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GMU Safety Interactive Platform organization and possibility of its applications

Keywords

data processing, database, critical infrastructure, impact model, prediction, risk, safety, software

Abstract

The organization and a possibility of the Gdynia Maritime University (GMU) Safety Interactive Platform applications are described. The GMU Platform structure and main functions of its particular parts are presented. Moreover, the future plans about the usage and extension of the GMU Platform are shown.

1. Introduction

The GMU team is investigating two scenarios (the Case Study) [Bogalecka M., Kołowrocki K., Soszyńska-Budny J., et. al., 2017] in the scope of the EU-CIRCLE project titled "A pan – European framework for strengthening Critical Infrastructure resilience to climate change":
i) Scenario 1 - Oil Transport in Port,
ii) Scenario 2 - Chemical Spill Due to Extreme Sea Surges.
First scenario concerns the port oil piping transportation system operating at one of the Baltic Oil Terminals. We have modeled, identified and predicted its safety on the basis of the statistical data and coming from experts opinions data. There is also considered an influence of the piping operation process and/or the climate-weather change process on the piping safety. Second scenario includes modelling, identification and prediction of the risk of dangerous chemicals accidents at the sea and their dangerous consequences for the environment. Moreover, the risk of chemical spills is also examined under the assumption of the stress of the climate-weather influence on the operation conditions.
During analysis these two scenarios, we have to process a lot of various data. To make this data processing more clear, we apply software based on MySQL and PHP languages to create databases with the data considered in our Case Study.
To predict safety of the piping system and dangerous chemicals accidents at sea and their dangerous consequences, we have to use one of Impact Models presented in [Blokus-Roszkowska A., Bogalecka M., Kołowrocki K., et. al., 2017]. Impact Models are describing how to evaluate the safety indicators of the critical infrastructure influenced by outside processes such the climate-weather change process or the critical infrastructure operating process. We decided to create for our own aims software supporting these models based on JavaScript and PHP languages due to generality of these models and a possibility of using them to other scenarios.
The databases with the data analyzed in the Case Study ("Databases") and software based on Impact Models ("Data processing") are placed at the GMU Safety Interactive Platform http://gmu.safety.am.gdynia.pl/. The detailed description of these two parts ("Databases" and "Data processing") of the GMU Platform is presented in next sections.

2. Organization and possibility of GMU Platform application

2.1 Organization and possibility of databases application

"Databases" (*Figure 1*) allows to view the data describing processes related to critical infrastructures from the Case Study [Bogalecka M., Kołowrocki K., Soszyńska-Budny J., et. al., 2017]. The available databases related to the Case Study are:

1) critical infrastructure (CI) operation process data,
2) climate-weather change process data for CI operating areas,
3) CI safety data,
4) CI accident initiating event process of environment threats data,
5) CI accident environment threats process data,
6) CI accident environment degradation process data,
7) operation process impact on CI safety data,
8) climate-weather change process impact on CI safety data,
9) climate-weather change process impact on CI accident environment degradation and losses data.

The link to the website with databases is shown in *Figure 1*.

To make stored data more clear, each database is divided into some subdatabases. The full list of available subdatabases is given in *Table 1*.

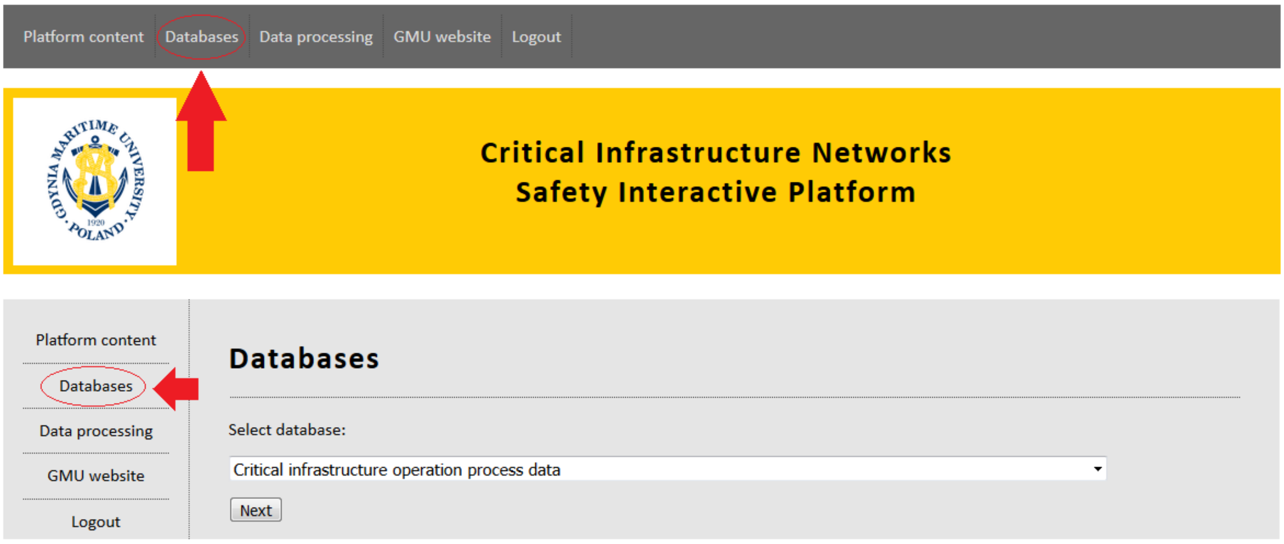


Figure 1. Links to “Databases”

Table 1. List of available subdatabases of GMU Platform

ID of database	Name of database	ID of sub-database	Name of subdatabase
1	Critical infrastructure operation process data	1	Number of CI operation process states
		2	Definitions of CI operation process states
		3	Realisations of CI operation process
		4	List of CI operating environment threats (OET)
		5	CI operation process including OET states
2	Climate-weather change process data for the critical infrastructure operating areas	1	Climate-weather change data measurement points
		2	Parameters of climate-weather change processes
		3	Climate-weather change processes states
		4	Realisations of climate-weather change process
3	Critical infrastructure safety data	1	CI structure
		2	CI substructures
		3	Number of CI safety states
		4	Definitions of CI safety states
		5	Mean values of CI asset lifetimes

4	Critical infrastructure accident initiating event process of environment threats data	1	Descriptions of initial events
		2	Definitions of CI accident initiating event process states
		3	Realisations of CI accident initiating event process for world sea waters
		4	Realisations of CI accident initiating event process for Baltic Sea waters
5	Critical infrastructure accident environment threats process data	1	Descriptions of marine environment chemical threats
		2	Descriptions of marine environment chemical threats parameters
		3	Descriptions of marine environment chemical threats parameters ranges
		4	Descriptions of sub-regions of environment threats process
		5	Marine environment chemical threats process states
		6	Realisations of CI accident environment threats process for world sea waters
		7	Realisations of CI accident environment threats process for Baltic Sea waters
6	Critical infrastructure accident environment degradation process data	1	Descriptions of environment degradations
		2	Descriptions of environment degradations levels
		3	CI accident environment degradations process states
		4	Realisations of CI accident environment degradations process for world sea waters
		5	Realisations of CI accident environment degradations process for Baltic Sea waters
7	Operation process impact on critical infrastructure safety data	1	Coefficients of operation process impact on CI safety
		2	Coefficients of operation process impact including operating environment threats on CI safety
8	Climate-weather change process impact on critical infrastructure safety data	1	Assignation CI assets to CI operating areas
		2	Coefficients of Climate-weather change process impact on CI safety
9	Climate-weather change process impact on critical infrastructure accident environment degradation and losses data	1	Coefficients of Climate-weather change process impact on critical infrastructure accident environment degradation and losses data

For example, the database with the critical infrastructure safety data consists of subdatabases with information about CI structure, CI substructures, number of CI safety states, definitions of CI safety states and mean values of CI asset lifetimes.

