)}(3)]^{(2)} t],$$

$$[s_{21}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{21}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{21}^{(2)}(1)]^{(2)},\ [\lambda_{21}^{(2)}(2)]^{(2)},\ [\lambda_{21}^{(2)}(3)]^{(2)},\ [\lambda_{21}^{(2)}(4)]^{(2)},$$

for component $E_{22}^{(2)}$

$$[s_{22}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{22}^{(2)}(t,1)]^{(2)}, [s_{22}^{(2)}(t,2)]^{(2)}, [s_{22}^{(2)}(t,3)]^{(2)}, [s_{22}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{22}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{22}^{(2)}(1)]^{(2)} t],$$

$$[s_{22}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{22}^{(2)}(2)]^{(2)} t],$$

$$[s_{22}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{22}^{(2)}(3)]^{(2)} t],$$

$$[s_{22}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{22}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{22}^{(2)}(1)]^{(2)},\ [\lambda_{22}^{(2)}(2)]^{(2)},\ [\lambda_{22}^{(2)}(3)]^{(2)},\ [\lambda_{22}^{(2)}(4)]^{(2)},$$

for component $E_{31}^{(2)}$

$$[s_{31}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{31}^{(2)}(t,1)]^{(2)}, [s_{31}^{(2)}(t,2)]^{(2)}, [s_{31}^{(2)}(t,3)]^{(2)}, [s_{31}^{(2)}(t,4)]^{(2)}]$$

coordinates

$$[s_{31}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{31}^{(2)}(1)]^{(2)} t],$$

$$[s_{31}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{31}^{(2)}(2)]^{(2)} t],$$

$$[s_{31}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{31}^{(2)}(3)]^{(2)} t],$$

$$[s_{31}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{31}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{31}^{(2)}(1)]^{(2)},\ [\lambda_{31}^{(2)}(2)]^{(2)},\ [\lambda_{31}^{(2)}(3)]^{(2)},\ [\lambda_{31}^{(2)}(4)]^{(2)},$$

for component $E_{41}^{(2)}$

$$[s_{41}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{41}^{(2)}(t,1)]^{(2)}, [s_{41}^{(2)}(t,2)]^{(2)}, [s_{41}^{(2)}(t,3)]^{(2)}, [s_{41}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{41}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(2)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(2)} t],$$

$$[s_{41}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(2)} t],$$

$$[s_{41}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{41}^{(2)}(1)]^{(2)},\ [\lambda_{41}^{(2)}(2)]^{(2)},\ [\lambda_{41}^{(2)}(3)]^{(2)},\ [\lambda_{41}^{(2)}(4)]^{(2)},$$

for component $E_{51}^{(2)}$

$$[s_{51}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{51}^{(2)}(t,1)]^{(2)}, [s_{51}^{(2)}(t,2)]^{(2)}, [s_{51}^{(2)}(t,3)]^{(2)}, [s_{51}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{51}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(2)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(2)} t],$$

$$[s_{51}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{51}^{(2)}(3)]^{(2)} t],$$

$$[s_{51}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{51}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{51}^{(2)}(1)]^{(2)},\ [\lambda_{51}^{(2)}(2)]^{(2)},\ [\lambda_{51}^{(2)}(3)]^{(2)},\ [\lambda_{51}^{(2)}(4)]^{(2)},$$

for component $E_{61}^{(2)}$

$$[s_{61}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{61}^{(2)}(t,1)]^{(2)}, [s_{61}^{(2)}(t,2)]^{(2)}, [s_{61}^{(2)}(t,3)]^{(2)}, [s_{61}^{(2)}(t,4)]^{(2)}],$$

coordinates

$$[s_{61}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{61}^{(2)}(1)]^{(2)} t],$$

$$[s_{61}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{61}^{(2)}(2)]^{(2)} t],$$

$$[s_{61}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{61}^{(2)}(3)]^{(2)} t],$$

$$[s_{61}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{61}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{61}^{(2)}(1)]^{(2)},\ [\lambda_{61}^{(2)}(2)]^{(2)},\ [\lambda_{61}^{(2)}(3)]^{(2)},\ [\lambda_{61}^{(2)}(4)]^{(2)},$$

for component $E_{71}^{(2)}$

$$[s_{71}^{(2)}(t,\cdot)]^{(2)} = [1, [s_{71}^{(2)}(t,1)]^{(2)}, [s_{71}^{(2)}(t,2)]^{(2)}, [s_{71}^{(2)}(t,3)]^{(2)}, [s_{71}^{(2)}(t,4)]^{(2)}]$$

coordinates

$$[s_{71}^{(2)}(t,1)]^{(2)} = \exp[-[\lambda_{71}^{(2)}(1)]^{(2)} t],$$

$$[s_{71}^{(2)}(t,2)]^{(2)} = \exp[-[\lambda_{71}^{(2)}(2)]^{(2)} t],$$

$$[s_{71}^{(2)}(t,3)]^{(2)} = \exp[-[\lambda_{71}^{(2)}(3)]^{(2)} t],$$

$$[s_{71}^{(2)}(t,4)]^{(2)} = \exp[-[\lambda_{71}^{(2)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{71}^{(2)}(1)]^{(2)},\ [\lambda_{71}^{(2)}(2)]^{(2)},\ [\lambda_{71}^{(2)}(3)]^{(2)},\ [\lambda_{71}^{(2)}(4)]^{(2)},$$

- the reliability functions of the subsystem S_5 components

for component $E_{11}^{(5)}$

$$[s_{11}^{(5)}(t,\cdot)]^{(2)} = [1, [s_{11}^{(5)}(t,1)]^{(2)}, [s_{11}^{(5)}(t,2)]^{(2)}, [s_{11}^{(5)}(t,3)]^{(2)}, [s_{11}^{(5)}(t,4)]^{(2)}]$$

coordinates

$$[s_{11}^{(5)}(t,1)]^{(2)} = \exp[-[\lambda_{11}^{(5)}(1)]^{(2)} t],$$

$$[s_{11}^{(5)}(t,2)]^{(2)} = \exp[-[\lambda_{11}^{(5)}(2)]^{(2)} t],$$

$$[s_{11}^{(5)}(t,3)]^{(2)} = \exp[-[\lambda_{11}^{(5)}(3)]^{(2)} t],$$

$$[s_{11}^{(5)}(t,4)]^{(2)} = \exp[-[\lambda_{11}^{(5)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(5)}(1)]^{(2)}$, $[\lambda_{11}^{(5)}(2)]^{(2)}$, $[\lambda_{11}^{(5)}(3)]^{(2)}$, $[\lambda_{11}^{(5)}(4)]^{(2)}$,

