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European Union global critical infrastructure safety management system. Research project proposition

Keywords

critical infrastructure, safety, operation cost, inside dependences, outside impacts, disaster, resilience, optimization, management, decision support, warning, protection, research project

Abstract

European Union Global Critical Infrastructure Safety Management System (EUSAFEGLOBE) will develop new modelling and assessment methods and tools to create novel comprehensive and coherent methodology for safety and resilience analysis of critical infrastructure with ageing dependent assets under outside extreme events impact. Project results and tools validated in real case studies will be integrated into sectorial safety management systems and risk reduction and accident consequences mitigation management systems for process industry, energy and transport. On the basis of created sectorial management systems and developed systemic approach to critical infrastructure cybersecurity the Early Warning System (EWS) will be designed. Created sectorial management and warning systems and systemic approach to critical infrastructure cybersecurity and training tools developed in the form of Critical Infrastructure Safety and Resilience Training System (CISRTS) will be integrated into the European Union Global Critical Infrastructure Safety Management System (EUGCISMS). EUGCISMS will be provided with clear for users instructions of its applications in all of any-sector critical infrastructures and will be placed at the developed during project implementation the internet interactive platform, to create its final form the European Union Global Critical Infrastructure Safety Internet Interactive Platform (EUGCISIIP). EUGCISIIP will be tested and approved for common use and placed at created the European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC). EUGCISMC will carry permanent education, dissemination and consultancy services to various industry and administration sectors including seminars, conferences, training courses and fully operational interactive internet service as the main gate to all critical infrastructures safety related resources and knowledge and it is planned to be exploited as a validated methodological approach and integrated component for strategic level decision making though the whole EU.

1. General approach to critical infrastructure safety analysis

The methodology and general approach to the critical infrastructure safety and resilience analysis (Bogalecka, 2020; Dąbrowska & Torbicki, 2021; De Porcellinis et al., 2009; Kołowrocki, 2019/2020; Kołowrocki et al., 2018; Lauge, et al., 2015; Magryta, 2020; Nieuwenhuijs et al., 2008; Ouyang, 2014; Rinaldi, Peerenboom & Kelly, 2001; Svedsen & Wolthunsen, 2007; Torbicki, 2018, 2019a, 2019b, 2019c; Torbicki & Drabiński, 2020) will be proposed.

The principles of multistate approach (Ancione et al., 2020; Bautista et al., 2021; Brunelle & Kapur, 1999; Dąbrowska, 2019, 2020; Kołowrocki, 2000, 2003, 2005, 2008, 2014; Natvig, 2007; Ramirez-Marquez & Coit, 2007; Szymkowiak, 2019; Xue, 1985; Xue & Yang, 1995a, 1995b; Yingkui & Jing, 2012; Zaitseva & Levashenko, 2017) to the critical infrastructure safety analysis will be

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introduced. The general approach to safety of a critical infrastructure free of outside impacts will be presented. The safety indicators of the critical infrastructure free of outside impacts will be defined. There will be introduced the notions of critical infrastructure basic safety indicators such as: the critical infrastructure safety function, the critical infrastructure risk function and the critical infrastructure fragility curve. An innovative approach and a significant for practical applications theoretical tools will be proposed for the safety analysis of critical infrastructure that considers its assets' ageing and dependency (Holden et al., 2013; Kołowrocki, 2020b, 2022) and its outside processes' degradation impacts (Ferreira & Pacheco, 2007; Glynn & Haas, 2006; Grabski, 2015; Klabjan & Adelman, 2016; Mercier, 2008; Limnios & Oprisan, 2005). A safety function will be defined and determined for a multistate ageing critical infrastructure with dependent assets impacted by its outside degradation processes. The critical infrastructure safety and resilience indicators (Torbicki, 2019c) will be proposed to be obtained using probabilistic approach to modelling of operation threats and extreme weather hazard impacts on its assets safety (Kołowrocki, 2020a, 2021; Kołowrocki, Kuligowska & Torbicki, 2017; Kołowrocki & Kuligowska, 2018; Kołowrocki & Magryta, 2020b; Kołowrocki & Magryta-Mut, 2020, 2022). There will be proposed safety and resilience indicators and availability and maintenance indicators (Bautista et al., 2020, 2022), crucial for operators and users of the critical infrastructure, defined as a complex system at its operating environment. The methodology for evaluation of safety and security culture, and shaping organizational factors in socio-technical systems of critical infrastructure will be proposed (Kosmowski, 2021). New approach to multi-state system reliability analysis will be proposed and its transformation to system safety will be done (Kossow & Preuss, 1995; Kvassay et al., 2020; Li & Pham, 2005; Lisnianski et al., 2010; Wang et al., 2011). The methods of power system reliability and safety with consideration of renewable energy sources replacing thermal power plants and power system reliability and safety in extreme conditions will be developed (Čepin, 2019, 2020a, 2020b). The Critical Infrastructure Safety Internet Interactive Platform (CISIIP) will be technically created (Gdynia Maritime University Critical Infrastructure Safety Interactive Platform, 2018).

