Torbicki Mateusz 0000-0003-4182-1932
Gdynia Maritime University, Gdynia, Poland, m.torbicki (at) wn.umg.edu.pl

Drabiński Bartosz 0000-0002-5379-0267
Gdynia, Poland, drabart (at) outlook.com

An application determining weather impact on critical infrastructure safety and resilience

Keywords

computer application, critical infrastructure, Python, safety, resilience, weather impact

Abstract

The organisation of an application calculating indicators of the weather impact on the critical infrastructure safety and resilience and reasons for creating it are described. The process of determining the indicators for an exemplary critical infrastructure influenced by extreme weather hazards is conducted in aim to show right usage of the application.

1. Introduction

The issue related to the weather impact on the critical infrastructure (CI) safety and resilience is discussed in [1]–[5]. Moreover, in order to make easier analyzing this problem even by critical infrastructure operators with lack of mathematical skills, Gdynia Maritime University (GMU) Safety Interactive Platform http://gmu.safety.umg.edu.pl/ was created.

It contains a guidebook, databases related with safety and resilience of real critical infrastructures, training courses from which it is possible to learn about evaluation of safety and resilience indicators of critical infrastructures impacted by their operation process and/or extreme weather conditions and a module titled "Data processing" (*Figure 1*).

This part uses algorithms and formulas from training courses to evaluate mentioned safety and resilience indicators after entering the safety input data by users.

Unfortunately, despite the automation of determining the indicators, the module has some significant drawbacks. First, the look of it is like calculator and because of this it can be unpleasant for some people and repel them. The analyzed safety structures are limited only to "series", "parallel", "m out of n" and "m_i out of l_i-series" and finally, the multitude of indicators can be overwhelming and some of them can be hard to understand for the average user without a math background (*Figures 2–3*).

In aim to improve those disadvantages there is created the application in Python called "WICISAR" (the application determining *Weather Impact on Critical Infrastructure Safety and Resilience*) which description and possibility of application are discussed in this paper. Shortly, it is more practical tool than "Data processing" from GMU Safety Platform because there is a possibility of marking locations of critical infrastructure assets on the map and creating complex safety structures and the safety and resilience indicators are limited to the most basic and easy to understand.

2. Description of WICISAR application

The WICISAR is written in Python with using PyGame. In *Figures 3–4* are shown exemplary views of the WICISAR application. There are disguised three different areas (*Figure 3*):

1) the control panel,
2) the inputting and displaying data area,
3) the map.

DOI: 10.26408/srsp-2020-16

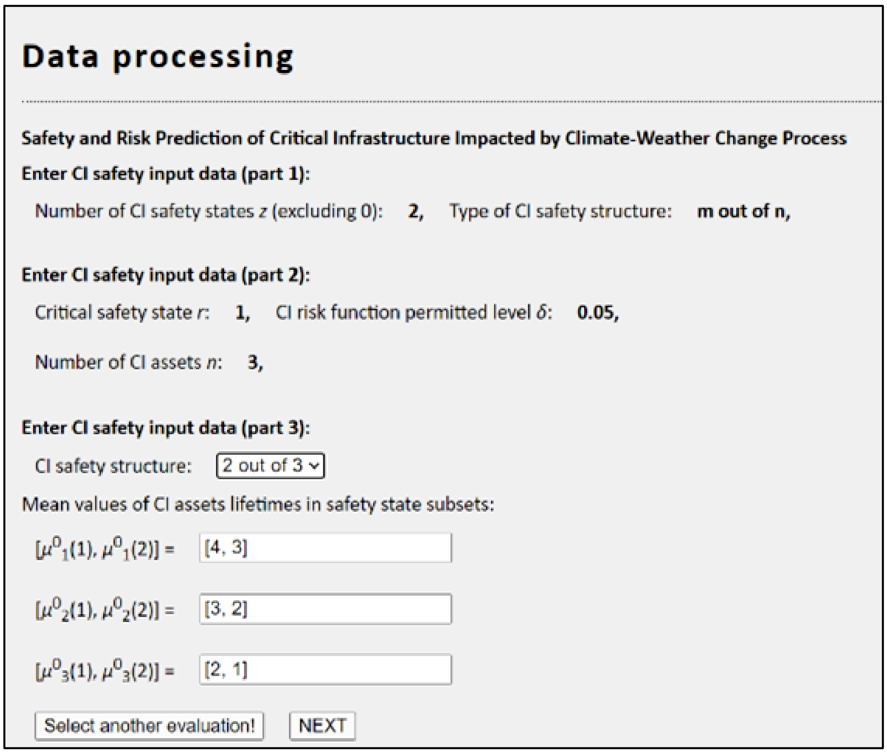

Figure 1. The view of inputting data in “Data processing”