To view interesting data, we have to select:

– the database containing the data,
– the critical infrastructure related to the data (optional),
– the subdatabase containing the data.

As an example of using above procedure, there is presented a way how to view data about the realisations of the CI accident initiating event process for the Baltic Sea waters and data about the parameters of climate-weather change processes at the port oil piping critical infrastructure operating area.

In the first case (if we want to view data about the realisations of the CI accident initiating event process for the Baltic Sea waters), we should choose "Critical infrastructure accident initiating event process of environment threats data" from the database selection field presented in *Figure 2*.

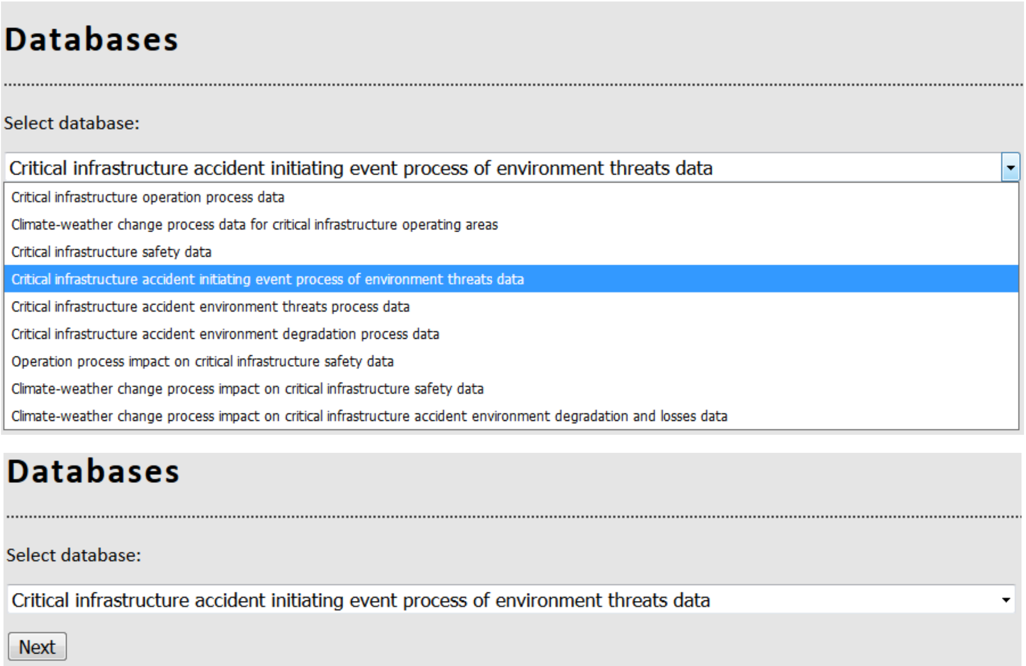


Figure 2. Selection of exemplary database (case 1)

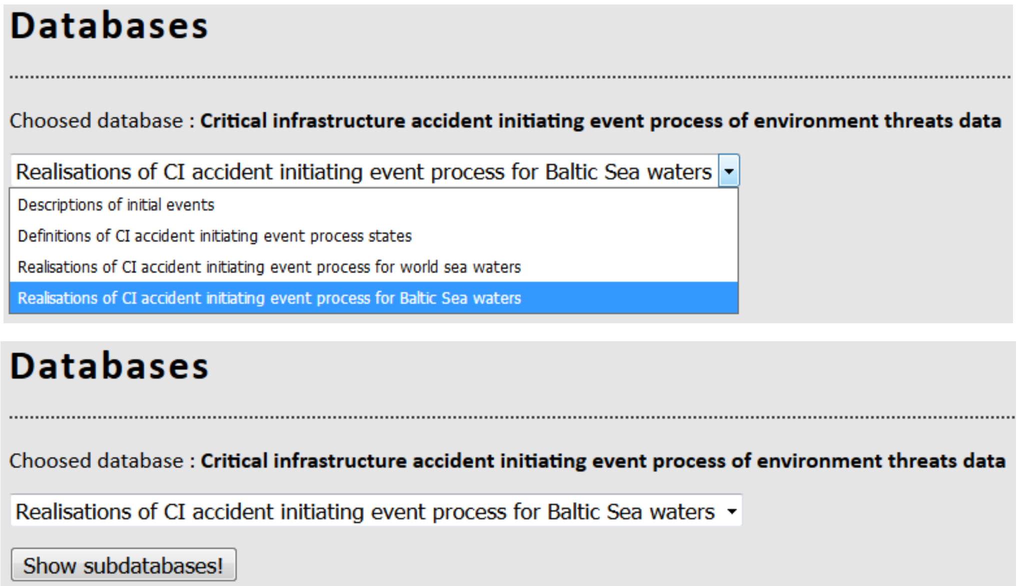
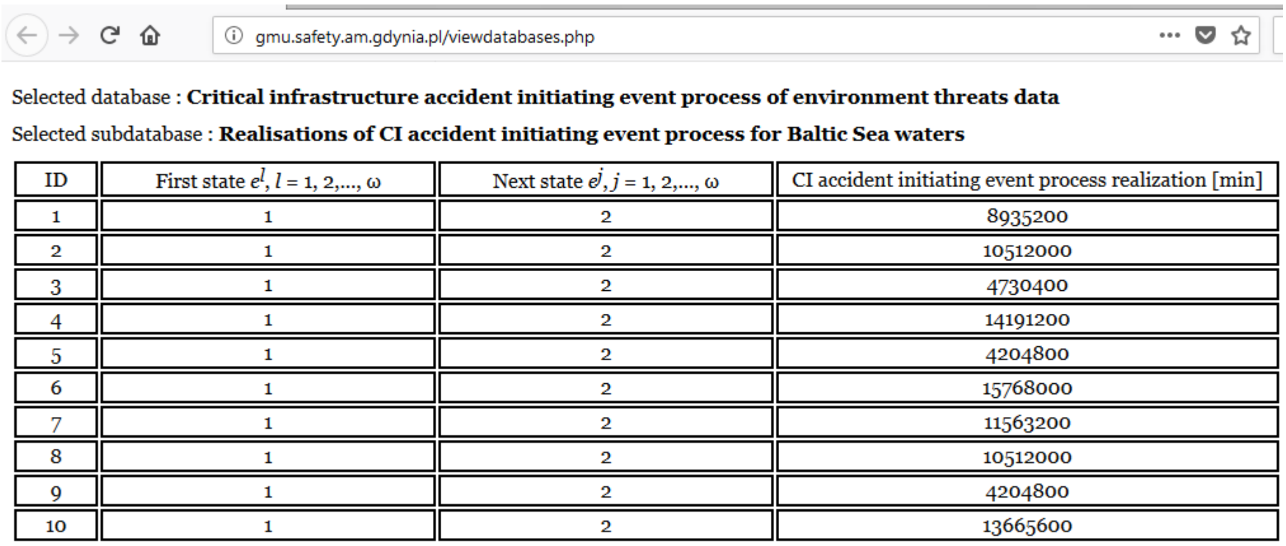


Figure 3. Selection of exemplary subdatabase (case 1)

Next, we choose the subdatabase related to the data (*Figure 3*). After clicking the button "Show subdatabases!", the selected subdatabase appears in the new tab (*Figure 4*).


gmu.safety.am.gdynia.pl/viewdatabases.php

Selected database : **Critical infrastructure accident initiating event process of environment threats data**

Selected subdatabase : **Realisations of CI accident initiating event process for Baltic Sea waters**

ID	First state e^l, $l = 1, 2,..., \omega$	Next state e^j, $j = 1, 2,..., \omega$	CI accident initiating event process realization [min]
1	1	2	8935200
2	1	2	10512000
3	1	2	4730400
4	1	2	14191200
5	1	2	4204800
6	1	2	15768000
7	1	2	11563200
8	1	2	10512000
9	1	2	4204800
10	1	2	13665600

Figure 4. Data from selected exemplary subdatabase (case 1)

On the presented example, we receive a table with data about the realisations of the CI accident initiating event process for the Baltic Sea waters. Information about a source of the presented data (the selected database and the subdatabase) are given above the table (*Figure 4*).