The project work plan structure is organised into 11 interconnected and interacting with each other thematic Work-Packages (WP1–P11) and 1 Work-Package (WP 12) for project management, as it is presented in Figure 1.

2. Safety of ageing critical infrastructure without outside impacts

Modelling safety of ageing critical infrastructure composed of independent assets without considering its impacts. Modelling safety of ageing critical infrastructure composed of dependent assets without considering its impacts. Defining ageing critical infrastructure free of outside impacts assets' safety parameters. Defining the coefficients of the critical infrastructure assets' ageing and dependency impact on its safety. Introducing safety indicators (characteristics) SafI1-10 of the ageing critical infrastructure impacted by the critical infrastructure assets' ageing and dependency without any outside impacts. Defining the critical infrastructure availability indicators (AvaI1-20) and maintenance indicators (Mai1-6). Defining the critical infrastructure intensities of degradation / the coefficients of the critical infrastructure assets' dependency impact on critical infrastructure intensities of departure from the safety state subsets (ResI1). Defining the indicator of critical infrastructure resilience to assets' dependency impact (ResI2). Performing safety analysis of selected real critical infrastructures (from process industry, energy distribution and transport) without considering outside impacts, based on identified their assets' safety parameters and determining their safety indicators SafI1-10, availability indicators (AvaI1-20), maintenance indicators (Mai1-6) and resilience indicators (ResI1-2).

3. Modelling, identification and prediction of processes involving hazards, threats and barriers impacting critical infrastructure safety

Defining hazards, threats, preventive and mitigative barriers, and classifying them would set the unified nomenclature and concepts to work in this area. This work package will collate the definition, adopt the classifications, and amend as necessary to aid as a setting the nomenclature of the subsequent work packages.

Figure 1. Project work plan structure. (The scheme made technically for EUSAFEGLOBE project proposal by Ewa Dąbrowska).

Existing classifications of hazards and threats will be reviewed based on existing literature (Ancione et al., 2020; Berg & Petrek, 2018; Berg & Röwekamp, 2018, 2021; Gouldby et al., 2010) and the United Nations Disaster Risk Reduction (UNDRR) classifications. Within this task, the available classifications will be reviewed and a suitable classification structure that will support the subsequent work packages will be developed.

Adaption and extension of an existing tool, the Hazard Screening Tool (HST) to the new database (for later application).

Constructing a general model of critical infrastructure operation process related to environment threats and hazard events. Defining and identifying the critical infrastructures operation process parameters and determining its characteristics. Defining the climate-weather change process at the critical infrastructure operating area and its parameters and determining the characteristics of this climate-weather change process. Definition, identification and prediction of joint critical infrastructure operation and climate-weather change process at its operating area. Proposing indicators expressing the influence of the critical infrastructure operation process, the climate-weather change process at the critical infrastructure and the joint critical infrastructure operation and the climate-weather process at its operating area on the critical infrastructure assets and in the consequence the influence on the critical infrastructure safety.

Constructing a general model of environmental pollution process (GMEPP). Elaboration of the methods of identification of the unknown parameters of the environmental pollution process and formulae to predict the main characteristics of the environmental pollution process. Application of the presented model and methods to modeling, identification and prediction of the environmental (air and seawater) pollution process generated by pollutants within the exemplary industrial agglomeration.

Application of the model and methods developed to identification, modelling, and prediction of the environmental (air and seawater) pollution process generated by pollutants within the exemplary industrial agglomeration.

4. Safety of ageing critical infrastructure impacted by hazards and threats modelling, identification and prediction

The safety of various critical infrastructure impacted by its operation process analysis. Modelling safety of the critical infrastructure impacted by its operation process. The modification of safety, availability and maintenance and resilience indicators of the critical infrastructure impacted by its operation process proposing. Modelling safety of the critical infrastructure impacted by the climate-weather change process at its operating area. The modification of safety, availability and maintenance and resilience indicators of the critical infrastructure impacted by the climate-weather change process at the critical infrastructure operating area proposing. Modelling the safety of critical infrastructure impacted jointly by its operation process and climate-weather change process at its operating area. The modification of safety, availability and maintenance and resilience of the critical infrastructure impacted jointly by its operation process and the climate-weather change process at its operating area proposing. Real critical infrastructures (from process industry, energy distribution and transport) and their assets impacted by their operation processes and the climate-weather change processes at their operating areas safety examination and their modified safety indicators (SafI1-10), availability indicators (AvaI1-20), maintenance indicators (MaiI1-6) and resilience indicators (ResI1-2) determination applying the proposed modification methods.