for component $E_{21}^{(5)}$

$$[s_{21}^{(5)}(t,\cdot)]^{(2)} = [1, [s_{21}^{(5)}(t,1)]^{(2)}, [s_{21}^{(5)}(t,2)]^{(2)}, [s_{21}^{(5)}(t,3)]^{(2)}, [s_{21}^{(5)}(t,4)]^{(2)}]$$

coordinates

$$[s_{21}^{(5)}(t,1)]^{(2)} = \exp[-[\lambda_{21}^{(5)}(1)]^{(2)} t],$$

$$[s_{21}^{(5)}(t,2)]^{(2)} = \exp[-[\lambda_{21}^{(5)}(2)]^{(2)} t],$$

$$[s_{21}^{(5)}(t,3)]^{(2)} = \exp[-[\lambda_{21}^{(5)}(3)]^{(2)} t],$$

$$[s_{21}^{(5)}(t,4)]^{(2)} = \exp[-[\lambda_{21}^{(5)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{21}^{(5)}(1)]^{(2)}$, $[\lambda_{21}^{(5)}(2)]^{(2)}$, $[\lambda_{21}^{(5)}(3)]^{(2)}$, $[\lambda_{21}^{(5)}(4)]^{(2)}$,

for component $E_{31}^{(5)}$

$$[s_{31}^{(5)}(t,\cdot)]^{(2)} = [1, [s_{31}^{(5)}(t,1)]^{(2)}, [s_{31}^{(5)}(t,2)]^{(2)}, [s_{31}^{(5)}(t,3)]^{(2)}, [s_{31}^{(5)}(t,4)]^{(2)}]$$

coordinates

$$[s_{31}^{(5)}(t,1)]^{(2)} = \exp[-[\lambda_{31}^{(5)}(1)]^{(2)} t],$$

$$[s_{31}^{(5)}(t,2)]^{(2)} = \exp[-[\lambda_{31}^{(5)}(2)]^{(2)} t],$$

$$[s_{31}^{(5)}(t,3)]^{(2)} = \exp[-[\lambda_{31}^{(5)}(3)]^{(2)} t],$$

$$[s_{31}^{(5)}(t,4)]^{(2)} = \exp[-[\lambda_{31}^{(5)}(4)]^{(2)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{31}^{(5)}(1)]^{(2)}$, $[\lambda_{31}^{(5)}(2)]^{(2)}$, $[\lambda_{31}^{(5)}(3)]^{(2)}$, $[\lambda_{31}^{(5)}(4)]^{(2)}$,

iii) at the system operation states z_3:

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(3)} = [1, [s_{11}^{(1)}(t,1)]^{(3)}, [s_{11}^{(1)}(t,2)]^{(3)}, [s_{11}^{(1)}(t,3)]^{(3)}, [s_{11}^{(1)}(t,4)]^{(3)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(3)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(3)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(3)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(3)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(3)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(3)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(3)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(3)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(1)}(1)]^{(3)}$, $[\lambda_{11}^{(1)}(2)]^{(3)}$, $[\lambda_{11}^{(1)}(3)]^{(3)}$, $[\lambda_{11}^{(1)}(4)]^{(3)}$,

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{11}^{(2)}(t,1)]^{(3)}, [s_{11}^{(2)}(t,2)]^{(3)}, [s_{11}^{(2)}(t,3)]^{(3)}, [s_{11}^{(2)}(t,4)]^{(3)}]$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(3)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(3)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(3)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(3)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{11}^{(2)}(1)]^{(3)}$, $[\lambda_{11}^{(2)}(2)]^{(3)}$, $[\lambda_{11}^{(2)}(3)]^{(3)}$, $[\lambda_{11}^{(2)}(4)]^{(3)}$,

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{12}^{(2)}(t,1)]^{(3)}, [s_{12}^{(2)}(t,2)]^{(3)}, [s_{12}^{(2)}(t,3)]^{(3)}, [s_{12}^{(2)}(t,4)]^{(3)}]$$

coordinates

$[s_{12}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(3)}t]$,

$[s_{12}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(3)}t]$,

$[s_{12}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(3)}t]$,

$[s_{12}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(3)}t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{12}^{(2)}(1)]^{(3)}$, $[\lambda_{12}^{(2)}(2)]^{(3)}$, $[\lambda_{12}^{(2)}(3)]^{(3)}$, $[\lambda_{12}^{(2)}(4)]^{(3)}$,

for component $E_{13}^{(2)}$

$[s_{13}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{13}^{(2)}(t,1)]^{(3)}, [s_{13}^{(2)}(t,2)]^{(3)}, [s_{13}^{(2)}(t,3)]^{(3)}, [s_{13}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{13}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(3)}t]$,

$[s_{13}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(3)}t]$,

$[s_{13}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(3)}t]$,

$[s_{13}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(3)}t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{13}^{(2)}(1)]^{(3)}$, $[\lambda_{13}^{(2)}(2)]^{(3)}$, $[\lambda_{13}^{(2)}(3)]^{(3)}$, $[\lambda_{13}^{(2)}(4)]^{(3)}$,

for component $E_{14}^{(2)}$

$[s_{14}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{14}^{(2)}(t,1)]^{(3)}, [s_{14}^{(2)}(t,2)]^{(3)}, [s_{14}^{(2)}(t,3)]^{(3)}, [s_{14}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{14}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(3)}t]$,

$[s_{14}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(3)}t]$,

$[s_{14}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(3)}t]$,

$[s_{14}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(3)}t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{14}^{(2)}(1)]^{(3)}$, $[\lambda_{14}^{(2)}(2)]^{(3)}$, $[\lambda_{14}^{(2)}(3)]^{(3)}$, $[\lambda_{14}^{(2)}(4)]^{(3)}$,

for component $E_{21}^{(2)}$

$[s_{21}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{21}^{(2)}(t,1)]^{(3)}, [s_{21}^{(2)}(t,2)]^{(3)}, [s_{21}^{(2)}(t,3)]^{(3)}, [s_{21}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{21}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{21}^{(2)}(1)]^{(3)}t]$,

$[s_{21}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{21}^{(2)}(2)]^{(3)}t]$,

$[s_{21}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{21}^{(2)}(3)]^{(3)}t]$,

$[s_{21}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{21}^{(2)}(4)]^{(3)}t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{21}^{(2)}(1)]^{(3)}$, $[\lambda_{21}^{(2)}(2)]^{(3)}$, $[\lambda_{21}^{(2)}(3)]^{(3)}$, $[\lambda_{21}^{(2)}(4)]^{(3)}$,

for component $E_{22}^{(2)}$

$[s_{22}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{22}^{(2)}(t,1)]^{(3)}, [s_{22}^{(2)}(t,2)]^{(3)}, [s_{22}^{(2)}(t,3)]^{(3)}, [s_{22}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{22}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{22}^{(2)}(1)]^{(3)}t]$,