The single row of data contains:

– ID (identification number) of a realisation,
– an initial state e^l, $l = 1,2,\dots, \omega$, at which the CI accident initiating event process is staying until it goes to a next state e^j, $j = 1,2,\dots, \omega$,
– a next state e^j, $j = 1,2,\dots, \omega$, to which the process goes after it was staying at an initial state e^l, $l = 1,2,\dots, \omega$,
– a realisation of this process – a period of time (in minutes) in which the process was staying at an initial state e^l, $l = 1,2,\dots, \omega$, until it went to the next state e^j, $j = 1,2,\dots, \omega$.

For example, the 7-th row includes information about that the CI accident initiating event process was staying 11563200 min at a first state e^1 until it goes to a second state e^2.

In the second case (if we want to view data about the parameters of climate-weather change processes at the port oil piping critical infrastructure operating area), we should choose “Climate-weather change process data for critical infrastructure operating areas” from the database selection field presented in *Figure 5*.

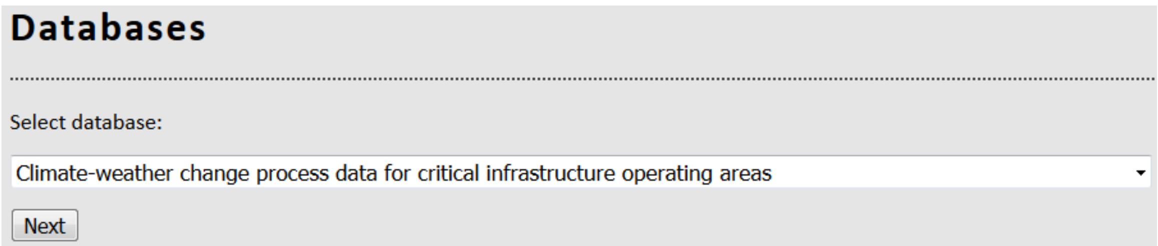


Figure 5. Selection of exemplary database (case 2)

In next step, we may select the critical infrastructure to which the database is related (*Figure 6*).

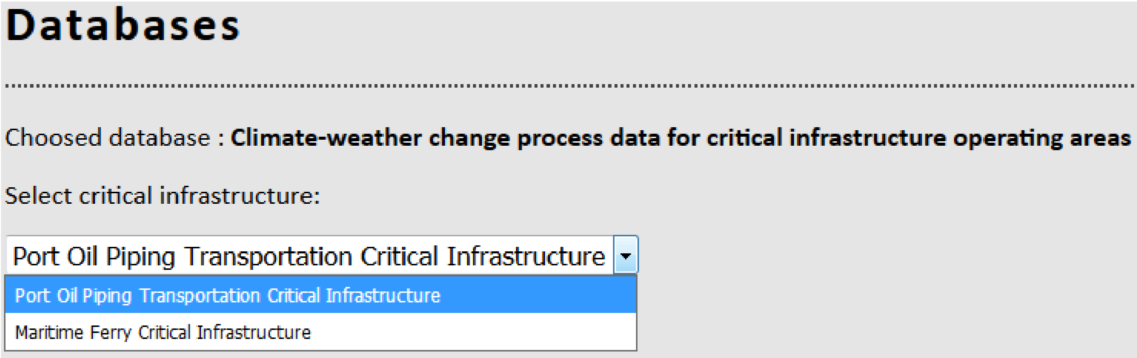


Figure 6. Selection of CI related to choosen database

After that, we select the subdatabase related to the interesting data - "parameters of climate-weather change processes" (*Figure 7*).

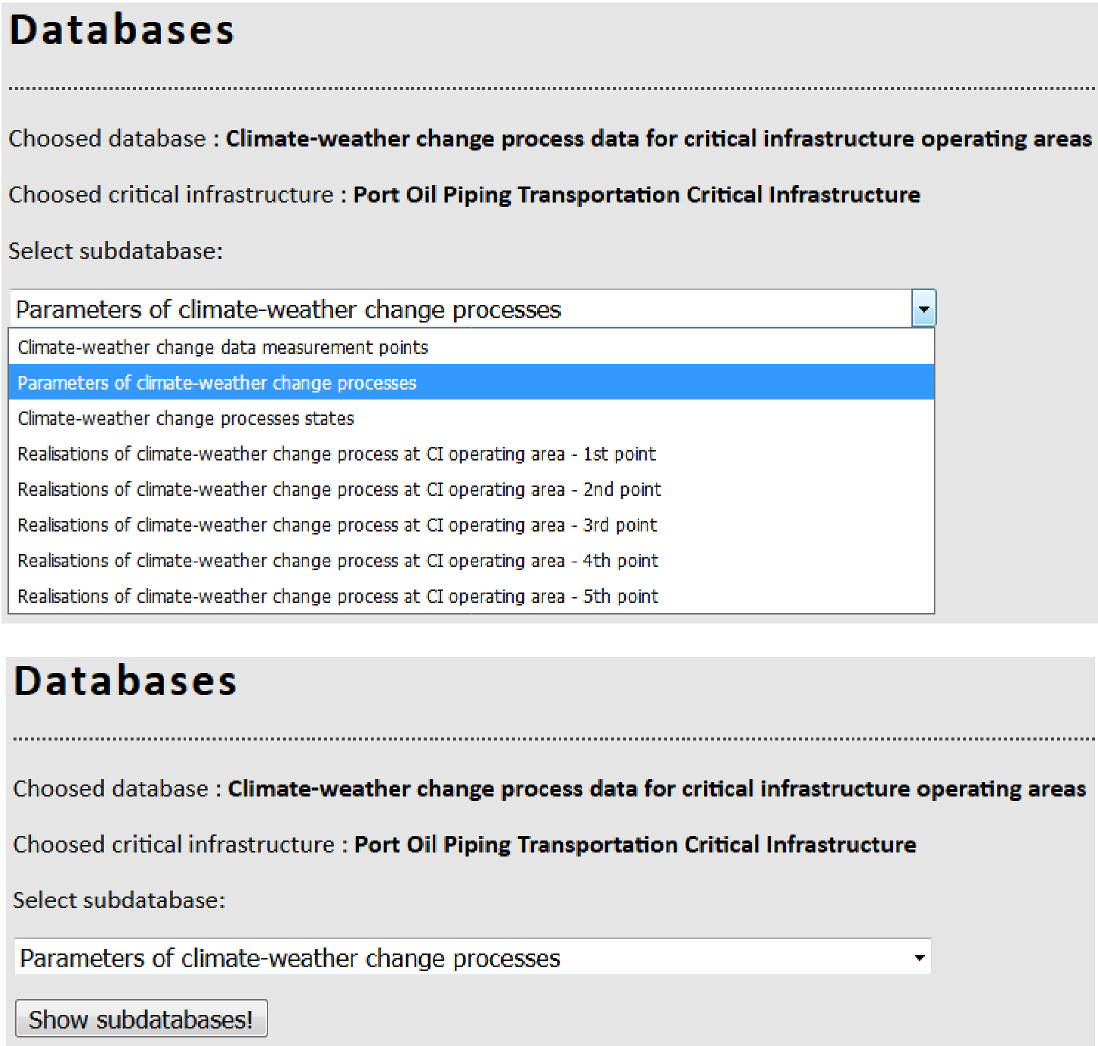


Figure 7. Selection exemplary subdatabase (case 2)

After clicking button "Show subdatabases!", selected subdatabase appears in the new tab (*Figure 8*).