5. Safety optimization of critical infrastructure impacted by hazards and threats

Proposing the critical infrastructure safety indicators optimization depending on maximization of the critical infrastructure lifetime mean value in the safety state subset not worse than the critical safety state through the system operation process modification (Kołowrocki & Magryta, 2020a; Magryta-Mut, 2020, 2022; Tang et al., 2007). Proposing the procedures of using the general safety analytical model of critical infrastructure related to its operation process and by the climate-weather change process at its operating area and the linear programming to ensuring its safety maximization. Determining the optimal safety, availability and maintenance and resilience indicators of the critical infrastructure impacted jointly by its operation process and the climate-weather change process at its operating area. Real critical infrastructures (from process industry, energy distribution and transport) and their assets impacted by their operation processes and the climate-weather change processes at their operating areas safety optimization and their optimal safety, availability and maintenance and resilience indicators determination applying the proposed optimization methods and procedures. Proposing the critical infrastructure operation process practical modification that allows to obtain the corresponding optimal forms and values of the critical infrastructure safety, availability, maintenance and resilience indicators and applying them to all investigated in the project real critical infrastructures from process industry, energy distribution and transport.

6. Operation cost optimization of critical infrastructure impacted by hazards and threats

Proposing the model of critical infrastructure operation total cost during the fixed operation time and the model of critical infrastructure operation total costs in the safety state subsets not worse than the critical safety state and their application to critical infrastructure operation cost determination. Creating the procedures of the critical infrastructure operation cost minimization based on the proposed cost models and linear programming. Including into the procedures of critical infrastructure operation cost minimization the impacts of operation environment threats and hazards of climate-weather change process at the critical infrastructure operating area. Proposing the critical infrastructure practical operation cost minimization through the creating procedures of the critical infrastructure operation process modification, improving the critical infrastructure economical effectiveness. Application the created cost models and procedures of operation cost minimization to real critical infrastructures from process industry, energy distribution and transport.

7. Safety and operation cost joint optimization of critical infrastructure impacted by hazards and threats

Creating the procedures of using the general safety analytical model and the operation cost models of critical infrastructure related to its operation process impacted by the climate-weather change process and the linear programming to joint analysis of the system safety maximization and its operation cost minimization. Proposing the procedures of joint critical infrastructure safety and its operation cost optimization using firstly the critical infrastructure safety maximization and next determining its conditional operation total cost during the fixed operation time and in the safety state subsets corresponding to this critical infrastructure maximal safety. Proposing the operation process modification allowing to find the critical infrastructure conditional operation total cost during the fixed operation time and in the safety state subsets corresponding to the critical infrastructure maximal safety indicators. There will be proposed critical infrastructure safety optimization procedures and the corresponding critical infrastructure operation total cost finding that gives practically important possibility of the critical infrastructure safety indicators maximization and keeping fixed corresponding to them the critical infrastructure operation total cost during the operation, through the system new operation strategy. There will be proposed the procedure of joint critical infrastructure safety and its operation cost optimization using firstly the critical infrastructure operation total cost during the fixed operation time and in the safety state subsets minimization and next determining its conditional safety function and remaining safety indicators corresponding to this critical infrastructure minimal operation total cost. There will be proposed the operation process modification allowing to find the critical infrastructure conditional safety indicators corresponding to the system minimal operation total cost during the fixed operation time and in the safety state subsets. There will be proposed the operation cost optimization procedures allowing to find the corresponding critical infrastructure safety indicators that gives practically important possibility of the critical infrastructure total operation cost minimizing and keeping the fixed corresponding conditional safety indicators during the operation through the critical infrastructure new operation strategy. Including a very important impact related to climate-weather factors and resolving the issues of critical infrastructure safety and operation cost optimization and discovering optimal values of safety, operation cost and resilience indicators of critical infrastructure, impacted by the operation and climate-weather conditions that can benefit the mitigation of critical infrastructure accident consequences and to minimize the system operation cost and to improve critical infrastructure resilience to operation threats and climate-weather hazards.