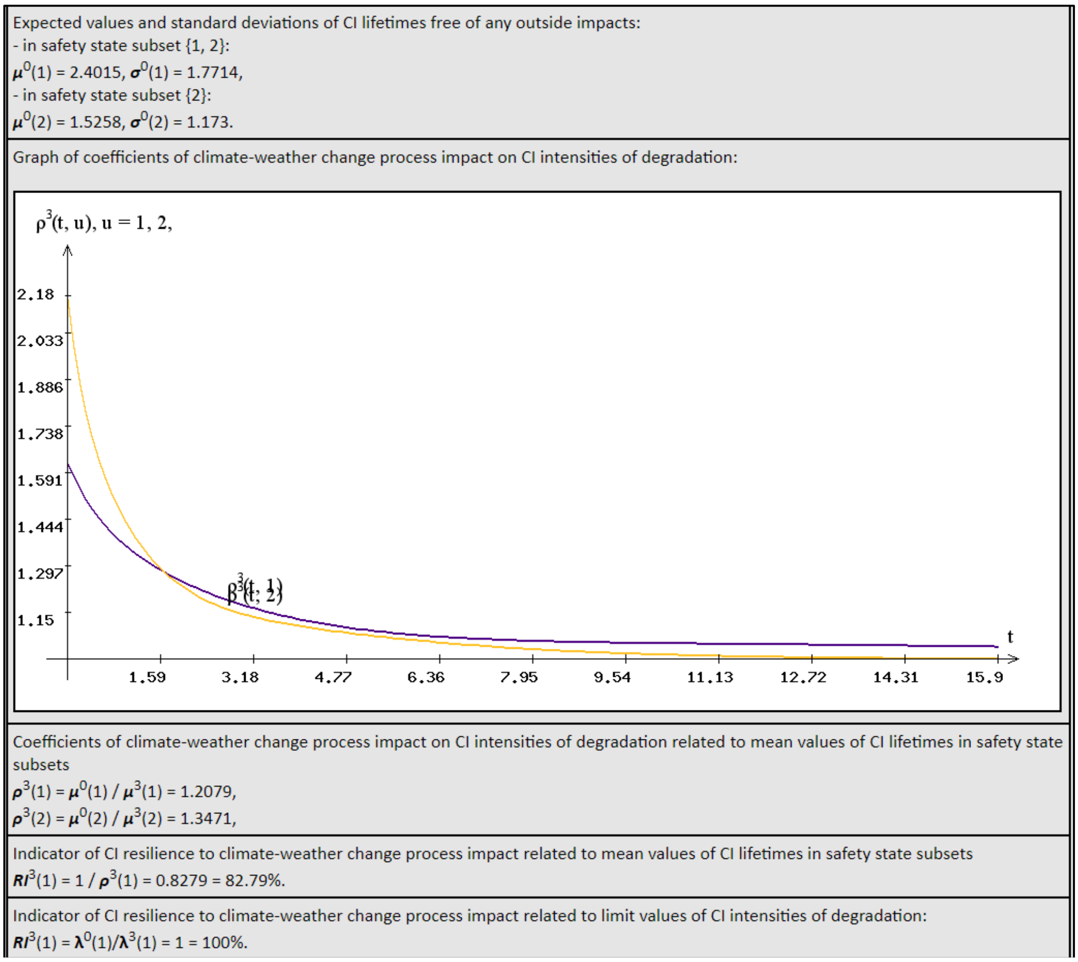

Figure 2. The view of the outputting data in “Data processing”

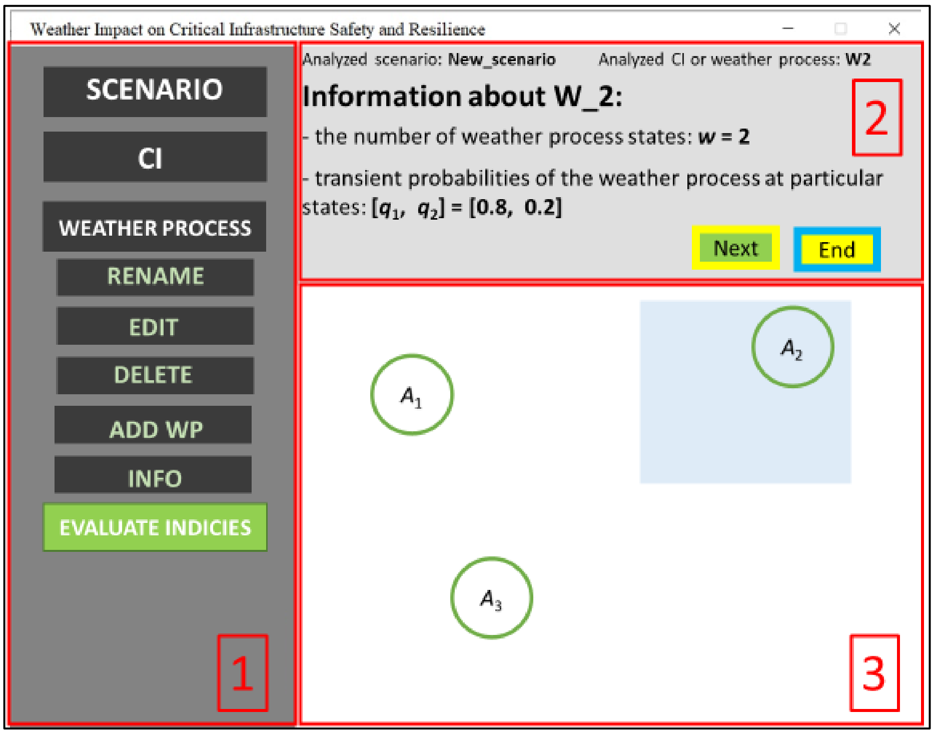

Figure 3. The view of the WICISAR application

In the first area are placed buttons to which are related different functions. They are divided into four groups (in brackets are explained assigned to buttons functions):

- buttons related to the scenario:
  - "New" (creating a new scenario),
  - "Load" (loading a saved scenario),
  - "Rename" (changing a name of a scenario),
  - "Save" (saving a scenario),
  - "Save and Exit" (saving scenario and exiting an application),
  - "Exit without Save" (exiting an application without saving a scenario),
  - "Delete" (deleting the created scenario);
- buttons related to critical infrastructures:
  - "Add CI" (creating a new critical infrastructure and adding it to the analysed scenario),
  - "Delete" (deleting the created critical infrastructure);
  - "Rename" (changing a name of a critical infrastructure),
  - "Edit" (editing the critical infrastructure data),
  - "Info" (displaying the critical infrastructure data);
- buttons related to weather processes influencing critical infrastructures operating area:
  - "Add WP" (creating a weather process and adding it to the analysed scenario),
  - "Delete" (deleting the created weather process);
  - "Rename" (changing a name of a weather process),
  - "Edit" (editing the weather process data)
  - "Info" (displaying the weather process data);
- a button related to evaluated indicators:
  - "Evaluate Indices" (displaying values of the indicator of the critical infrastructure resilience on extreme weather conditions in the graphic way),
  - "Detailed Values" (displaying of main critical infrastructure safety and resilience indicators).

The second area is dedicated to the inputting and outputting data. Moreover, there are showing tips helping users finishing the procedure of inputting data by displaying the required next steps. This area also includes the name of actually analyzed scenario, critical infrastructure and weather process. Also, the entering data is confirmed/denied here by pressing one of buttons.

On the map are marked locations of critical infrastructure assets and influencing areas of weather processes. Moreover, the procedure of creating safety structure of critical infrastructures allows on grouping assets into sub-critical infrastructures by pointing their locations on the map. It makes possible to input very complex critical infrastructures safety structure. Additionally, the received output data (the resilience indicator of the critical infrastructure on extreme weather conditions) are presented using colors of assigned to assets circles (*Figure 4*). Moreover, there is introduced a new indicator corresponded to colors of circumscribed squares of assigned to asset locations circles. It is created in aim to show which assets should be strengthened first against the negative effects of extreme weather hazards. It is a value of the resilience indicator in the case when the weather impact on the asset assigned to this square is half the value.