$[s_{22}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{22}^{(2)}(2)]^{(3)}t]$,

$[s_{22}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{22}^{(2)}(3)]^{(3)}t]$,

$[s_{22}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{22}^{(2)}(4)]^{(3)}t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{22}^{(2)}(1)]^{(3)}$, $[\lambda_{22}^{(2)}(2)]^{(3)}$, $[\lambda_{22}^{(2)}(3)]^{(3)}$, $[\lambda_{22}^{(2)}(4)]^{(3)}$,

for component $E_{31}^{(2)}$

$[s_{31}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{31}^{(2)}(t,1)]^{(3)}, [s_{31}^{(2)}(t,2)]^{(3)}, [s_{31}^{(2)}(t,3)]^{(3)}, [s_{31}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{31}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{31}^{(2)}(1)]^{(3)} t]$,

$[s_{31}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{31}^{(2)}(2)]^{(3)} t]$,

$[s_{31}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{31}^{(2)}(3)]^{(3)} t]$,

$[s_{31}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{31}^{(2)}(4)]^{(3)} t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{31}^{(2)}(1)]^{(3)}$, $[\lambda_{31}^{(2)}(2)]^{(3)}$, $[\lambda_{31}^{(2)}(3)]^{(3)}$, $[\lambda_{31}^{(2)}(4)]^{(3)}$,

for component $E_{41}^{(2)}$

$[s_{41}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{41}^{(2)}(t,1)]^{(3)}, [s_{41}^{(2)}(t,2)]^{(3)}, [s_{41}^{(2)}(t,3)]^{(3)}, [s_{41}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{41}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(3)} t]$,

$[s_{41}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(3)} t]$,

$[s_{41}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(3)} t]$,

$[s_{41}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(3)} t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{41}^{(2)}(1)]^{(3)}$, $[\lambda_{41}^{(2)}(2)]^{(3)}$, $[\lambda_{41}^{(2)}(3)]^{(3)}$, $[\lambda_{41}^{(2)}(4)]^{(3)}$,

for component $E_{51}^{(2)}$

$[s_{51}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{51}^{(2)}(t,1)]^{(3)}, [s_{51}^{(2)}(t,2)]^{(3)}, [s_{51}^{(2)}(t,3)]^{(3)}, [s_{51}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{51}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(3)} t]$,

$[s_{41}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(3)} t]$,

$[s_{51}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{51}^{(2)}(3)]^{(3)} t]$,

$[s_{51}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{51}^{(2)}(4)]^{(3)} t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{51}^{(2)}(1)]^{(3)}$, $[\lambda_{51}^{(2)}(2)]^{(3)}$, $[\lambda_{51}^{(2)}(3)]^{(3)}$, $[\lambda_{51}^{(2)}(4)]^{(3)}$,

for component $E_{61}^{(2)}$

$[s_{61}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{61}^{(2)}(t,1)]^{(3)}, [s_{61}^{(2)}(t,2)]^{(3)}, [s_{61}^{(2)}(t,3)]^{(3)}, [s_{61}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{61}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{61}^{(2)}(1)]^{(3)} t]$,

$[s_{61}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{61}^{(2)}(2)]^{(3)} t]$,

$[s_{61}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{61}^{(2)}(3)]^{(3)} t]$,

$[s_{61}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{61}^{(2)}(4)]^{(3)} t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{61}^{(2)}(1)]^{(3)}$, $[\lambda_{61}^{(2)}(2)]^{(3)}$, $[\lambda_{61}^{(2)}(3)]^{(3)}$, $[\lambda_{61}^{(2)}(4)]^{(3)}$,

for component $E_{71}^{(2)}$

$[s_{71}^{(2)}(t,\cdot)]^{(3)} = [1, [s_{71}^{(2)}(t,1)]^{(3)}, [s_{71}^{(2)}(t,2)]^{(3)}, [s_{71}^{(2)}(t,3)]^{(3)}, [s_{71}^{(2)}(t,4)]^{(3)}]$

coordinates

$[s_{71}^{(2)}(t,1)]^{(3)} = \exp[-[\lambda_{71}^{(2)}(1)]^{(3)} t]$,

$[s_{71}^{(2)}(t,2)]^{(3)} = \exp[-[\lambda_{71}^{(2)}(2)]^{(3)} t]$,

$[s_{71}^{(2)}(t,3)]^{(3)} = \exp[-[\lambda_{71}^{(2)}(3)]^{(3)} t]$,

$[s_{71}^{(2)}(t,4)]^{(3)} = \exp[-[\lambda_{71}^{(2)}(4)]^{(3)} t]$,

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$[\lambda_{71}^{(2)}(1)]^{(3)}$, $[\lambda_{71}^{(2)}(2)]^{(3)}$, $[\lambda_{71}^{(2)}(3)]^{(3)}$, $[\lambda_{71}^{(2)}(4)]^{(3)}$,

iv) at the system operation states z_4:

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(4)} = [1, [s_{11}^{(1)}(t,1)]^{(4)}, [s_{11}^{(1)}(t,2)]^{(4)}, [s_{11}^{(1)}(t,3)]^{(4)}, [s_{11}^{(1)}(t,4)]^{(4)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(4)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(4)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(4)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(4)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(4)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(4)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(4)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(1)}(1)]^{(4)},\ [\lambda_{11}^{(1)}(2)]^{(4)},\ [\lambda_{11}^{(1)}(3)]^{(4)},\ [\lambda_{11}^{(1)}(4)]^{(4)},$$

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{11}^{(2)}(t,1)]^{(4)}, [s_{11}^{(2)}(t,2)]^{(4)}, [s_{11}^{(2)}(t,3)]^{(4)}, [s_{11}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(4)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(4)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(4)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(2)}(1)]^{(4)},\ [\lambda_{11}^{(2)}(2)]^{(4)},\ [\lambda_{11}^{(2)}(3)]^{(4)},\ [\lambda_{11}^{(2)}(4)]^{(4)},$$