Selected database : **Climate-weather change process data for critical infrastructure operating areas**

Selected critical infrastructure : **Port oil piping critical infrastructure**

Selected subdatabase : **Parameters of climate-weather change processes**

ID of CI operating area	First parameter	Unit of first parameter measurement	Second parameter	Unit of second parameter measurement
1	wave height	meters	wind speed	meters per second
2	air temperature	Celsius degrees	soil temperature	Celsius degrees

Figure 8. Data from selected subdatabase (case 2)

We get a table with the parameters of climate-weather change processes at the port oil piping critical infrastructure operating area. The single row of data contains:

- ID (identification number) of a different piping operating area,
- first parameter of the climate-weather change process at the considered piping operating area,
- unit of first parameter measurement of the climate-weather change process at the considered piping operating area,
- second parameter of the climate-weather change process at the considered piping operating area,
- unit of second parameter measurement of the climate-weather change process at the considered piping operating area.

For example, the first row includes information about that the climate-weather change process at the first piping operating area is described by two parameters: a wave height measured in meters and a wind speed measured in meters per second.

2.2. Organization and possibility of data processing application

"Data processing" consists of the software created with the JavaScript and PHP programming languages and supports main Impact Models [Blokus-Roszkowska A., Bogalecka M., Kołowrocki K., et. al., 2017] used in the Case Study [Bogalecka M., Kołowrocki K., Soszyńska-Budny J., et. al., 2017]. Links to the website with "Data processing" are shown in *Figure 9*. Moreover, the data processing selection field are presented in *Figures 9-10*.

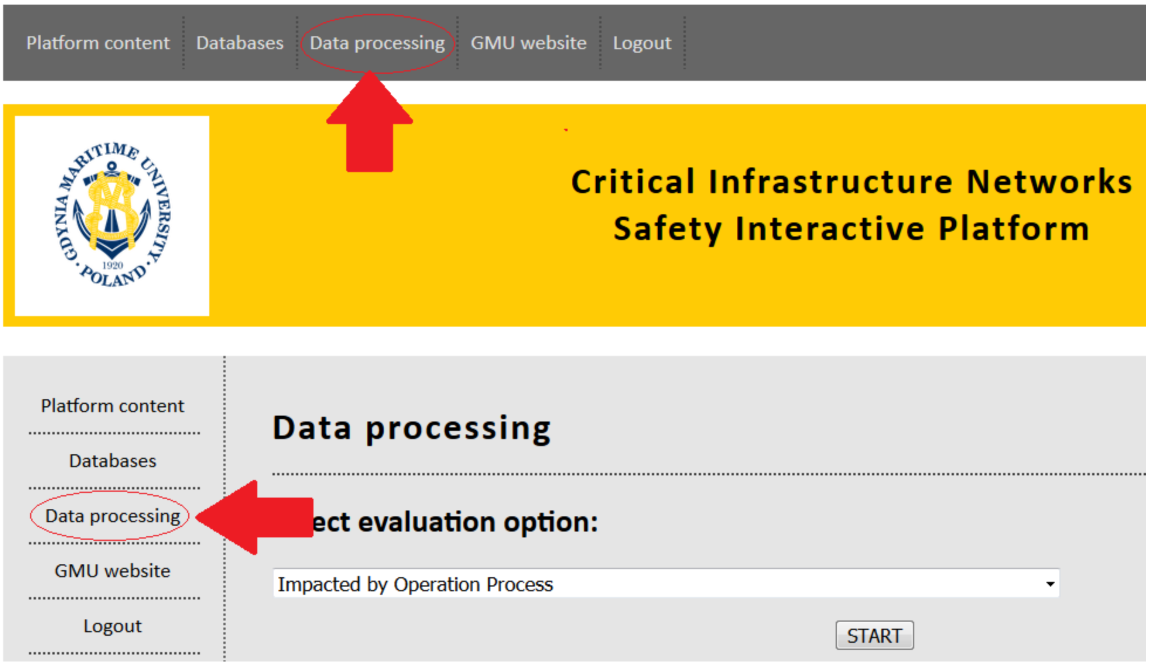


Figure 9. Links to "Data processing"

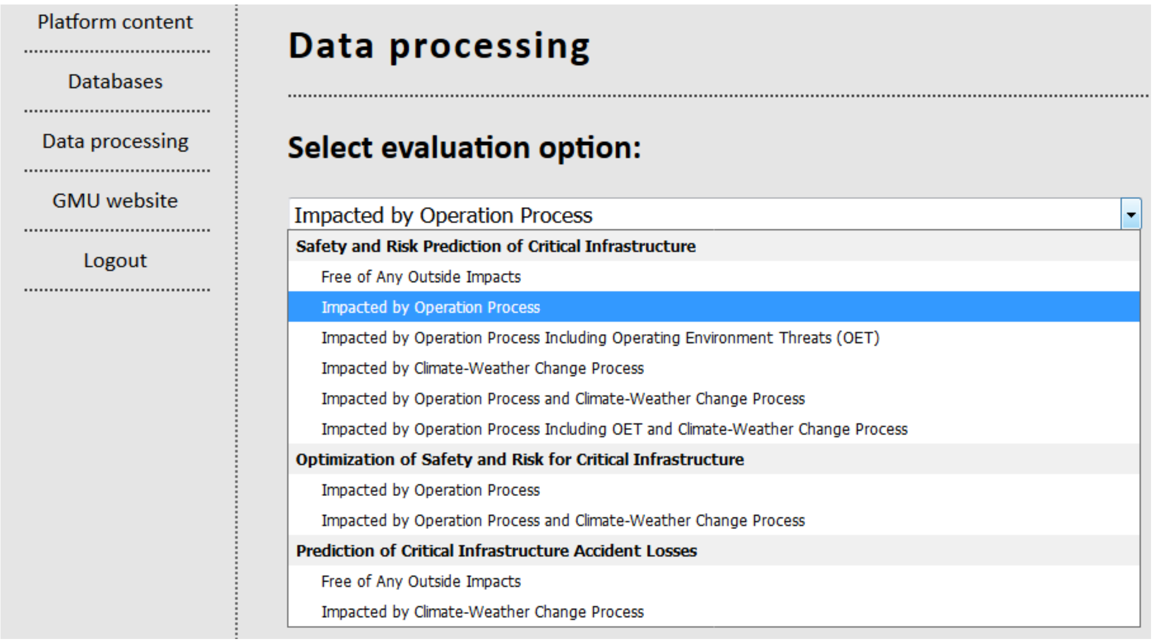


Figure 10. **"**Data processing" selection field

The available software based on Impact Models related to the Case Study are forming three groups:

i) the safety and risk prediction of the critical infrastructure,

ii) the optimization of the safety and risk for the critical infrastructure,

iii) the prediction of the critical infrastructure accident losses.