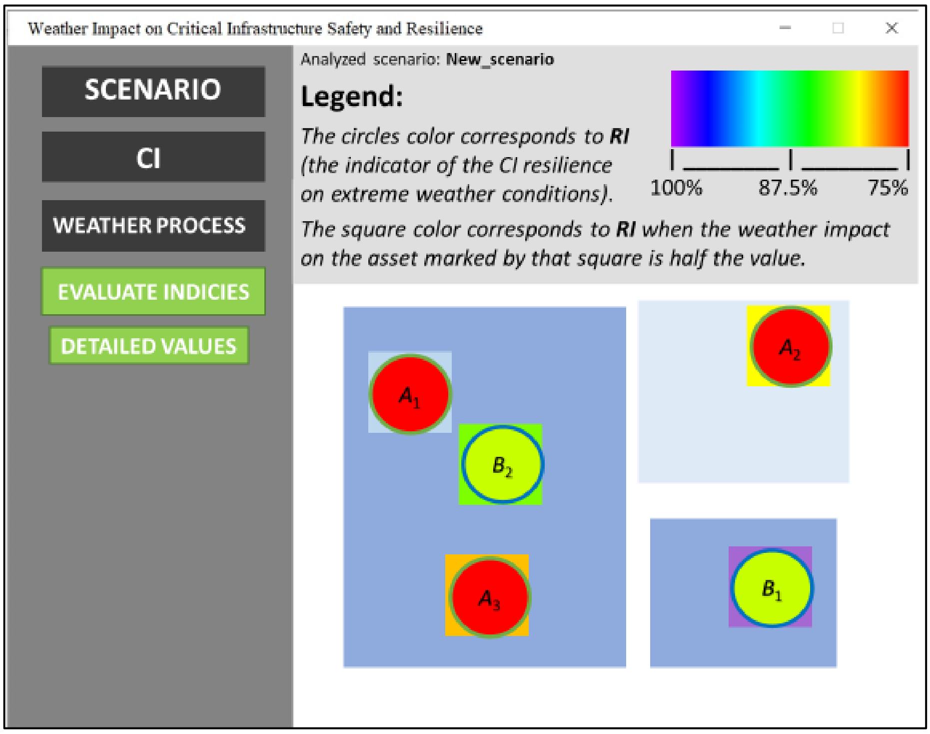

Figure 4. The view of the WICISAR output data

The detailed description of those parts is in next chapter containing a scenario with an exemplary critical infrastructure impacted by extreme weather conditions.

3. Executing an exemplary scenario

In aim to present in more detail way the WICISAR application, there is conducted the procedure of safety and resilience indicators evaluation of an exemplary critical infrastructure impacted by two different weather processes.

First, we have to create a new scenario containing a critical infrastructure and impacting it weather processes (*Figure 5*).

After that, we are able to add a critical infrastructure. Due to fact that the scenario could contain more than one critical infrastructure, we have to introduce a denoting of an analyzed critical infrastructure (*Figure 6*).

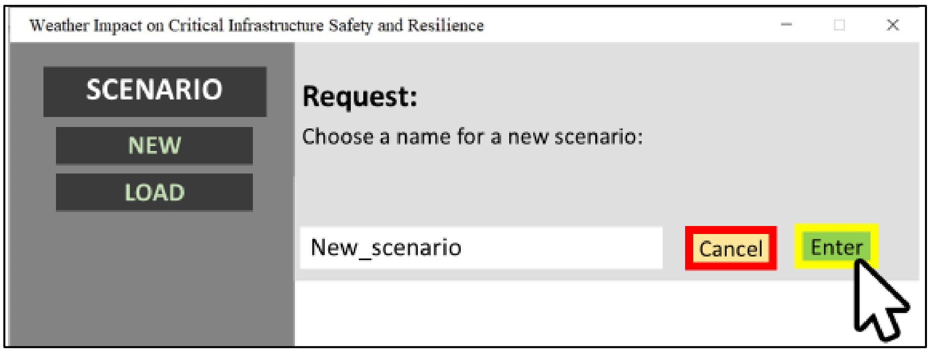

Figure 5. Naming a new scenario

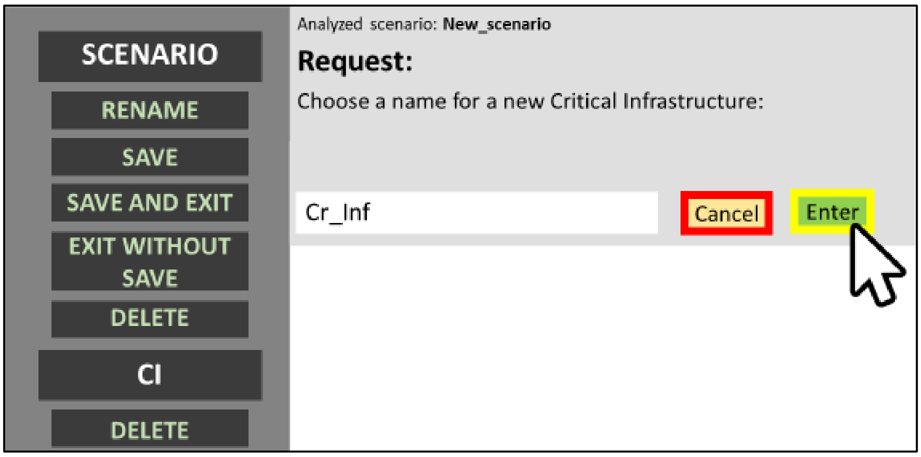

Figure 6. Denoting a new critical infrastructure

Next steps of inputting data related to the critical infrastructure safety are:

- fixing the number of CI safety states z excluding 0 (*Figure 7*)

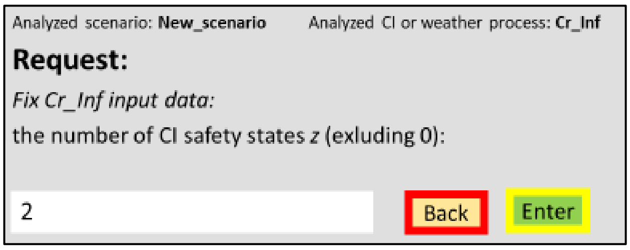

Figure 7. Fixing the number of CI safety states

- fixing the CI risk function permitted level δ (*Figure 8*)

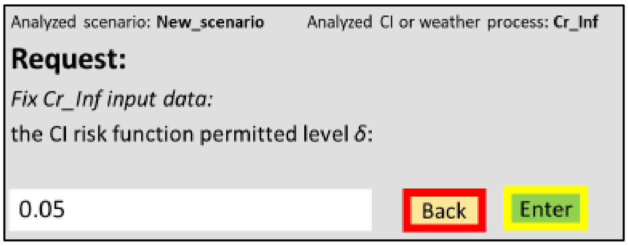

Figure 8. Fixing the CI risk function permitted level

- fixing the critical safety state r (*Figure 9*)

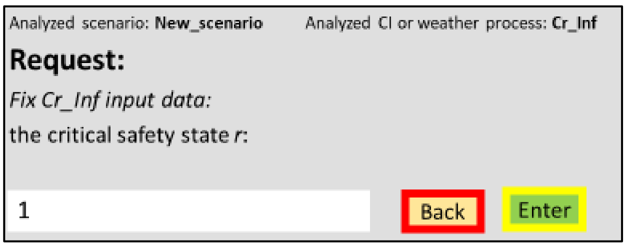

Figure 9. Fixing the critical safety state

- marking on the map locations of critical infrastructure assets (*Figures 10–11*)