8. Critical infrastructure accident consequences modelling, identification, prediction and optimization

Constructing a general model of critical infrastructure accident consequences including the superposition of three models, the process of the initiating events generated by a critical infrastructure accident, the process of the environmental threats and the process of environmental degradation. Defining, identifying and predicting three particular processes of the general model of critical infrastructure accident consequences parameters and determining their characteristics. The superposition of the process of initiating events, the process of environmental threats and the process of environmental degradation will be done to create the joint probabilistic general model of critical infrastructure accident consequences. Applying the general model of critical infrastructure accident consequences to forecasting environmental losses associated with the process of environmental degradation and performing the cost analysis of these environment losses. Creating the procedures of using the results of the general model of critical infrastructure accident consequences and the linear programming to the critical infrastructures accident consequences optimization and the environmental losses associated with the process of environmental degradation minimization (Bogalecka, 2020; Dąbrowska, 2021; Piperopoulos et al., 2020). Proposing general procedures and the new strategy assuring lower environment losses concerned with critical infrastructure accidents. Application of the presented model and methods to modelling, identification prediction, optimization and mitigation of critical infrastructure accident consequences generated by the examined in the project real critical infrastructures from process industry, energy and transport.

9. Validation of project results and tools

This WP is concerned with validation of the EUSAFEGLOBE results and tools in 12 Case Studies concerned with the analyzed in the project sectorial critical infrastructures from process industry, energy and transport. Some of the Case Studies consists of different Scenarios giving in total 29 of all Case Study Scenarios. The selected large number of Case Study Scenarios have been designed to address climate-weather hazards that are considered to be of high importance to the European Union and cover all types of critical infrastructure. The Case Studies will be organized by EUSAFEGLOBE partners coordinating individually each Case Study Conduction Meeting and ensuring that respective critical infrastructure operators and national authorities will attend them and have a first hand-on experience on the project's outcomes.

Developed in project tools and procedures will be validated through performing large number of real Case Studies that address climate-weather hazards and operation threats as most important impacts on critical infrastructure safety and operation cost (Bogalecka, 2020; Čepin, 2019, 2020a, 2020b Dąbrowska, 2021; Kołowrocki, 2020a, 2021; Kołowrocki & Kuligowska, 2018; Kołowrocki & Magryta, 2020b; Kołowrocki & Magryta-Mut, 2020, 2022; Kołowrocki et al., 2017; Torbicki, 2018, 2019a, 2019b, 2019c; Zaitseva & Levashenko, 2017; Zieja et al., 2019, 2020). On the basis of project tools and procedures local validation, the general tools and procedures will be modified and developed with the ways of making the possibility of their use to all types of the European and World critical infrastructures. The Case Studies Conduction Meetings will be organized by the project partners coordinating particular cases in the ways that ensure active attendance of project partners, various critical infrastructures operators and local authorities.

Consolidated evaluation report of all the Case Studies conducted in terms of performance, feedback received and evaluation conclusions regarding the EUSAFEGLOBE resilience framework aligned with the evaluation procedure and considerations and final modifications of the project models and tools will be done.

10. Dissemination and exploitation of project results

This WP is designed to manage and facilitate the dissemination and exploitation of project results from the scientific and public understanding point of view. The dissemination and exploitation will focus on:

- promotion of the project results through the establishment of a bi-directional communication channel with the critical infrastructure stakeholders,
- internal dissemination by means of collaboration, synergy and information exchange between partners,
- alignment of project activities with calendar events of relevant EU programs and initiatives,
- sharing of gained knowhow and project outcomes with relevant scientific communities,
- promotion of European Union Global Critical Infrastructure Safety Internet Interactive Platform (EUGCISIIP) and other project results to stakeholder communities.

The exploitation plan will aim at:

- better defining the vision of using the project results to resilient infrastructures on an EU level;
- developing the strategic approach to define the appropriate business plan and elaborate a suitable market model which can support the perspective of commercializing the project results,
- training material developed in the form of the Critical Infrastructure Safety and Resilience Training System (CISRTS) – the collection of Training Packages for each of Training Courses will be promoted among the critical

infrastructure stakeholders, allowing the reinforcement of the project outcome and its introduction as reference material in the European critical infrastructure protection perspective,
- training Workshops based on CISRTS and using EUGCISIIP will be organized,
- there will be promoted the Encyclopedia of Quantitative Critical Infrastructure Safety Analysis – the very ambitious and useful project result, intended to be wide and deep look at the safety science methodology and standardization.

Monographs and conference and journal scientific papers will published internationally to promote the project results.