All of them are divided into cases depending on the choice of the impact process (considered impact processes are the operation process, the operation process including operating environment threats and the climate-weather change process) i.e. we distinguish the following software:

i) safety and risk prediction of the critical infrastructure:

1) free of any outside impacts,
2) impacted by its operation process,
3) impacted by its operation process including operating environment threats (OET),
4) impacted by the climate-weather change process,
5) impacted by its operation process and the climate-weather change process,
6) impacted by its operation process including OET and the climate-weather change process,

ii) optimization of safety and risk for the critical infrastructure:

1) impacted by its operation process,
2) impacted by its operation process and the climate-weather change process,

iii) prediction of the critical infrastructure accident losses:

1) free of any outside impacts,
2) impacted by the climate-weather change process.

The theoretical background of used Impact Models is presented in [Blokus-Roszkowska A., Bogalecka M., Kołowrocki K. et al., 2017]. Depending on the choice of the software, we have to enter several input data to receive results. Data entering in all softwares are very similar:

i) to predict or to optimize the safety and risk of the critical infrastructure we have to:

- enter data describing the critical infrastructure and its safety,
- enter data about processes impacting the critical infrastructure,
- enter data about the influence of impact processes on the critical infrastructure.

ii) to predict the critical infrastructure accident losses we have to:

- enter data describing the critical infrastructure initiating events process, the accident environment threats process, the accident environment degradation process and costs of accident consequences,
- enter data about the climate-weather change process impacting the accident losses,
- enter data about the influence of the climate-weather change process on the accident losses.

The detailed procedure of entering data is presented below for the safety and risk prediction of the exemplary critical infrastructure impacted by its operation process.

After selecting "Safety and Risk Prediction of Critical Infrastructure Impacted by Operation Process" in the software selection field (*Figure 10*), we have to enter CI safety input data (*Figures 11-13*). First of all, we select a number of CI safety states z (excluding 0) and a type of the CI safety structure (*Figure 11*). Next, we enter the critical safety state r, the CI risk function permitted level δ and the number of CI assets n (*Figure 12*). Further, we have to input mean values of CI assets lifetimes in the particular safety state subsets (*Figure 13*).

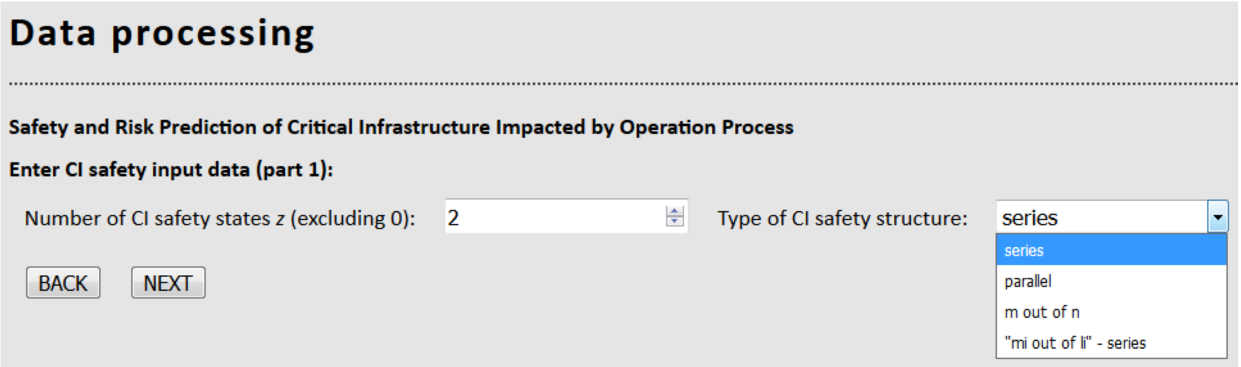


Figure 11. Entering exemplary CI safety input data (part 1)

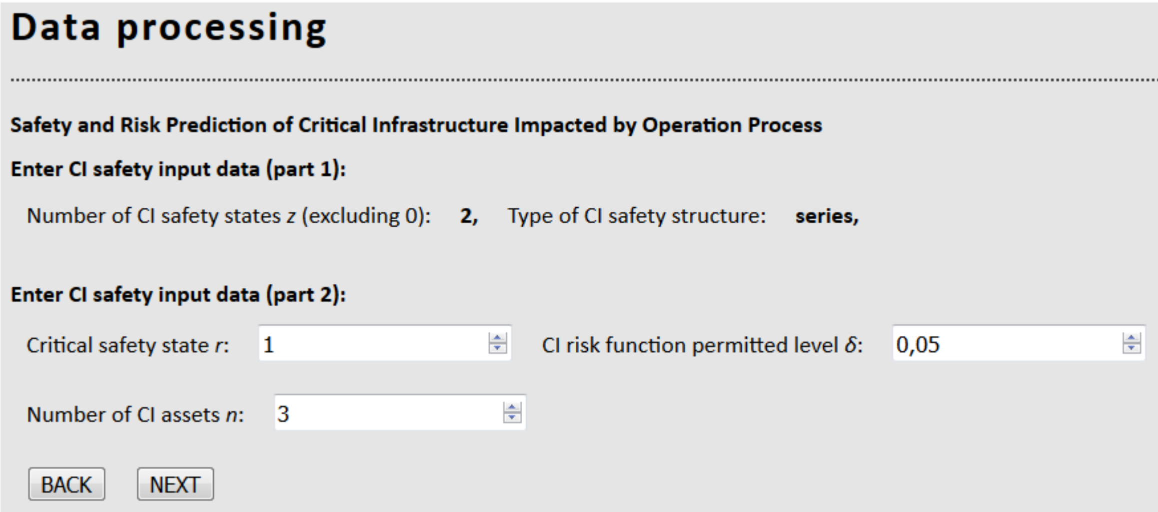


Figure 12. Entering exemplary CI safety input data (part 2)