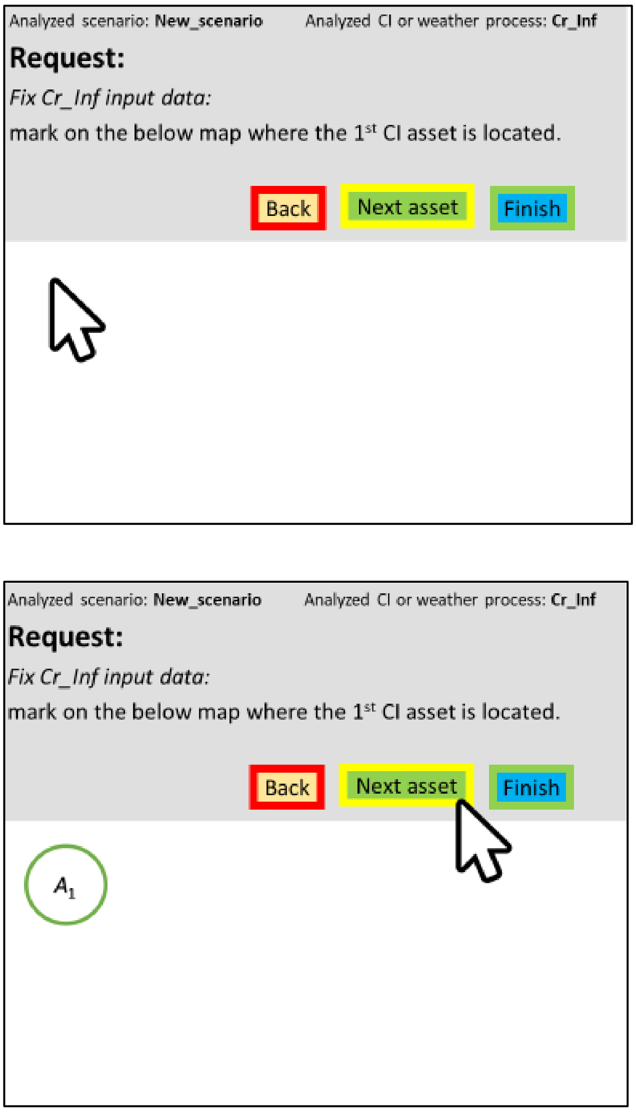

Figure 10. Marking on the map locations of assets (part 1)

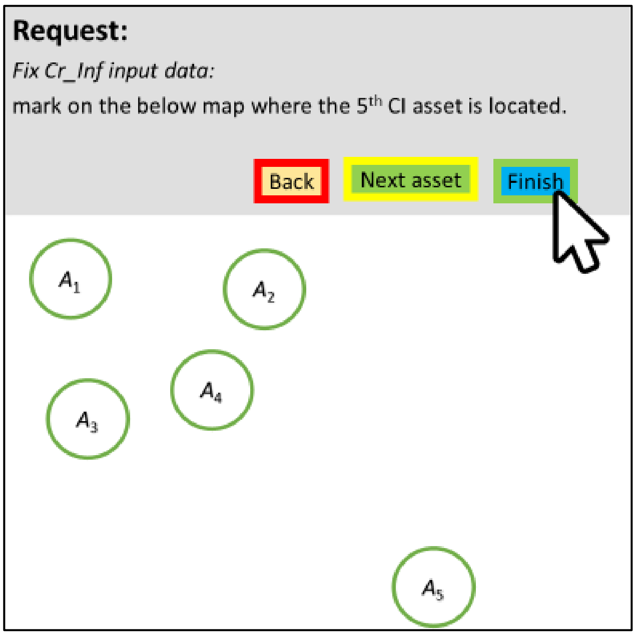

Figure 11. Marking on the map locations of assets (part 2)

- fixing the mean values of assets lifetimes in safety state subsets (*Figure 12*)

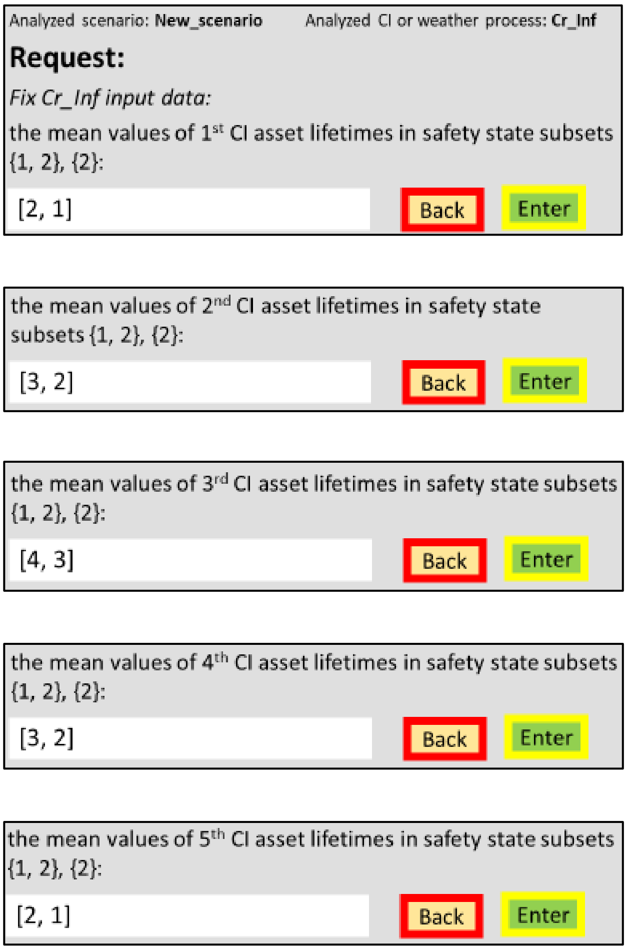

Figure 12. Fixing the mean values of assets lifetimes in safety state subsets

- grouping assets in the sub-critical infrastructure and fixing the safety structure of each sub-critical infrastructures in aim to introduce the safety structure of the whole critical infrastructure (*Figures 13–15*).