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{12}^{(2)}(t,1)]^{(4)}, [s_{12}^{(2)}(t,2)]^{(4)}, [s_{12}^{(2)}(t,3)]^{(4)}, [s_{12}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{12}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(4)} t],$$

$$[s_{12}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(4)} t],$$

$$[s_{12}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(4)} t],$$

$$[s_{12}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{12}^{(2)}(1)]^{(4)},\ [\lambda_{12}^{(2)}(2)]^{(4)},\ [\lambda_{12}^{(2)}(3)]^{(4)},\ [\lambda_{12}^{(2)}(4)]^{(4)},$$

for component $E_{13}^{(2)}$

$$[s_{13}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{13}^{(2)}(t,1)]^{(4)}, [s_{13}^{(2)}(t,2)]^{(4)}, [s_{13}^{(2)}(t,3)]^{(4)}, [s_{13}^{(2)}(t,4)]^{(4)}],$$

coordinates

$$[s_{13}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(4)} t],$$

$$[s_{13}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(4)} t],$$

$$[s_{13}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(4)} t],$$

$$[s_{13}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{13}^{(2)}(1)]^{(4)},\ [\lambda_{13}^{(2)}(2)]^{(4)},\ [\lambda_{13}^{(2)}(3)]^{(4)},\ [\lambda_{13}^{(2)}(4)]^{(4)},$$

for component $E_{14}^{(2)}$

$$[s_{14}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{14}^{(2)}(t,1)]^{(4)}, [s_{14}^{(2)}(t,2)]^{(4)}, [s_{14}^{(2)}(t,3)]^{(4)}, [s_{14}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{14}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(4)} t],$$

$$[s_{14}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(4)} t],$$

$$[s_{14}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(4)} t],$$

$$[s_{14}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{14}^{(2)}(1)]^{(4)},\ [\lambda_{14}^{(2)}(2)]^{(4)},\ [\lambda_{14}^{(2)}(3)]^{(4)},\ [\lambda_{14}^{(2)}(4)]^{(4)},$$

for component $E_{41}^{(2)}$

$$[s_{41}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{41}^{(2)}(t,1)]^{(4)}, [s_{41}^{(2)}(t,2)]^{(4)}, [s_{41}^{(2)}(t,3)]^{(4)}, [s_{41}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{41}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(4)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(4)} t],$$

$$[s_{41}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(4)} t],$$

$$[s_{41}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{41}^{(2)}(1)]^{(4)},\ [\lambda_{41}^{(2)}(2)]^{(4)},\ [\lambda_{41}^{(2)}(3)]^{(4)},\ [\lambda_{41}^{(2)}(4)]^{(4)},$$

for component $E_{51}^{(2)}$

$$[s_{51}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{51}^{(2)}(t,1)]^{(4)}, [s_{51}^{(2)}(t,2)]^{(4)}, [s_{51}^{(2)}(t,3)]^{(4)}, [s_{51}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{51}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(4)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(4)} t],$$

$$[s_{51}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{51}^{(2)}(3)]^{(4)} t],$$

$$[s_{51}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{51}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{51}^{(2)}(1)]^{(4)},\ [\lambda_{51}^{(2)}(2)]^{(4)},\ [\lambda_{51}^{(2)}(3)]^{(4)},\ [\lambda_{51}^{(2)}(4)]^{(4)},$$

for component $E_{61}^{(2)}$

$$[s_{61}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{61}^{(2)}(t,1)]^{(4)}, [s_{61}^{(2)}(t,2)]^{(4)}, [s_{61}^{(2)}(t,3)]^{(4)}, [s_{61}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{61}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{61}^{(2)}(1)]^{(4)} t],$$

$$[s_{61}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{61}^{(2)}(2)]^{(4)} t],$$

$$[s_{61}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{61}^{(2)}(3)]^{(4)} t],$$

$$[s_{61}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{61}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{61}^{(2)}(1)]^{(4)},\ [\lambda_{61}^{(2)}(2)]^{(4)},\ [\lambda_{61}^{(2)}(3)]^{(4)},\ [\lambda_{61}^{(2)}(4)]^{(4)},$$

for component $E_{71}^{(2)}$

$$[s_{71}^{(2)}(t,\cdot)]^{(4)} = [1, [s_{71}^{(2)}(t,1)]^{(4)}, [s_{71}^{(2)}(t,2)]^{(4)}, [s_{71}^{(2)}(t,3)]^{(4)}, [s_{71}^{(2)}(t,4)]^{(4)}]$$

coordinates

$$[s_{71}^{(2)}(t,1)]^{(4)} = \exp[-[\lambda_{71}^{(2)}(1)]^{(4)} t],$$

$$[s_{71}^{(2)}(t,2)]^{(4)} = \exp[-[\lambda_{71}^{(2)}(2)]^{(4)} t],$$

$$[s_{71}^{(2)}(t,3)]^{(4)} = \exp[-[\lambda_{71}^{(2)}(3)]^{(4)} t],$$

$$[s_{71}^{(2)}(t,4)]^{(4)} = \exp[-[\lambda_{71}^{(2)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{71}^{(2)}(1)]^{(4)},\ [\lambda_{71}^{(2)}(2)]^{(4)},\ [\lambda_{71}^{(2)}(3)]^{(4)},\ [\lambda_{71}^{(2)}(4)]^{(4)},$$

- the reliability functions of the subsystem S_4 components

for component $E_{11}^{(4)}$

$$[s_{11}^{(4)}(t,\cdot)]^{(4)} = [1, [s_{11}^{(4)}(t,1)]^{(4)}, [s_{11}^{(4)}(t,2)]^{(4)}, [s_{11}^{(4)}(t,3)]^{(4)}, [s_{11}^{(4)}(t,4)]^{(4)}]$$

coordinates

$$[s_{11}^{(4)}(t,1)]^{(4)} = \exp[-[\lambda_{11}^{(4)}(1)]^{(4)} t],$$

$$[s_{11}^{(4)}(t,2)]^{(4)} = \exp[-[\lambda_{11}^{(4)}(2)]^{(4)} t],$$

$$[s_{11}^{(4)}(t,3)]^{(4)} = \exp[-[\lambda_{11}^{(4)}(3)]^{(4)} t],$$

$$[s_{11}^{(4)}(t,4)]^{(4)} = \exp[-[\lambda_{11}^{(4)}(4)]^{(4)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(4)}(1)]^{(4)},\ [\lambda_{11}^{(4)}(2)]^{(4)},\ [\lambda_{11}^{(4)}(3)]^{(4)},\ [\lambda_{11}^{(4)}(4)]^{(4)},$$

v) at the system operation states z_5 :

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(5)} = [1, [s_{11}^{(1)}(t,1)]^{(5)}, [s_{11}^{(1)}(t,2)]^{(5)}, [s_{11}^{(1)}(t,3)]^{(5)}, [s_{11}^{(1)}(t,4)]^{(5)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(5)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(5)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(5)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(5)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(5)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(5)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(5)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(1)}(1)]^{(5)},\ [\lambda_{11}^{(1)}(2)]^{(5)},\ [\lambda_{11}^{(1)}(3)]^{(5)},\ [\lambda_{11}^{(1)}(4)]^{(5)},$$