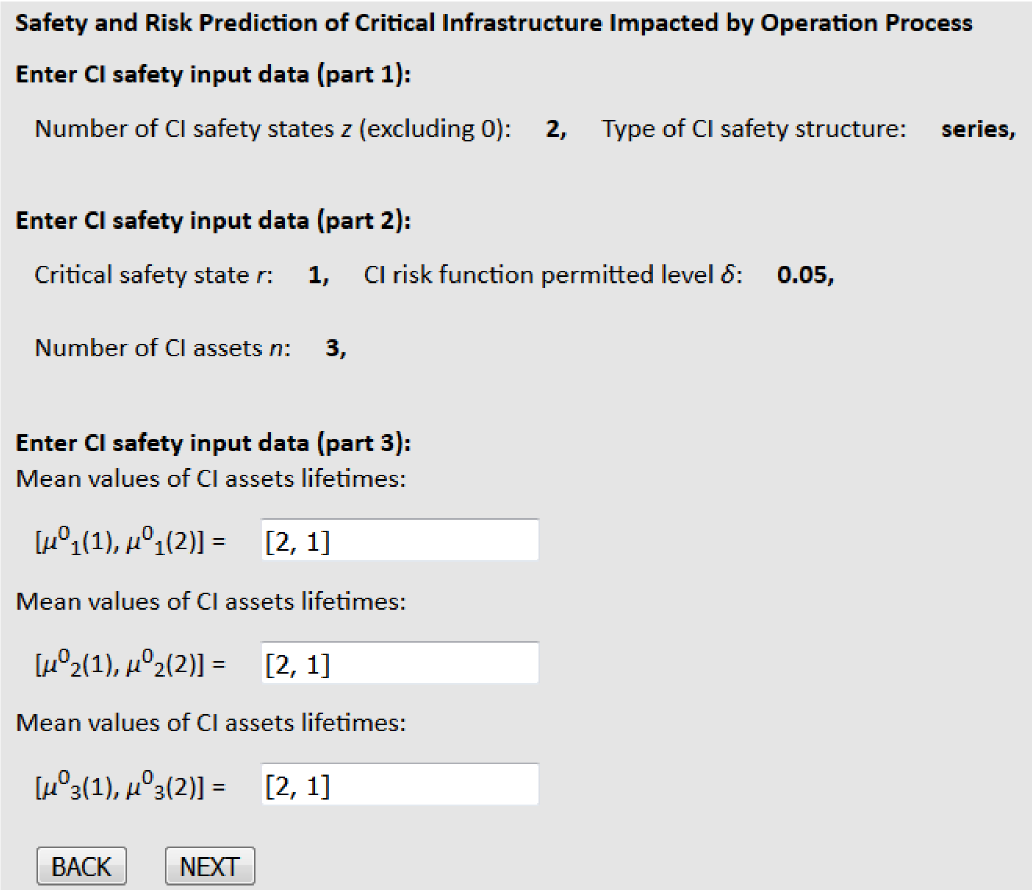


Figure 13. Entering exemplary CI safety input data (part 3)

In the next step, we have to describe main parameters of the CI operation process:

– a number of operation process states v (*Figure 14*),
– transient probabilities of the operation process at particular states z_b, $b = 1,2, \ldots, v$ (*Figure 15*).

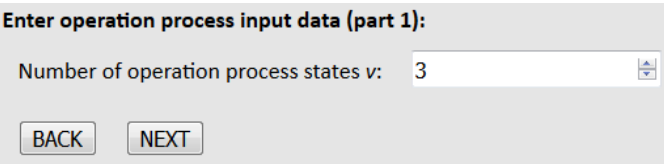


Figure 14. Entering exemplary operation process input data (part 1)

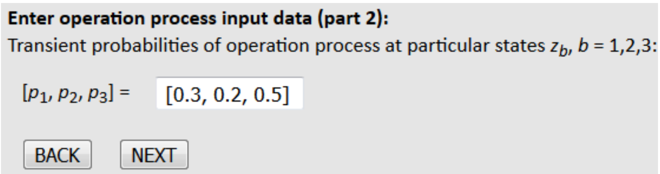


Figure 15. Entering exemplary operation process input data (part 2)

Finally, we have to input coefficients of the operation process impact on CI assets intensities of degradation (*Figure 16*).

Figure 16. Entering exemplary operation process input data (part 3)

After clicking button “Next”, we receive an information about correctness of the entered data (*Figure 17*) and we are able to go to the website with the evaluated safety and risk indicators of a critical infrastructure impacted by the operation process (*Figure 18*).

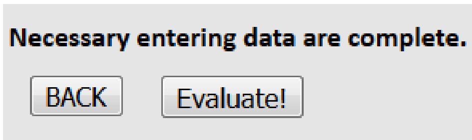


Figure 17. End of entering exemplary input data

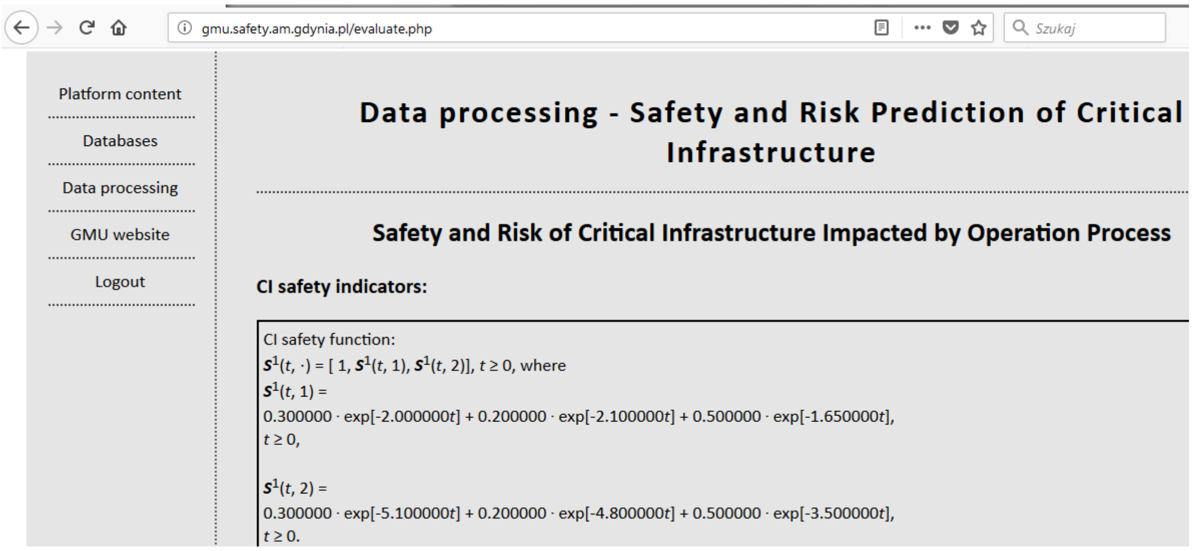


Figure 18. Website with exemplary CI output data

The output data (CI safety indicators) in the case of “Safety and Risk Prediction of Critical Infrastructure Impacted by Operation Process” are:

– the CI safety function and graphs of its coordinates (*Figures 19-20*),

CI safety function:

$\boldsymbol{S}^1(t, \cdot) = [\,1, \boldsymbol{S}^1(t, 1), \boldsymbol{S}^1(t, 2)],\ t \geq 0$, where

$\boldsymbol{S}^1(t, 1) =$

$0.300000 \cdot \exp[-2.000000t] + 0.200000 \cdot \exp[-2.100000t] + 0.500000 \cdot \exp[-1.650000t]$,

$t \geq 0$,

$\boldsymbol{S}^1(t, 2) =$

$0.300000 \cdot \exp[-5.100000t] + 0.200000 \cdot \exp[-4.800000t] + 0.500000 \cdot \exp[-3.500000t]$,

$t \geq 0$.