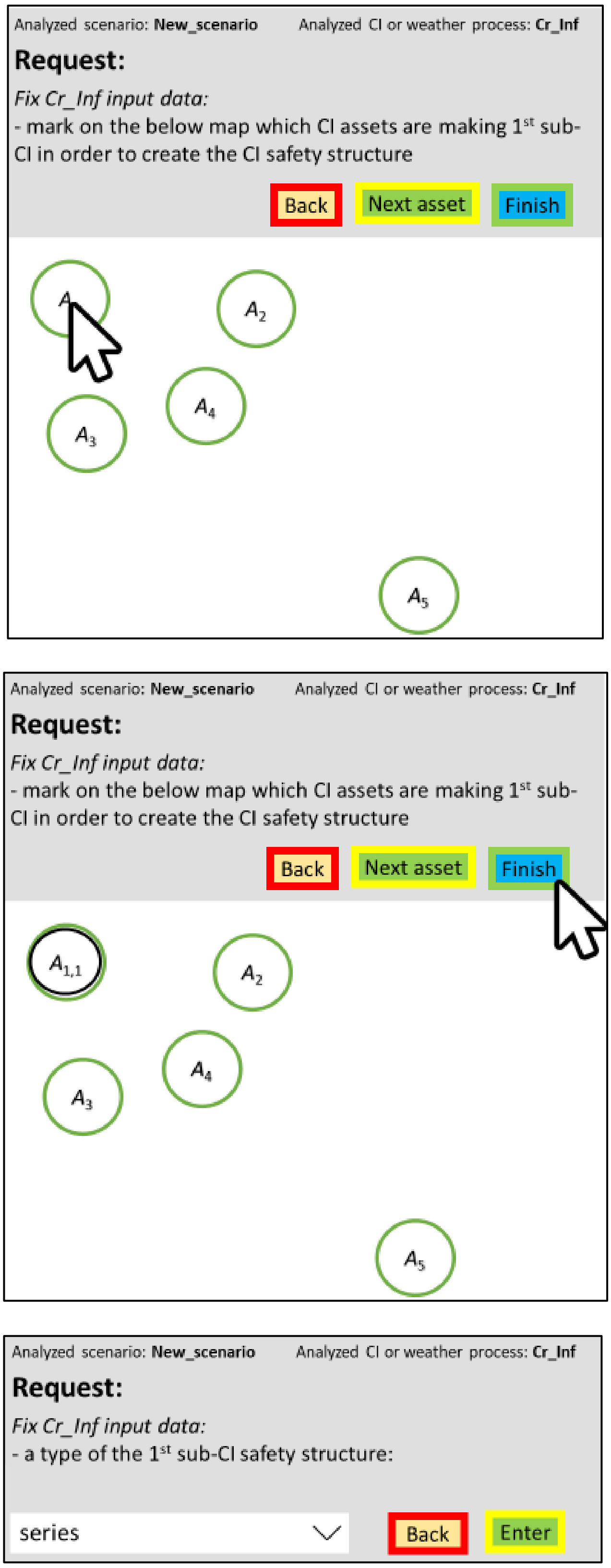

Figure 13. Fixing the safety structure (part 1)

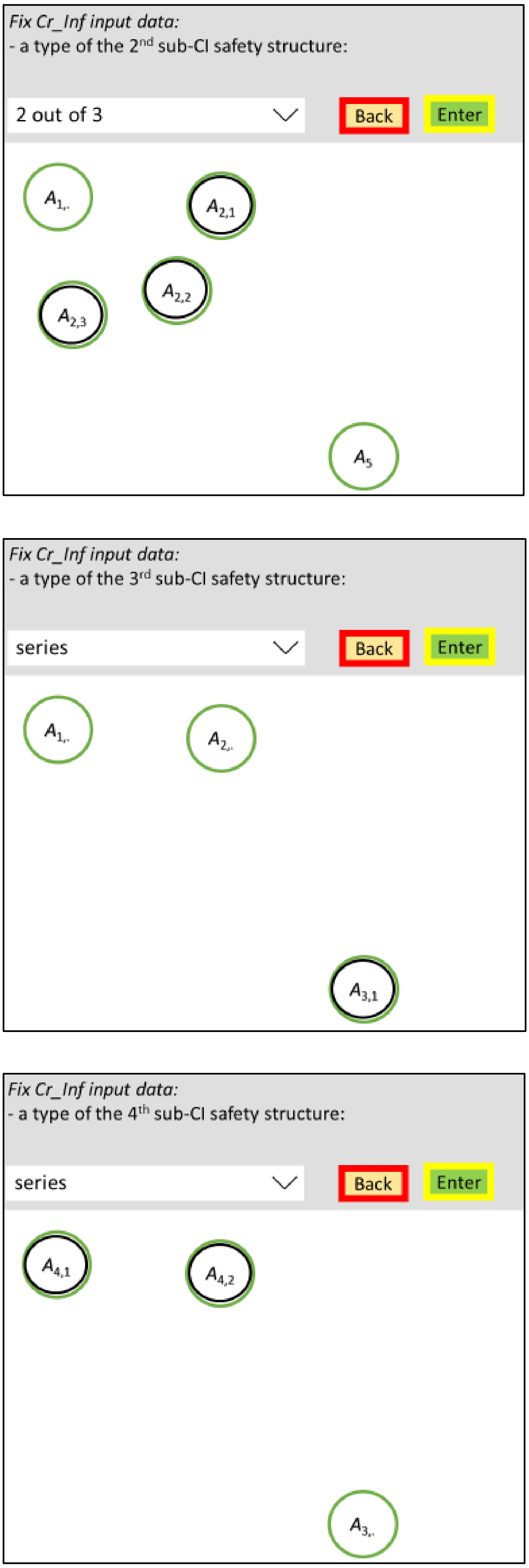

Figure 14. Fixing the safety structure (part 2)

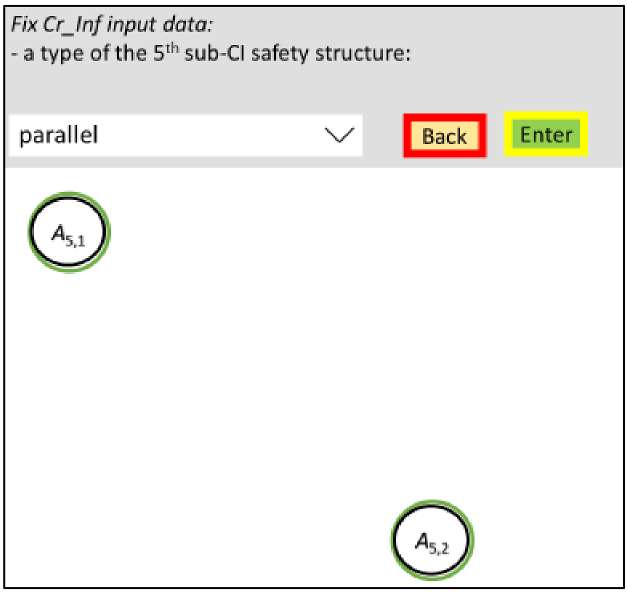

Figure 15. Fixing the safety structure (part 3)

The analyzed critical infrastructure safety structure is presented in *Figure 16*.