11. European Union Global Critical Infrastructure Safety Management System (EUGCISMS)

Predictive modelling, simulation and assessment methods and tools for services supply under extreme events worked out in the project will be collected and integrated and proposed to common use.

The project results and tools validated in several real Case Studies will be completed and integrated into the following sectorial safety management systems:
- Integrated Process Industry Critical Infrastructure Safety Management (IPICISM),
- Integrated Energy Distribution Critical Infrastructure Safety Management (IEDCISM),
- Integrated Transport Critical Infrastructure Safety Management (ITCISM).

The project results and tools validated in real several Case Studies will be completed and integrated into the following sectorial risk reduction and accident consequences mitigation management systems:
- Integrated Process Industry Critical Infrastructure Risk Reduction and Accident Consequences Mitigation Management (IPICIRA&ACMM),
- Integrated Energy Distribution Critical Infrastructure Risk Reduction and Accident Consequences Mitigation Management (IEDCIRA&ACMM),
- Integrated Transport Critical Infrastructure Risk Reduction and Accident Consequences Mitigation Management (ITCIRA&ACMM).

On the basis of the created sectorial safety management systems and the sectorial risk reduction and accident consequences mitigation management systems, the Early Warning System (EWS) specification will be fixed and finally designed.

The systemic approach to evaluation of critical infrastructure cybersecurity requirements will be proposed.

The created safety management systems and the sectorial risk reduction and accident consequences mitigation management systems, the designed Warning System (EWS), the systemic proposed approach to critical infrastructure cybersecurity requirements and the training tools developed in the form of Critical Infrastructure Safety and Resilience Training System (CISRTS) will be integrated into the European Union Global Critical Infrastructure Safety Management System (EUGCISMS). The EUGCISMS will be provided with clear instructions of their applications in all of any-sector critical infrastructures.

The European Union Global Critical Infrastructure Safety Management System (EUGCISMS) will be placed at the developed during the project implementation the Critical Infrastructure Safety Internet Interactive Platform (CISSIIP) primarily created in WP 1, to create its final form European Union Global Critical Infrastructure Safety Internet Interactive Platform (EUGCISIIP). The EUGCISIIP will be finally tested and approved for common use.

The EUGCISIIP will be placed at the newly created European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC). The EUGCISMC will carry permanent education, dissemination and consultancy services to various industry and administration sectors including seminars, conferences, training courses and fully operational interactive internet service as the main gate to all critical infrastructures safety related resources and knowledge and it is planned to be exploited as a validated methodological approach and integrated component for strategic level decision making though the whole EU.

The principles of commercialization of the project results and tools based on the use of CISSIIP and EUGCISMC will be work out.

Conclusion

Several questions concerned the Project Proposal sensibility and the appropriate answers are given below.

What are the specific needs that triggered this project?

There is no serious and comprehensive methodology for the critical infrastructure safety and resilience that considers its assets' ageing and dependency and its outside processes' degradation impacts. There are no effective practical tools like the critical infrastructure safety and resilience indicators of operation threats and extreme weather and climate hazard impacts on the critical infrastructure safety. There are no easily accessible tools in the form of safety and resilience indicators, availability and maintenance indicators, crucial for operators and users of the critical infrastructure. Also, it is difficult to find the comprehensive and coherent methodology for safety and security culture, and shaping organisational factors in socio-technical systems of critical infrastructure and for the systemic approach to evaluation of critical infrastructure cybersecurity requirements.

What do we expect to generate by the end of the project?

There will be created the following innovative tools:

- the Early Warning System (EWS),
- the Critical Infrastructure Safety and Resilience Training System (CISRTS),
- the European Union Global Critical Infrastructure Safety Management System (EUGCISMS),

that will form:

- the Union Global Critical Infrastructure Safety Internet Interactive Platform (EUGCISIIP);

for common use.

The EUGCISIIP will be placed at created during the project implementation:

- the European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC).

At the end of the project implementation, the principles of commercialization of the project results and tools based on the sale of Training Packages of CISSIIP and the paid common use of EUGCISIIP placed at EUGCISMC will be worked out.

What dissemination, exploitation and communication measures will we apply to the results?

The main project measures of disseminations, exploitation and communication will be:

- the Union Global Critical Infrastructure Safety Internet Interactive Platform (EUGCISIIP),

placed at:

- the European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC),

that will carry permanent education, dissemination and consultancy services to various industry and administration sectors including seminars, conferences, training courses and fully operational interactive internet service as the main gate to all critical infrastructures safety related resources and knowledge and it is planned to be exploited as a validated methodological approach and integrated component for strategic level decision making though the whole European Union.