Figure 19. Exemplary CI safety function

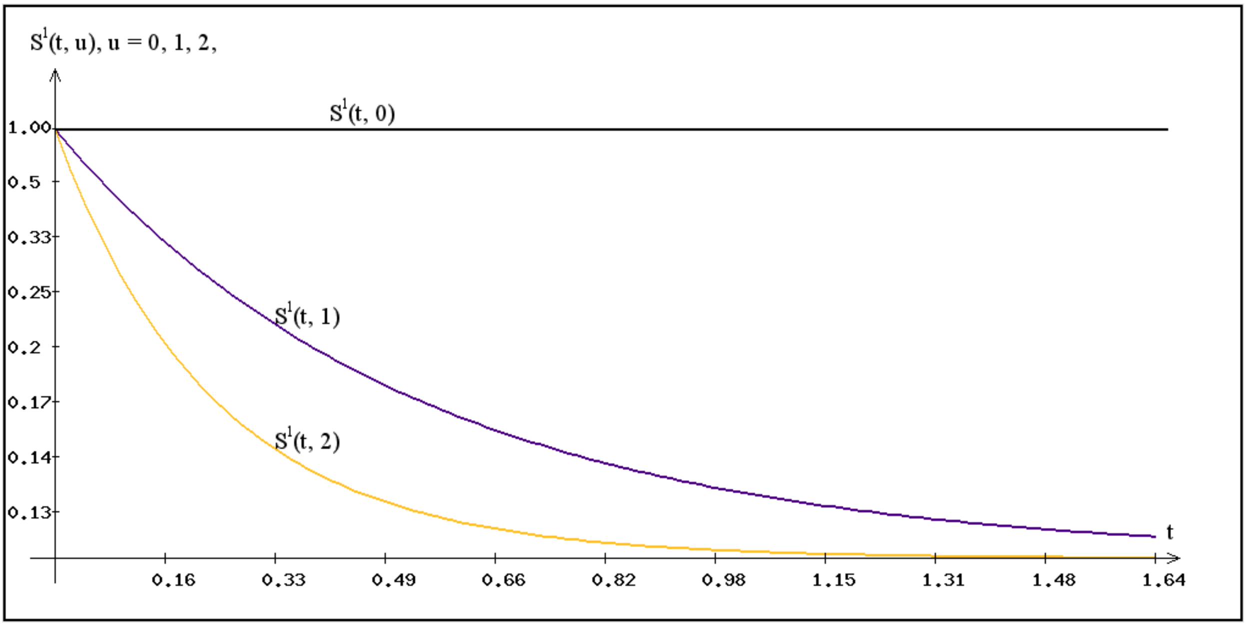


Figure 20. Graphs of exemplary CI safety function coordinates

– unconditional expected values and standard deviations of CI lifetimes in safety state subsets (*Figure 21*),
– conditional expected values of CI lifetimes in safety state subsets (*Figure 21*),

Expected values and standard deviations of CI lifetimes:
- in safety state subset {1, 2}:
$\boldsymbol{\mu}^1(1) = 0.5483$, $\boldsymbol{\sigma}^1(1) = 0.5544$,
- in safety state subset {2}:
$\boldsymbol{\mu}^1(2) = 0.2433$, $\boldsymbol{\sigma}^1(2) = 0.2507$.

Conditional expected values of CI lifetimes:
- in safety state subset {1, 2}:
$[[\boldsymbol{\mu}^1(1)]^b]_{1\times 3} = [0.5, 0.47619, 0.606061]$,
- in safety state subset {2}:
$[[\boldsymbol{\mu}^1(2)]^b]_{1\times 3} = [0.196078, 0.208333, 0.285714]$,

Figure 21. Conditional and unconditional expected values and standard deviations of exemplary CI lifetimes in safety state subsets

– expected values of CI lifetimes in particular safety states (*Figure 22*),

Expected values of CI lifetimes:
- in safety state 1: $\bar{\boldsymbol{\mu}}^1(1) = 0.305$,
- in safety state 2: $\bar{\boldsymbol{\mu}}^1(2) = 0.2433$.

Figure 22. Expected values of exemplary CI lifetimes in particular safety states

– the mean value and the standard deviation of the CI lifetime up to exceeding the critical safety state *r* (*Figure 23*),
– the moment of exceeding by the CI risk function the permitted level δ (*Figure 23*),
– the CI risk function and its graph (the damage curve) (*Figures 24-25*),
– CI intensities of degradation and their graphs (*Figures 26-27*),

Mean value and standard deviation of CI lifetime up to exceeding critical safety state *r*:
$\boldsymbol{\mu}^1(1) = 0.5483$, $\boldsymbol{\sigma}^1(1) = 0.5544$.

Moment of exceeding by CI risk function permitted level $\delta = 0.05$:
$\boldsymbol{\tau}^1 = (\boldsymbol{r}^1)^{-1}(0.05) = 0.0278$.

Figure 23. Exemplary CI safety indicators

CI risk function:
$\boldsymbol{r}^1(t) = 1 - \boldsymbol{S}^1(t, 1) =$
$1 - (0.300000\exp[-2.000000t] + 0.200000\exp[-2.100000t] + 0.500000\exp[-1.650000t]),\ t \ge 0.$

Figure 24. Exemplary CI risk function

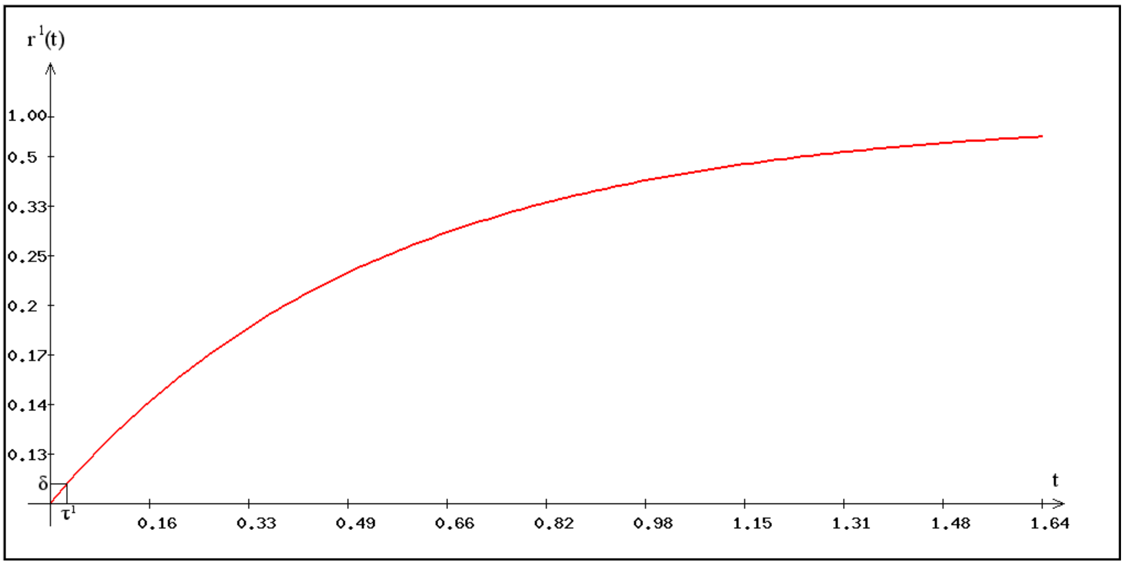


Figure 25. Graph of exemplary CI risk function (damage curve)

CI intensities of degradation:

$\boldsymbol{\lambda}^1(t, 1)$ =
{2.000000 · 0.300000exp[-2.000000t] + 2.100000 · 0.200000exp[-2.100000t] + 1.650000 · 0.500000exp[-1.650000t]}/{0.300000 · exp[-2.000000t] + 0.200000 · exp[-2.100000t] + 0.500000 · exp[-1.650000t]},
$t \geq 0$,

$\boldsymbol{\lambda}^1(t, 2)$ =
{5.100000 · 0.300000exp[-5.100000t] + 4.800000 · 0.200000exp[-4.800000t] + 3.500000 · 0.500000exp[-3.500000t]}/{0.300000 · exp[-5.100000t] + 0.200000 · exp[-4.800000t] + 0.500000 · exp[-3.500000t]},
$t \geq 0$.