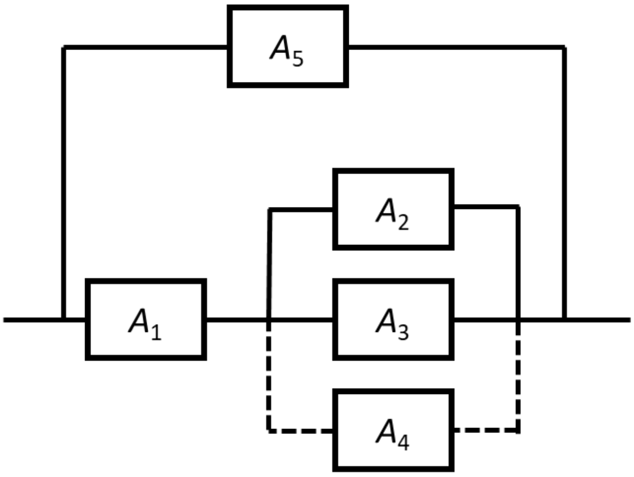

Figure 16. The safety structure considered in the scenario

Weather processes influencing the critical infrastructure safety are considered as semi-Markov processes. This indicates that the weather process input data are as follows:

- the denoting of the weather process (*Figure 17*),

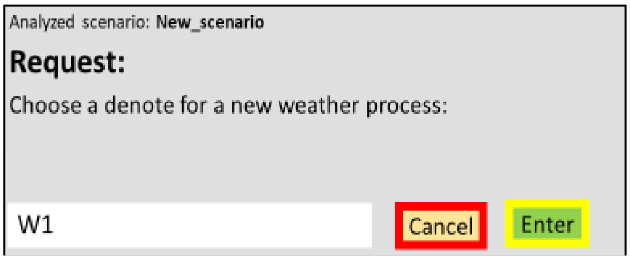

Figure 17. Denoting of the first weather process

- the number of weather process states *w* (*Figure 18*),
- transient probabilities of the weather process at particular weather states (*Figure 19*).

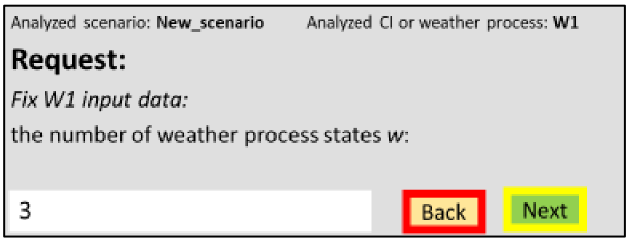

Figure 18. Fixing the number of weather process states

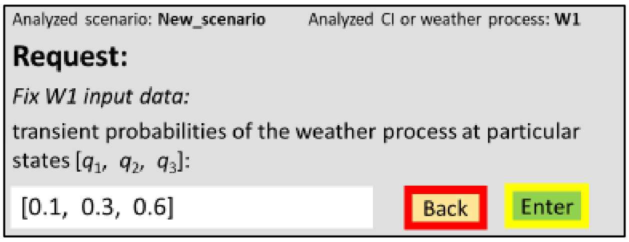

Figure 19. Fixing transient probabilities of the weather process at particular weather states

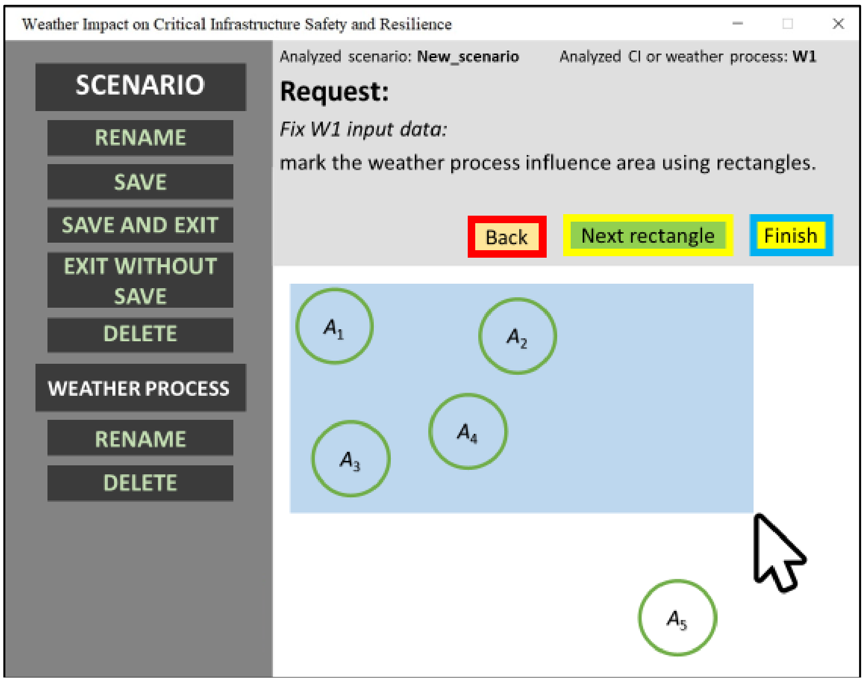

Figure 20. Marking the weather process influence area

Next, the user should mark on the map the weather process influence area including locations of impacted assets (*Figure 20*).

The weather affects on assets lifetime in safety states subsets depends on currently weather process states, therefore there should be introduced coefficients of the weather process impact on asset intensities of degradation at particular weather states (*Figures 21–23*).

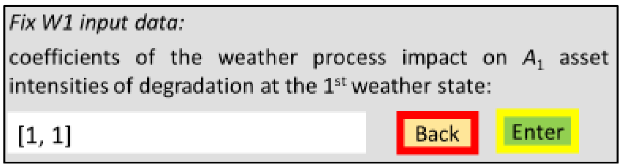

Figure 21. Fixing coefficients of the weather process impact on asset intensities of degradation (part 1)

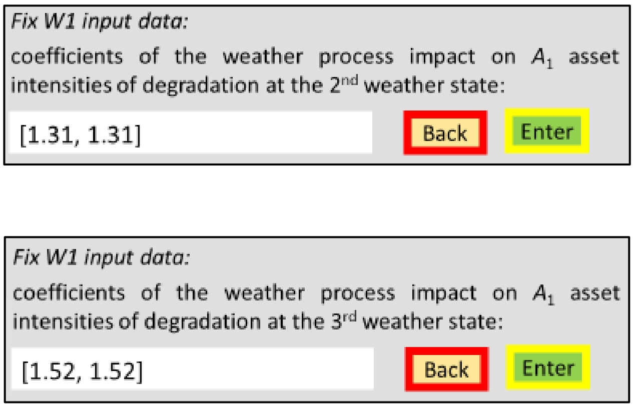

Figure 22. Fixing coefficients of the weather process impact (part 2)