Moreover, the project results will be published internationally in:

- the Encyclopaedia of Quantitative Critical Infrastructure Safety Analysis,
- monographs,
- the journal and conference papers.

The information project website and project partners' websites will also play this role.

Who will use or further up-take the results of the project? Who will benefit from the results of the project?

The results will be used by the Associated Partners Advisory Group and the Stakeholders Advisory Group created from process industry, energy and transport sectors at the beginning involved in the project implementation. The second main users will be administrative bodies and government institutions like regional voivodes, port authorities, ministries of climate, ministries of transport, ministers of energy and industry and government security centres that at the beginning of the project implementation will be invited to cooperate with the project Consortium. The industry companies and administrative bodies and government institutions will be asked to attend training courses, workshops and other project events and asked for feedback on the project results and for project results promotion. The high consumable user of the project result will be university scientists and students.

What change do we expect to see after successful dissemination and exploitation of project results to the target group(s)?

After successful dissemination and exploitation of project results to the target group, the real common use of the project results is expected. Especially, industrial companies and administration and government bodies should be interested in the creating their special offices everyday use of the EUGCISIIP placed at the European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC). Every day use of EUGCISIIP will give them an intelligent and innovative tool for giving by themselves their own data and getting at once the prognosis on the safety of the critical infrastructure they are operating. To be clever in this forecasting activities, the appropriate Training Courses of CISRTS should be taken using EUGCISIIP. Alternatively, Training Packages of CISRTS composed of the following 3 items:

- Training Course theoretical backgrounds in the form of a guide,
- Training Course Power Point presentation,
- video of Training Course to the audience,

can be bought by the interested in it persons or companies.

The Training Packages should also be extremely popular among the lecturers and students of the universities.

What are the expected wider scientific, economic and societal effects of the project contributing to the expected impacts outlined in the respective destination in the work programme?

The expected wider scientific, economic and societal effects of the project contributing to the expected impacts outlined in the respective destination in the work programme boil down to a deep conviction that the final results of the project will receive very positive recognition in the world. Therefore, at the end of the project implementation, the principles of commercialization of the project results and tools based on the sale of Training Packages of CISRTS and the paid common use of EUGCISIIP placed at EUGCISMC will be worked out. Moreover, at the end of the project implementation the European Commission will be asked for serious financial support to develop significantly, under the auspices of the European Union, the initially created the European Union Global Critical Infrastructure Safety Management Centre (EUGCISMC) into the high quality, well recognizable in the world, the Centre that will carry permanent education, dissemination and consultancy services to various industry and administration sectors and fully operational interactive internet service as the main gate to all critical infrastructures safety related resources and knowledge for strategic level decision making though the whole EU and the World.

The project approaches will be based on the results of the publications cited above in the text and below in References.

References

Ancione, G., Bragatto, P. & Milazzo, M.F. 2020. A Bayesian network-based approach for the assessment and management of ageing in major hazard establishments. *Journal of Loss Prevention in the Process Industries* 64, 10408.

Ancione, G., Paltrinieri, N. & Milazzo, M.F. 2020. Integrating real-time monitoring data in risk assessment for crane related offshore operations. *Journal of Marine Science and Engineering* 8(7), 1–28, 532.

Bautista, B.L., Torres, C.I. & Landesa, P.L. 2020. A condition-based maintenance for complex systems consisting of two different types of components. K. Kołowrocki et al. (Eds.), *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar* 2020. Gdynia Maritime University, Gdynia, 7–16.

Bautista, B.L., Torres, C.I. & Landesa, P.L. 2021. Cox processes in system degradation modelling. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar*. Gdynia Maritime University, Gdynia, 7–16.

Bautista, L., Castro, I.T. & Landesa L. 2022. Maintenance cost assessment for heterogeneous multi-component systems incorporating perfect inspections and waiting time to maintenance. To appear in *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*.

Berg, H.P. & Petrek, N. 2018. Threats and possible approaches of vulnerability of natural hazards on road infrastructure. *Journal of Polish Safety and Reliability Association Summer Safety and Reliability Seminars* 9(3), 1–10.

Berg, H.P. & Röwekamp, M. 2018. Natural hazards: systematic assessment of their contribution to risk and their consequences. *Probabilistic Modelling in System Engineering*, IntechOpen, Chapter 6, 1–10.

Berg, H.P. & Röwekamp, M. 2021. Combinations of fires with other types of hazards in nuclear and process industry installations. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2021.* Gdynia Maritime University, Gdynia, 17–29.