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{11}^{(2)}(t,1)]^{(5)}, [s_{11}^{(2)}(t,2)]^{(5)}, [s_{11}^{(2)}(t,3)]^{(5)}, [s_{11}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(5)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(5)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(5)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(2)}(1)]^{(5)},\ [\lambda_{11}^{(2)}(2)]^{(5)},\ [\lambda_{11}^{(2)}(3)]^{(5)},\ [\lambda_{11}^{(2)}(4)]^{(5)},$$

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{12}^{(2)}(t,1)]^{(5)}, [s_{12}^{(2)}(t,2)]^{(5)}, [s_{12}^{(2)}(t,3)]^{(5)}, [s_{12}^{(2)}(t,4)]^{(5)}],$$

coordinates

$$[s_{12}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(5)} t],$$

$$[s_{12}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(5)} t],$$

$$[s_{12}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(5)} t],$$

$$[s_{12}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{12}^{(2)}(1)]^{(5)},\ [\lambda_{12}^{(2)}(2)]^{(5)},\ [\lambda_{12}^{(2)}(3)]^{(5)},\ [\lambda_{12}^{(2)}(4)]^{(5)},$$

for component $E_{13}^{(2)}$

$$[s_{13}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{13}^{(2)}(t,1)]^{(5)}, [s_{13}^{(2)}(t,2)]^{(5)}, [s_{13}^{(2)}(t,3)]^{(5)}, [s_{13}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{13}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(5)} t],$$

$$[s_{13}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(5)} t],$$

$$[s_{13}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(5)} t],$$

$$[s_{13}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{13}^{(2)}(1)]^{(5)},\ [\lambda_{13}^{(2)}(2)]^{(5)},\ [\lambda_{13}^{(2)}(3)]^{(5)},\ [\lambda_{13}^{(2)}(4)]^{(5)},$$

for component $E_{14}^{(2)}$

$$[s_{14}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{14}^{(2)}(t,1)]^{(5)}, [s_{14}^{(2)}(t,2)]^{(5)}, [s_{14}^{(2)}(t,3)]^{(5)}, [s_{14}^{(2)}(t,4)]^{(5)}],$$

coordinates

$$[s_{14}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(5)} t],$$

$$[s_{14}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(5)} t],$$

$$[s_{14}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(5)} t],$$

$$[s_{14}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{14}^{(2)}(1)]^{(5)},\ [\lambda_{14}^{(2)}(2)]^{(5)},\ [\lambda_{14}^{(2)}(3)]^{(5)},\ [\lambda_{14}^{(2)}(4)]^{(5)},$$

for component $E_{41}^{(2)}$

$$[s_{41}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{41}^{(2)}(t,1)]^{(5)}, [s_{41}^{(2)}(t,2)]^{(5)}, [s_{41}^{(2)}(t,3)]^{(5)}, [s_{41}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{41}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(5)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(5)} t],$$

$$[s_{41}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(5)} t],$$

$$[s_{41}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{41}^{(2)}(1)]^{(5)},\ [\lambda_{41}^{(2)}(2)]^{(5)},\ [\lambda_{41}^{(2)}(3)]^{(5)},\ [\lambda_{41}^{(2)}(4)]^{(5)},$$

for component $E_{51}^{(2)}$

$$[s_{51}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{51}^{(2)}(t,1)]^{(5)}, [s_{51}^{(2)}(t,2)]^{(5)}, [s_{51}^{(2)}(t,3)]^{(5)}, [s_{51}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{51}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(5)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(5)} t],$$

$$[s_{51}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{51}^{(2)}(3)]^{(5)} t],$$

$$[s_{51}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{51}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{51}^{(2)}(1)]^{(5)},\ [\lambda_{51}^{(2)}(2)]^{(5)},\ [\lambda_{51}^{(2)}(3)]^{(5)},\ [\lambda_{51}^{(2)}(4)]^{(5)},$$

for component $E_{61}^{(2)}$

$$[s_{61}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{61}^{(2)}(t,1)]^{(5)}, [s_{61}^{(2)}(t,2)]^{(5)}, [s_{61}^{(2)}(t,3)]^{(5)}, [s_{61}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{61}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{61}^{(2)}(1)]^{(5)} t],$$

$$[s_{61}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{61}^{(2)}(2)]^{(5)} t],$$

$$[s_{61}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{61}^{(2)}(3)]^{(5)} t],$$

$$[s_{61}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{61}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{61}^{(2)}(1)]^{(5)},\ [\lambda_{61}^{(2)}(2)]^{(5)},\ [\lambda_{61}^{(2)}(3)]^{(5)},\ [\lambda_{61}^{(2)}(4)]^{(5)},$$

for component $E_{71}^{(2)}$

$$[s_{71}^{(2)}(t,\cdot)]^{(5)} = [1, [s_{71}^{(2)}(t,1)]^{(5)}, [s_{71}^{(2)}(t,2)]^{(5)}, [s_{71}^{(2)}(t,3)]^{(5)}, [s_{71}^{(2)}(t,4)]^{(5)}]$$

coordinates

$$[s_{71}^{(2)}(t,1)]^{(5)} = \exp[-[\lambda_{71}^{(2)}(1)]^{(5)} t],$$

$$[s_{71}^{(2)}(t,2)]^{(5)} = \exp[-[\lambda_{71}^{(2)}(2)]^{(5)} t],$$

$$[s_{71}^{(2)}(t,3)]^{(5)} = \exp[-[\lambda_{71}^{(2)}(3)]^{(5)} t],$$

$$[s_{71}^{(2)}(t,4)]^{(5)} = \exp[-[\lambda_{71}^{(2)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{71}^{(2)}(1)]^{(5)},\ [\lambda_{71}^{(2)}(2)]^{(5)},\ [\lambda_{71}^{(2)}(3)]^{(5)},\ [\lambda_{71}^{(2)}(4)]^{(5)},$$

- the reliability functions of the subsystem S_4 components

for component $E_{11}^{(4)}$

$$[s_{11}^{(4)}(t,\cdot)]^{(5)} = [1, [s_{11}^{(4)}(t,1)]^{(5)}, [s_{11}^{(4)}(t,2)]^{(5)}, [s_{11}^{(4)}(t,3)]^{(5)}, [s_{11}^{(4)}(t,4)]^{(5)}]$$

coordinates

$$[s_{11}^{(4)}(t,1)]^{(5)} = \exp[-[\lambda_{11}^{(4)}(1)]^{(5)} t],$$

$$[s_{11}^{(4)}(t,2)]^{(5)} = \exp[-[\lambda_{11}^{(4)}(2)]^{(5)} t],$$

$$[s_{11}^{(4)}(t,3)]^{(5)} = \exp[-[\lambda_{11}^{(4)}(3)]^{(5)} t],$$

$$[s_{11}^{(4)}(t,4)]^{(5)} = \exp[-[\lambda_{11}^{(4)}(4)]^{(5)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(4)}(1)]^{(5)},\ [\lambda_{11}^{(4)}(2)]^{(5)},\ [\lambda_{11}^{(4)}(3)]^{(5)},\ [\lambda_{11}^{(4)}(4)]^{(5)},$$

vi) at the system operation states z_6 :