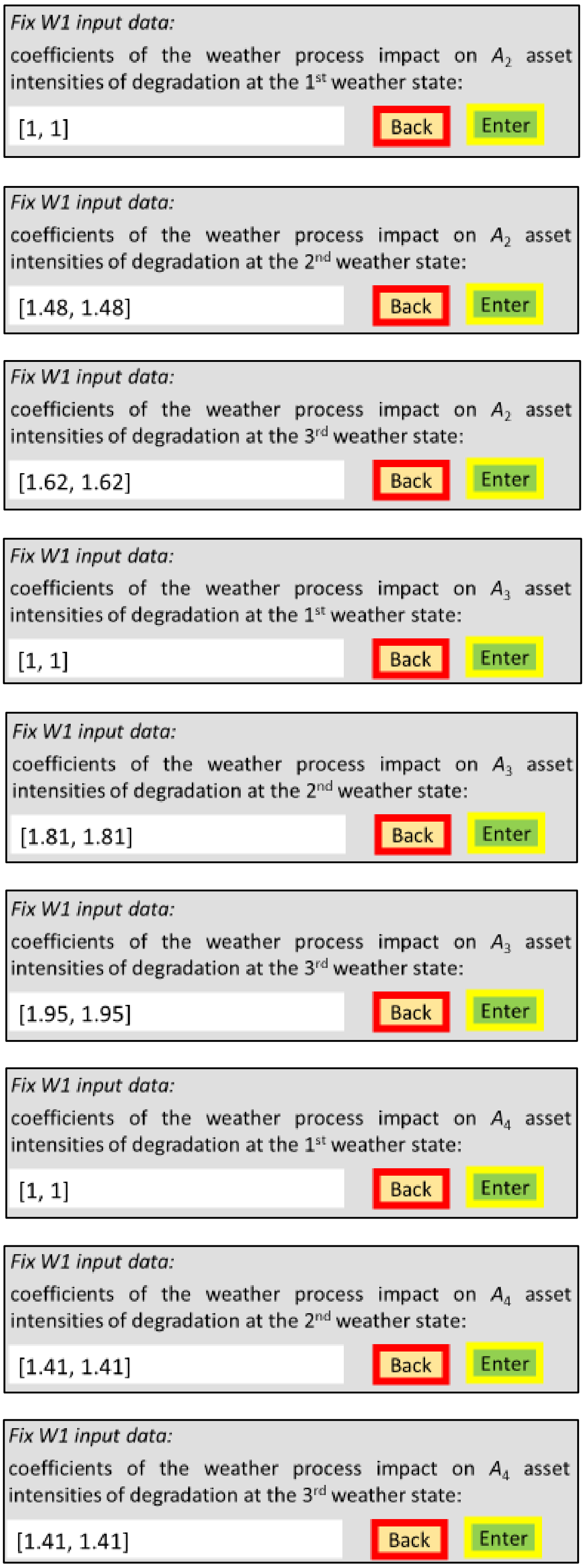

Figure 23. Fixing coefficients of the weather process impact (part 3)

The same procedure must be prepared during inputting data related to the second weather process impacting the A_5 asset (*Figure 24*).

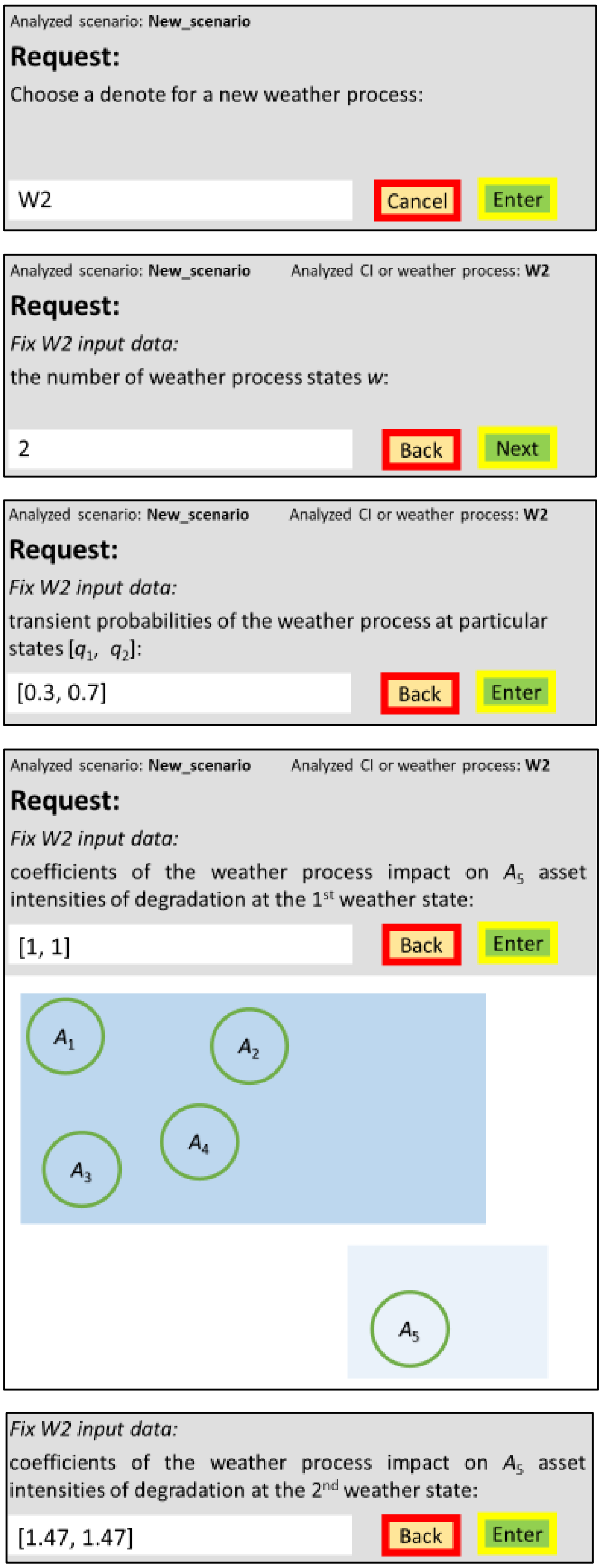

Figure 24. The second weather process input data

Finally, after entering all previously data we can determine safety and resilience indicators of the critical infrastructure. The two of them are presented in a graphic way using the color gradient (*Figure 25*).