Bogalecka, M. 2020. *Consequences of Maritime Critical Infrastructure Accidents. Environmental Impacts. Modeling – Identification – Prediction – Optimization – Mitigation*. Elsevier, Amsterdam – Oxford – Cambridge.

Brunelle, R.D. & Kapur, K.C. 1999. Review and classification of reliability measures for multistate and continuum models. *IEEE Transactions* 31, 1117–1180.

Čepin, M. 2019. Evaluation of the importance factors of the power plants within the power system reliability evaluation. *Eksploatacja i Niezawodność* 21(4), 631–637.

Čepin, M. 2020a. Probability of restoring power to the transmission power system and the time to restore power. *Reliability Engineering & Systems Safety* 193(106595), 1–7.

Čepin, M. 2020b. The extended living probabilistic safety assessment. *Proceedings of the Institution of Mechanical Engineers. Pt. O: Journal of Risk and Reliabilit*y 234(1), 183–192.

Dąbrowska, E. 2019. *Monte Carlo Simulation Approach to Reliability Analysis of Complex Systems*, PhD Thesis, Polish Academy of Science, System Research Institute, Warsaw.

Dąbrowska, E. 2020. Safety analysis of car wheel system impacted by operation process. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2020*. Gdynia Maritime University, Gdynia, 61–76.

Dąbrowska, E. 2021. Short term forecasting of accidental oil spill movement in harbours, K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2021.* Gdynia Maritime University, Gdynia, 59–76.

Dąbrowska, E. & Torbicki, M. 2021. Identification of climate-weather change processes at Baltic Sea water area impacted on critical infrastructure safety and their accident consequences. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2021.* Gdynia Maritime University, Gdynia, 77–116.

De Porcellinis, S., Oliva, G., Panzieri, S. & Setola, R. 2009. A holistic-reductionistic approach for modeling interdependencies. *Critical Infrastructure Protection III*. Springer, USA, 215–227.

Ferreira, F. & Pacheco, A. 2007. Comparison of level-crossing times for Markov and semi-Markov processes. *Statistics & Probability Letters* 77(2), 151–157.

Glynn, P.W. & Haas, P.J. 2006. Laws of large numbers and functional central limit theorems for generalized semi-Markov processes. *Stochastic Models* 22(2), 201–231.

Gdynia Maritime University Critical Infrastructure Safety Interactive Platform, http://gmu.safety.umg.edu.pl/ (accessed 2018).

Gouldby, B.P., Schultz, M.T., Simm, J.D. & Wibowo, J.L. 2010. *Beyond the Factor of Safety: Developing Fragility Curves to Characterize System Reliability, Report in Water Resources Infrastructure Program ERDC SR-10-1, Prepared for Headquarters*. U.S. Army Corps of Engineers, Washington.

Grabski, F. 2015. *Semi-Markov Processes: Applications in System Reliability and Maintenance*. Elsevier, Amsterdam – Boston – Heidelberg – London – New York – Oxford – Paris – San Diego – San Francisco – Sydney – Tokyo.

Holden, R., Val, D.V., Burkhard, R. & Nodwell, S. 2013. A network flow model for interdependent infrastructures at the local scale. *Safety Science* 53(3), 51–60.

Klabjan, D. & Adelman, D. 2016. Existence of optimal policies for semi-Markov decision processes using duality for infinite linear programming. *Society for Industrial and Applied Mathematics Control and Optimization* 44(6), 2104–212.

Kołowrocki, K. 2000. On asymptotic approach to multi-state systems reliability evaluation. Chapter 11, in *Recent Advances in Reliability Theory: Methodology, Practice and Inference.* Birkhauser, Boston, 163–180.

Kołowrocki, K. 2003. Asymptotic approach to reliability analysis of large systems with degrading components. *International Journal of Reliability, Quality and Safety Engineering* 10(3), 249–288.

Kołowrocki, K. 2005. *Reliability of Large Systems*. Elsevier, Amsterdam – Boston – Heidelberg – London – New York – Oxford – Paris – San Diego – San Francisco – Singapore – Sydney – Tokyo.

Kołowrocki, K. 2008. Reliability and risk analysis of multi-state systems with degrading components. *International Journal of Reliability, Quality and Safety Engineering* 6(2), 213–228.

Kołowrocki, K. 2014. *Reliability of Large and Complex Systems. 2nd Edition.* Elsevier, Amsterdam – Boston –Heidelberg – London – New York – Oxford – Paris – San Diego – San Francisco – Singapore – Sydney – Tokyo.

Kołowrocki, K. 2019/2020. *Safety Analysis of Critical Infrastructure Impacted by Operation Process and Climate-Weather Change Process – theoretical backgrounds*. Report in the Scope of GMU Research Projects.