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(6)} = [1, [s_{11}^{(1)}(t,1)]^{(6)}, [s_{11}^{(1)}(t,2)]^{(6)}, [s_{11}^{(1)}(t,3)]^{(6)}, [s_{11}^{(1)}(t,4)]^{(6)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(6)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(6)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(6)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(6)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(6)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(6)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(6)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(1)}(1)]^{(6)},\ [\lambda_{11}^{(1)}(2)]^{(6)},\ [\lambda_{11}^{(1)}(3)]^{(6)},\ [\lambda_{11}^{(1)}(4)]^{(6)},$$

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{11}^{(2)}(t,1)]^{(6)}, [s_{11}^{(2)}(t,2)]^{(6)}, [s_{11}^{(2)}(t,3)]^{(6)}, [s_{11}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(6)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(6)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(6)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(2)}(1)]^{(6)},\ [\lambda_{11}^{(2)}(2)]^{(6)},\ [\lambda_{11}^{(2)}(3)]^{(6)},\ [\lambda_{11}^{(2)}(4)]^{(6)},$$

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{12}^{(2)}(t,1)]^{(6)}, [s_{12}^{(2)}(t,2)]^{(6)}, [s_{12}^{(2)}(t,3)]^{(6)}, [s_{12}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{12}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(6)} t],$$

$$[s_{12}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(6)} t],$$

$$[s_{12}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(6)} t],$$

$$[s_{12}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{12}^{(2)}(1)]^{(6)},\ [\lambda_{12}^{(2)}(2)]^{(6)},\ [\lambda_{12}^{(2)}(3)]^{(6)},\ [\lambda_{12}^{(2)}(4)]^{(6)},$$

for component $E_{13}^{(2)}$

$$[s_{13}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{13}^{(2)}(t,1)]^{(6)}, [s_{13}^{(2)}(t,2)]^{(6)}, [s_{13}^{(2)}(t,3)]^{(6)}, [s_{13}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{13}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(6)} t],$$

$$[s_{13}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(6)} t],$$

$$[s_{13}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(6)} t],$$

$$[s_{13}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{13}^{(2)}(1)]^{(6)},\ [\lambda_{13}^{(2)}(2)]^{(6)},\ [\lambda_{13}^{(2)}(3)]^{(6)},\ [\lambda_{13}^{(2)}(4)]^{(6)},$$

for component $E_{14}^{(2)}$

$$[s_{14}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{14}^{(2)}(t,1)]^{(6)}, [s_{14}^{(2)}(t,2)]^{(6)}, [s_{14}^{(2)}(t,3)]^{(6)}, [s_{14}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{14}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(6)} t],$$

$$[s_{14}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(6)} t],$$

$$[s_{14}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(6)} t],$$

$$[s_{14}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{14}^{(2)}(1)]^{(6)},\ [\lambda_{14}^{(2)}(2)]^{(6)},\ [\lambda_{14}^{(2)}(3)]^{(6)},\ [\lambda_{14}^{(2)}(4)]^{(6)},$$

for component $E_{21}^{(2)}$

$$[s_{21}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{21}^{(2)}(t,1)]^{(6)}, [s_{21}^{(2)}(t,2)]^{(6)}, [s_{21}^{(2)}(t,3)]^{(6)}, [s_{21}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{21}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{21}^{(2)}(1)]^{(6)} t],$$

$$[s_{21}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{21}^{(2)}(2)]^{(6)} t],$$

$$[s_{21}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{21}^{(2)}(3)]^{(6)} t],$$

$$[s_{21}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{21}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{21}^{(2)}(1)]^{(6)},\ [\lambda_{21}^{(2)}(2)]^{(6)},\ [\lambda_{21}^{(2)}(3)]^{(6)},\ [\lambda_{21}^{(2)}(4)]^{(6)},$$

for component $E_{22}^{(2)}$

$$[s_{22}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{22}^{(2)}(t,1)]^{(6)}, [s_{22}^{(2)}(t,2)]^{(6)}, [s_{22}^{(2)}(t,3)]^{(6)}, [s_{22}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{22}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{22}^{(2)}(1)]^{(6)} t],$$

$$[s_{22}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{22}^{(2)}(2)]^{(6)} t],$$

$$[s_{22}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{22}^{(2)}(3)]^{(6)} t],$$

$$[s_{22}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{22}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{22}^{(2)}(1)]^{(6)},\ [\lambda_{22}^{(2)}(2)]^{(6)},\ [\lambda_{22}^{(2)}(3)]^{(6)},\ [\lambda_{22}^{(2)}(4)]^{(6)},$$

for component $E_{31}^{(2)}$

$$[s_{31}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{31}^{(2)}(t,1)]^{(6)}, [s_{31}^{(2)}(t,2)]^{(6)}, [s_{31}^{(2)}(t,3)]^{(6)}, [s_{31}^{(2)}(t,4)]^{(6)}]$$

coordinates

$$[s_{31}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{31}^{(2)}(1)]^{(6)} t],$$

$$[s_{31}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{31}^{(2)}(2)]^{(6)} t],$$

$$[s_{31}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{31}^{(2)}(3)]^{(6)} t],$$

$$[s_{31}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{31}^{(2)}(4)]^{(6)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{31}^{(2)}(1)]^{(6)},\ [\lambda_{31}^{(2)}(2)]^{(6)},\ [\lambda_{31}^{(2)}(3)]^{(6)},\ [\lambda_{31}^{(2)}(4)]^{(6)},$$

for component $E_{41}^{(2)}$

$$[s_{41}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{41}^{(2)}(t,1)]^{(6)}, [s_{41}^{(2)}(t,2)]^{(6)}, [s_{41}^{(2)}(t,3)]^{(6)}, [s_{41}^{(2)}(t,4)]^{(6)}]$$

coordinates

$[s_{41}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(6)} t]$,

$[s_{41}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(6)} t]$,

$[s_{41}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(6)} t]$,

$[s_{41}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(6)} t]$,

or the intensities of departure from the safety states subsets {1,2,3,4}, {2,3,4}, {3,4}, {4}, respectively

$[\lambda_{41}^{(2)}(1)]^{(6)}$, $[\lambda_{41}^{(2)}(2)]^{(6)}$, $[\lambda_{41}^{(2)}(3)]^{(6)}$, $[\lambda_{41}^{(2)}(4)]^{(6)}$,

for component $E_{51}^{(2)}$

$$[s_{51}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{51}^{(2)}(t,1)]^{(6)}, [s_{51}^{(2)}(t,2)]^{(6)}, [s_{51}^{(2)}(t,3)]^{(6)}, [s_{51}^{(2)}(t,4)]^{(6)}],$$

coordinates

$[s_{51}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(6)} t]$,

$[s_{41}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(6)} t]$,

$[s_{51}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{51}^{(2)}(3)]^{(6)} t]$,