Figure 26. Exemplary CI intensities of degradation

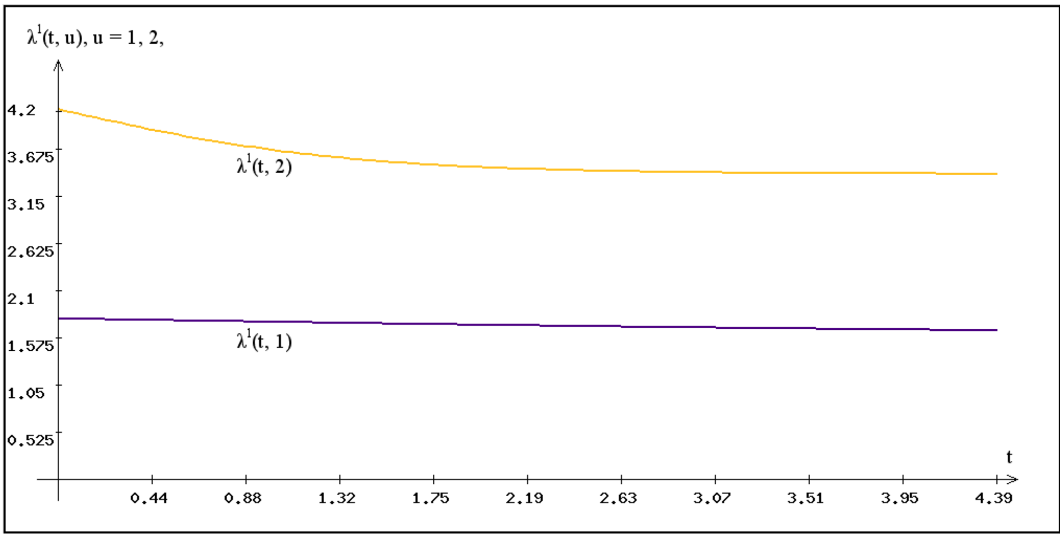


Figure 27. Graphs of exemplary CI intensities of degradation

– limit values of CI intensities of degradation (*Figure 28*),
– expected values and standard deviations of CI lifetimes free of any outside impacts (*Figure 28*),
– graph of coefficients of the operation process impact on CI intensities of degradation (*Figure 29*),

Limit values of CI intensities of degradation:

$\boldsymbol{\lambda}^1(1) = \lim_{t \to \infty} \lambda^1(t, u) = 1.8446077867789$,

$\boldsymbol{\lambda}^1(2) = \lim_{t \to \infty} \lambda^1(t, u) = 3.5$,

Expected values and standard deviations of CI lifetimes free of any outside impacts:
- in safety state subset {1, 2}:
$\boldsymbol{\mu}^0(1) = 0.6667$, $\boldsymbol{\sigma}^0(1) = 0.6667$,
- in safety state subset {2}:
$\boldsymbol{\mu}^0(2) = 0.3333$, $\boldsymbol{\sigma}^0(2) = 0.3333$.

Figure 28. Exemplary CI safety indicators

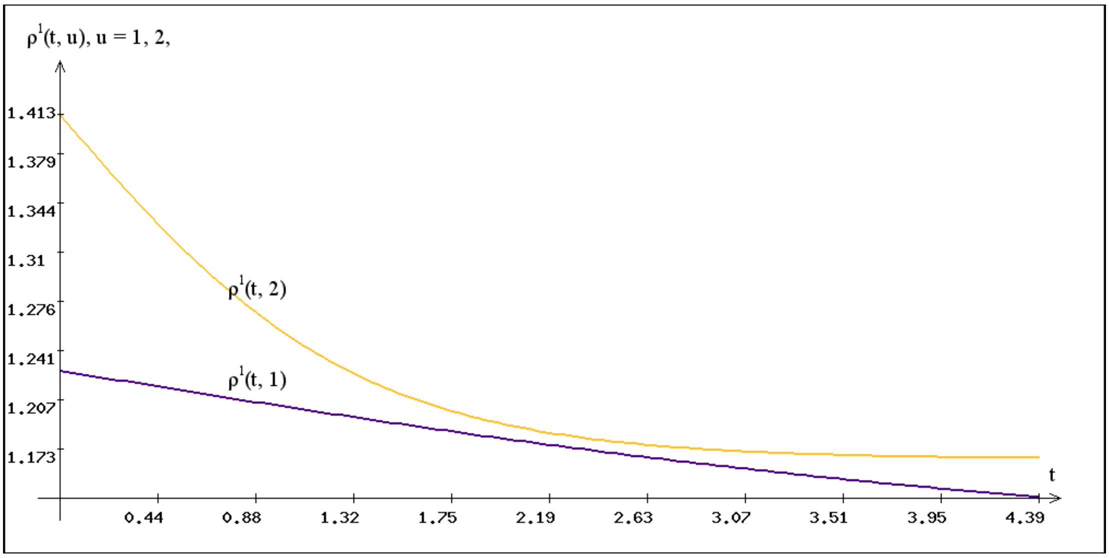


Figure 29. Graphs of coefficients of operation process impact on exemplary CI intensities of degradation

- coefficients of the operation process impact on CI intensities of degradation related to mean values of CI lifetimes in safety state subsets (*Figure 30*),
- indicator of the critical infrastructure resilience to the operation process impact related to mean values of CI lifetimes in safety state subsets (*Figure 30*),
- indicator of the critical infrastructure resilience to the operation process impact related to limit values of CI intensities of degradation (*Figure 30*).

Coefficients of operation process impact on CI intensities of degradation related to mean values of CI lifetimes in safety state subsets:
$\boldsymbol{\rho}^1(1) = \boldsymbol{\mu}^0(1) / \boldsymbol{\mu}^1(1) = 1.2159$,
$\boldsymbol{\rho}^1(2) = \boldsymbol{\mu}^0(2) / \boldsymbol{\mu}^1(2) = 1.3698$,

Indicator of CI resilience to operation process impact related to mean values of CI lifetimes in safety state subsets:
$\boldsymbol{RI}^1(1) = 1 / \boldsymbol{\rho}^1(1) = 0.8224 = 82.24\%$.

Indicator of CI resilience to operation process impact related to limit values of CI intensities of degradation:
$\boldsymbol{RI}^1(1) = \boldsymbol{\lambda}^0(1)/\boldsymbol{\lambda}^1(1) = 0.9091 = 90.91\%$.

Figure 30. Exemplary CI resilience indicators

3. Future plans for GMU Platform application

3.1 Future plans for databases application

Currently, the main application of “Databases” is storing data ordered in tables. User may send to the GMU Platform administrator their databases to share them or to store them in the GMU Platform. In future, we are planning add more functionality of “Databases” i.e. there will be added new data selection functions. For example, it will be able to show the data of climate-weather change processes realisations from particular months.

3.2 Future plans for data processing application

“Data processing” is currently used as a practical tool for the evaluation and prediction output indicators of main Impact Models [Blokus-Roszkowska A., Bogalecka M., Kołowrocki K., et. al., 2017] for the Case Study [Bogalecka M., Kołowrocki K., Soszyńska-Budny J., et. al., 2017]. Through placing this software on the GMU Platform, user can apply Impact Models to own case studies. In the future, we are planning to add more software based on Impact Models and to expand the actually existed software. For example, the number of available types of critical infrastructure structures will be increased in the safety and risk prediction of the critical infrastructure. Moreover, the optimization losses software will be added in the case of the prediction of the critical infrastructure accident losses.

4. Conclusions

GMU Safety Interactive Platform consisting of two different parts: "Databases" and "Data processing", fulfills several functions. "Databases" is applied as a place to store data used in the Case Study [Bogalecka M., Kołowrocki K., Soszyńska-Budny J., et. al., 2017], "Data processing" are used to evaluate indicators from Impact Models [Blokus-Roszkowska A., Bogalecka M., Kołowrocki K., et. al., 2017], where input data are prepared on the basis of the data given in "Databases". In the future, the GMU Platform will be expanded in order to make it more functional and friendly for users and as well as to increase the number of available models.

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