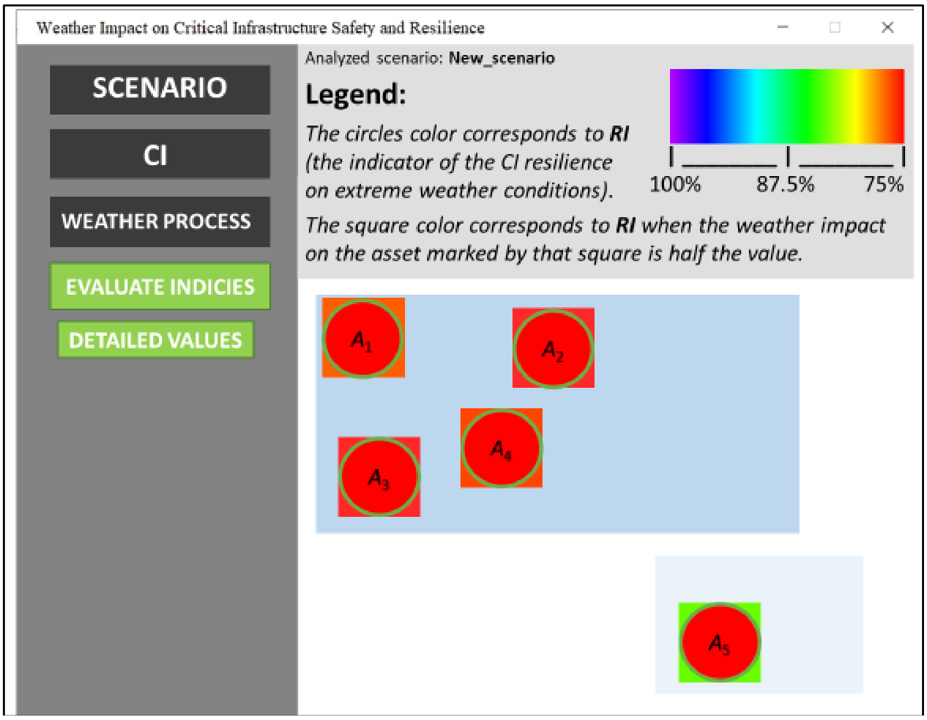

Figure 25. The view of the WICISAR output data

The first is the indicator of the critical infrastructure resilience on extreme weather hazards evaluated as

$$RI(r) = \mu_{WI}(r) \,/\, \mu_0(r), \qquad (1)$$

where $\mu_{WI}(r)$ and $\mu_0(r)$ respectively are the mean lifetimes of the CI in safety state subsets higher and equal the critical safety state calculated in the case when the weather impact on the critical infrastructure is considered and in the case when the weather impact is ignored. It corresponds to the fill color of circles related to assets.

The fill color of squares related to assets presents how the resilience indicator $RI(r)$ would equal if the weather impact on the asset assigned to the square was half the value. This indicator is marked by $RI_{half}(i)$, $i = 1,2,\ldots,n$, where n is the number of assets.

The rest indices are available after clicking the button "Detailed Values". They are as follows (*Figures 26–28*):

- expected values and standard deviations of CI lifetimes (*Figure 26*),

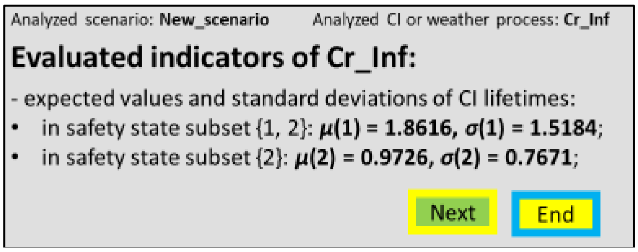

Figure 26. Evaluated indicators (part 1)

- moment of exceeding by the CI risk function permitted level (*Figure 27*),

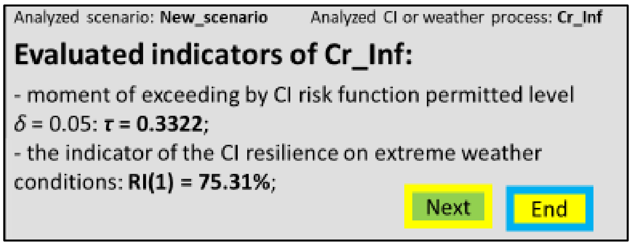

Figure 27. Evaluated indicators (part 2)

- mentioned earlier resilience indicators but expressed by numbers (*Figures 27–28*).

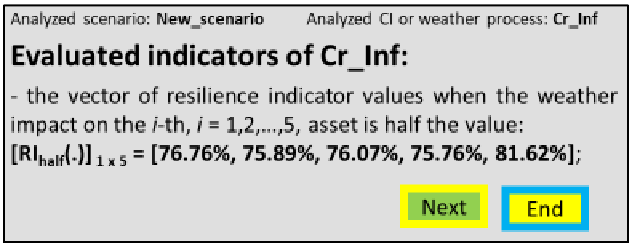

Figure 28. Evaluated indicators (part 3)

The calculated values of the $RI_{half}(i)$, $i = 1,2,\ldots,n$, indicator for the analyzed critical infrastructure are showing that strengthening only the A_5 asset resilience can improve the whole critical infrastructure resilience by 6.31% and it is more profitable than strengthening resilience one of the rest of assets.

4. Conclusion

The application calculating the safety and resilience indicies of the critical infrastructure exposed to extreme weather conditions is presented. Moreover, the scenario containing the critical infrastructure impacted by two different weather processes is conducted in aim to show the application right usage. In the future, this application will be improved by adding more outside processes influencing critical infrastructures.

Acknowledgement

The chapter presents results developed in the scope of the research project WN/2020/PI/08 “Analysis and optimization of critical infrastructures' safety dependent on changing weather conditions”, granted by Gdynia Maritime University in 2020.

References

[1] Bogalecka, M. 2020. *Consequences of Maritime Critical Infrastructure Accidents: Environmental Impacts. Modeling – Identification – Prediction – Optimization – Mitigation*. Elsevier, Amsterdam, Oxford, Cambridge (MA).

[2] Gdynia Maritime University Safety Interactive Platform, http://gmu.safety.umg.edu.pl/ (accessed 15 Aug 2020).

[3] Kuligowska, E. & Torbicki, M. 2018. GMU Safety Interactive Platform organization and possibility of applications *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 9(2), 97–110.

[4] Kołowrocki, K. 2014. *Reliability of Large and Complex Systems*. 2nd ed., Elsevier, Amsterdam – Boston – Heidelberd – London – New York – Oxford – Paris – San Diego – San Francisco – Singapore – Sidney – Tokyo.

[5] Torbicki, M. 2019. *Safety of critical network infrastructure exposed to operation and weather condition changes*. PhD Thesis.