$[s_{51}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{51}^{(2)}(4)]^{(6)} t]$,

or the intensities of departure from the safety states subsets {1,2,3,4}, {2,3,4}, {3,4}, {4}, respectively

$[\lambda_{51}^{(2)}(1)]^{(6)}$, $[\lambda_{51}^{(2)}(2)]^{(6)}$, $[\lambda_{51}^{(2)}(3)]^{(6)}$, $[\lambda_{51}^{(6)}(4)]^{(3)}$,

for component $E_{61}^{(2)}$

$$[s_{61}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{61}^{(2)}(t,1)]^{(6)}, [s_{61}^{(2)}(t,2)]^{(6)}, [s_{61}^{(2)}(t,3)]^{(6)}, [s_{61}^{(2)}(t,4)]^{(6)}],$$

coordinates

$[s_{61}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{61}^{(2)}(1)]^{(6)} t]$,

$[s_{61}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{61}^{(2)}(2)]^{(6)} t]$,

$[s_{61}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{61}^{(2)}(3)]^{(6)} t]$,

$[s_{61}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{61}^{(2)}(4)]^{(6)} t]$,

or the intensities of departure from the safety states subsets {1,2,3,4}, {2,3,4}, {3,4}, {4}, respectively

$[\lambda_{61}^{(2)}(1)]^{(6)}$, $[\lambda_{61}^{(2)}(2)]^{(6)}$, $[\lambda_{61}^{(2)}(3)]^{(6)}$, $[\lambda_{61}^{(2)}(4)]^{(6)}$,

for component $E_{71}^{(2)}$

$$[s_{71}^{(2)}(t,\cdot)]^{(6)} = [1, [s_{71}^{(2)}(t,1)]^{(6)}, [s_{71}^{(2)}(t,2)]^{(6)}, [s_{71}^{(2)}(t,3)]^{(6)}, [s_{71}^{(2)}(t,4)]^{(6)}]$$

coordinates

$[s_{71}^{(2)}(t,1)]^{(6)} = \exp[-[\lambda_{71}^{(2)}(1)]^{(6)} t]$,

$[s_{71}^{(2)}(t,2)]^{(6)} = \exp[-[\lambda_{71}^{(2)}(2)]^{(6)} t]$,

$[s_{71}^{(2)}(t,3)]^{(6)} = \exp[-[\lambda_{71}^{(2)}(3)]^{(6)} t]$,

$[s_{71}^{(2)}(t,4)]^{(6)} = \exp[-[\lambda_{71}^{(2)}(4)]^{(6)} t]$,

or the intensities of departure from the safety states subsets {1,2,3,4}, {2,3,4}, {3,4}, {4}, respectively

$[\lambda_{71}^{(2)}(1)]^{(6)}$, $[\lambda_{71}^{(2)}(2)]^{(6)}$, $[\lambda_{71}^{(2)}(3)]^{(6)}$, $[\lambda_{71}^{(2)}(4)]^{(6)}$,

- the reliability functions of the subsystem S_4 components

for component $E_{11}^{(4)}$

$$[s_{11}^{(4)}(t,\cdot)]^{(6)} = [1, [s_{11}^{(4)}(t,1)]^{(6)}, [s_{11}^{(4)}(t,2)]^{(6)}, [s_{11}^{(4)}(t,3)]^{(6)}, [s_{11}^{(4)}(t,4)]^{(6)}],$$

coordinates

$[s_{11}^{(4)}(t,1)]^{(6)} = \exp[-[\lambda_{11}^{(4)}(1)]^{(6)} t]$,

$[s_{11}^{(4)}(t,2)]^{(6)} = \exp[-[\lambda_{11}^{(4)}(2)]^{(6)} t]$,

$[s_{11}^{(4)}(t,3)]^{(6)} = \exp[-[\lambda_{11}^{(4)}(3)]^{(6)} t]$,

$[s_{11}^{(4)}(t,4)]^{(6)} = \exp[-[\lambda_{11}^{(4)}(4)]^{(6)} t]$,

or the intensities of departure from the safety states subsets {1,2,3,4}, {2,3,4}, {3,4}, {4}, respectively

$[\lambda_{11}^{(4)}(1)]^{(6)}$, $[\lambda_{11}^{(4)}(2)]^{(6)}$, $[\lambda_{11}^{(4)}(3)]^{(6)}$, $[\lambda_{11}^{(4)}(4)]^{(6)}$,

vii) at the system operation states z_7:

- the reliability functions of the subsystem S_1 components

for component $E_{11}^{(1)}$

$$[s_{11}^{(1)}(t,\cdot)]^{(7)} = [1, [s_{11}^{(1)}(t,1)]^{(7)}, [s_{11}^{(1)}(t,2)]^{(7)}, [s_{11}^{(1)}(t,3)]^{(7)}, [s_{11}^{(1)}(t,4)]^{(7)}]$$

coordinates

$$[s_{11}^{(1)}(t,1)]^{(7)} = \exp[-[\lambda_{11}^{(1)}(1)]^{(7)} t],$$

$$[s_{11}^{(1)}(t,2)]^{(7)} = \exp[-[\lambda_{11}^{(1)}(2)]^{(7)} t],$$

$$[s_{11}^{(1)}(t,3)]^{(7)} = \exp[-[\lambda_{11}^{(1)}(3)]^{(7)} t],$$

$$[s_{11}^{(1)}(t,4)]^{(7)} = \exp[-[\lambda_{11}^{(1)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(1)}(1)]^{(7)},\ [\lambda_{11}^{(1)}(2)]^{(7)},\ [\lambda_{11}^{(1)}(3)]^{(7)},\ [\lambda_{11}^{(1)}(4)]^{(7)},$$

- the reliability functions of the subsystem S_2 components

for component $E_{11}^{(2)}$

$$[s_{11}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{11}^{(2)}(t,1)]^{(7)}, [s_{11}^{(2)}(t,2)]^{(7)}, [s_{11}^{(2)}(t,3)]^{(7)}, [s_{11}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{11}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{11}^{(2)}(1)]^{(7)} t],$$

$$[s_{11}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{11}^{(2)}(2)]^{(7)} t],$$

$$[s_{11}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{11}^{(2)}(3)]^{(7)} t],$$

$$[s_{11}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{11}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{11}^{(2)}(1)]^{(7)},\ [\lambda_{11}^{(2)}(2)]^{(7)},\ [\lambda_{11}^{(2)}(3)]^{(7)},\ [\lambda_{11}^{(2)}(4)]^{(7)},$$

for component $E_{12}^{(2)}$

$$[s_{12}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{12}^{(2)}(t,1)]^{(7)}, [s_{12}^{(2)}(t,2)]^{(7)}, [s_{12}^{(2)}(t,3)]^{(7)}, [s_{12}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{12}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{12}^{(2)}(1)]^{(7)} t],$$

$$[s_{12}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{12}^{(2)}(2)]^{(7)} t],$$

$$[s_{12}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{12}^{(2)}(3)]^{(7)} t],$$

$$[s_{12}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{12}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{12}^{(2)}(1)]^{(7)},\ [\lambda_{12}^{(2)}(2)]^{(7)},\ [\lambda_{12}^{(2)}(3)]^{(7)},\ [\lambda_{12}^{(2)}(4)]^{(7)},$$

for component $E_{13}^{(2)}$

$$[s_{13}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{13}^{(2)}(t,1)]^{(7)}, [s_{13}^{(2)}(t,2)]^{(7)}, [s_{13}^{(2)}(t,3)]^{(7)}, [s_{13}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{13}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{13}^{(2)}(1)]^{(7)} t],$$

$$[s_{13}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{13}^{(2)}(2)]^{(7)} t],$$

$$[s_{13}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{13}^{(2)}(3)]^{(7)} t],$$

$$[s_{13}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{13}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{13}^{(2)}(1)]^{(7)},\ [\lambda_{13}^{(2)}(2)]^{(7)},\ [\lambda_{13}^{(2)}(3)]^{(7)},\ [\lambda_{13}^{(2)}(4)]^{(7)},$$

for component $E_{14}^{(2)}$

$$[s_{14}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{14}^{(2)}(t,1)]^{(7)}, [s_{14}^{(2)}(t,2)]^{(7)}, [s_{14}^{(2)}(t,3)]^{(7)}, [s_{14}^{(2)}(t,4)]^{(7)}],$$

coordinates

$$[s_{14}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{14}^{(2)}(1)]^{(7)} t],$$

$$[s_{14}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{14}^{(2)}(2)]^{(7)} t],$$

$$[s_{14}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{14}^{(2)}(3)]^{(7)} t],$$

$$[s_{14}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{14}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{14}^{(2)}(1)]^{(7)}, \ [\lambda_{14}^{(2)}(2)]^{(7)}, \ [\lambda_{14}^{(2)}(3)]^{(7)}, \ [\lambda_{14}^{(2)}(4)]^{(7)},$$

for component $E_{21}^{(2)}$

$$[s_{21}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{21}^{(2)}(t,1)]^{(7)}, [s_{21}^{(2)}(t,2)]^{(7)}, [s_{21}^{(2)}(t,3)]^{(7)}, [s_{21}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{21}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{21}^{(2)}(1)]^{(7)} t],$$

$$[s_{21}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{21}^{(2)}(2)]^{(7)} t],$$

$$[s_{21}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{21}^{(2)}(3)]^{(7)} t],$$

$$[s_{21}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{21}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{21}^{(2)}(1)]^{(7)}, \ [\lambda_{21}^{(2)}(2)]^{(7)}, \ [\lambda_{21}^{(2)}(3)]^{(7)}, \ [\lambda_{21}^{(2)}(4)]^{(7)},$$

for component $E_{22}^{(2)}$

$$[s_{22}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{22}^{(2)}(t,1)]^{(7)}, [s_{22}^{(2)}(t,2)]^{(7)}, [s_{22}^{(2)}(t,3)]^{(7)}, [s_{22}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{22}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{22}^{(2)}(1)]^{(7)} t],$$

$$[s_{22}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{22}^{(2)}(2)]^{(7)} t],$$

$$[s_{22}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{22}^{(2)}(3)]^{(7)} t],$$

$$[s_{22}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{22}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{22}^{(2)}(1)]^{(7)}, \ [\lambda_{22}^{(2)}(2)]^{(7)}, \ [\lambda_{22}^{(2)}(3)]^{(7)}, \ [\lambda_{22}^{(2)}(4)]^{(7)},$$

for component $E_{31}^{(2)}$

$$[s_{31}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{31}^{(2)}(t,1)]^{(7)}, [s_{31}^{(2)}(t,2)]^{(7)}, [s_{31}^{(2)}(t,3)]^{(7)}, [s_{31}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{31}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{31}^{(2)}(1)]^{(7)} t],$$

$$[s_{31}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{31}^{(2)}(2)]^{(7)} t],$$

$$[s_{31}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{31}^{(2)}(3)]^{(7)} t],$$

$$[s_{31}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{31}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{31}^{(2)}(1)]^{(7)}, \ [\lambda_{31}^{(2)}(2)]^{(7)}, \ [\lambda_{31}^{(2)}(3)]^{(7)}, \ [\lambda_{31}^{(2)}(4)]^{(7)},$$

for component $E_{41}^{(2)}$

$$[s_{41}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{41}^{(2)}(t,1)]^{(7)}, [s_{41}^{(2)}(t,2)]^{(7)}, [s_{41}^{(2)}(t,3)]^{(7)}, [s_{41}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{41}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{41}^{(2)}(1)]^{(7)} t],$$

$$[s_{41}^{(2)}(t,2)]^{(7)} = \exp[-[\lambda_{41}^{(2)}(2)]^{(7)} t],$$

$$[s_{41}^{(2)}(t,3)]^{(7)} = \exp[-[\lambda_{41}^{(2)}(3)]^{(7)} t],$$

$$[s_{41}^{(2)}(t,4)]^{(7)} = \exp[-[\lambda_{41}^{(2)}(4)]^{(7)} t],$$

or the intensities of departure from the safety states subsets $\{1,2,3,4\}$, $\{2,3,4\}$, $\{3,4\}$, $\{4\}$, respectively

$$[\lambda_{41}^{(2)}(1)]^{(7)}, \ [\lambda_{41}^{(2)}(2)]^{(7)}, \ [\lambda_{41}^{(2)}(3)]^{(7)}, \ [\lambda_{41}^{(2)}(4)]^{(7)},$$

for component $E_{51}^{(2)}$

$$[s_{51}^{(2)}(t,\cdot)]^{(7)} = [1, [s_{51}^{(2)}(t,1)]^{(7)}, [s_{51}^{(2)}(t,2)]^{(7)}, [s_{51}^{(2)}(t,3)]^{(7)}, [s_{51}^{(2)}(t,4)]^{(7)}]$$

coordinates

$$[s_{51}^{(2)}(t,1)]^{(7)} = \exp[-[\lambda_{51}^{(2)}(1)]^{(7)} t],$$