Kołowrocki, K. 2020a. Port oil terminal safety examination. *Scientific Journals of the Maritime University of Szczecin*.

Kołowrocki, K. 2020b. Safety analysis of multi-state ageing car wheel system with dependent components. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2020*. Gdynia Maritime University, Gdynia, 101–116.

Kołowrocki, K. 2021. Safety analysis of critical infrastructure impacted by operation and climate-weather changes – theoretical backgrounds. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2021*. Gdynia Maritime University, Gdynia, 139–180.

Kołowrocki, K. 2022. Safety analysis of multi-state ageing system with inside dependences and outside impacts. A. Lecko (Ed.) Chapter in *Monograph Current Research in Mathematical and Computer Science*.

Kołowrocki, K. & Kuligowska, E. 2018. Operation and climate-weather change impact on maritime ferry safety. *European Safety and Reliability Conference – ESREL*. Proceeding Paper.

Kołowrocki, K., Kuligowska, E. & Torbicki, M. 2017. *Tools for Processing Climate Hazards Information. Report in the Scope of EU-CIRCLE Research Project*. WP2, Task 2.3, D2.3

Kołowrocki, K. & Magryta, B. 2020a. Port oil terminal reliability optimization. *Scientific Journals Maritime University of Szczecin.*

Kołowrocki, K. & Magryta, B. 2020b. Changing system operation states influence on its total operation cost. *Theory and Applications of Dependable Computer Systems, Proceedings of the 15th International Conference on Dependability of Computer Systems, DepCos-Relcomex,* Springer, 355–365.

Kołowrocki, K. & Magryta-Mut, B. 2020. Safety of maritime ferry technical system impacted by operation process. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2020*. Gdynia Maritime University, Gdynia, 117–134.

Kołowrocki, K. & Magryta-Mut, B. 2022. Operation cost and safety optimization of maritime transportation system. Chapter in *Monograph Current Research in Mathematical and Computer Science*.

Kołowrocki, K. et al. 2018. *Inventory of Critical Infrastructure Impact Assessment Models for Climate Hazards*. Reports in the Scope of EU-CIRCLE Research Project, WP3. Tasks 3.3–3.4, D3.3.

Kosmowski, K.T. 2021. Functional safety and cybersecurity analysis and management in smart manufacturing systems. *Handbook of Advanced Performability Engineering* (K.B. Misra (Ed.). Chapter 3. Springer Nature Switzerland AG.

Kossow, A. & Preuss, W. 1995. Reliability of linear consecutively-connected systems with multistate components. *IEEE Transactions on Reliability* 44, 518–522.

Kvassay, M., Rusnak, P., Zaitseva, E. & Kostolny, J. 2020. Minimal cut vectors of multi-state systems identified using logic differential calculus and multi-valued decision diagrams, *30th European Safety and Reliability Conference, ESREL 2020 and 15th Probabilistic Safety Assessment and Management Conference, PSAM* 2020, 3053–3060.

Lauge, A., Hernantes, J. & Sarriegi, J.M. 2015. Critical infrastructure dependencies: a holistic, dynamic and quantitative approach. *International Journal of Critical Infrastructure Protection* 8, 16–23.

Li, W. & Pham, H. 2005. Reliability modeling of multi-state degraded systems with multi-competing failures and random shocks. *IEEE Transactions on Reliability* 54(2), 297–303.

Limnios, N. & Oprisan, G. 2005. *Semi-Markov Processes and Reliability*. Birkhauser. Boston.

Lisnianski, A., Frenkel, I. & Ding, Y. 2010. *Multi-state Systems Reliability Analysis and Optimization for Engineers and Industrial Managers*. Springer, London.

Magryta, B. 2020. Reliability approach to resilience of critical infrastructure impacted by operation process. *Journal of KONBiN* 50(1), 131–153.

Magryta-Mut, B. 2020. Safety optimization of maritime ferry technical system K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2020*. Gdynia Maritime University, Gdynia, 175–182.

Magryta-Mut, B. 2022. *Safety and Operation Cost Optimization of Port and Maritime Transportation System*. PhD Thesis (under completion).

Mercier, S. 2008. Numerical bounds for semi-Markovian quantities and application to reliability. *Methodology and Computing in Applied Probability* 10(2), 179–198.

Natvig, B. 2007. Multi-state reliability theory, Chapter in *Encyclopedia of Statistics in Quality and Reliability*. Wiley, New York, 1160–1164.

Nieuwenhuijs, A., Luiijf, E. & Klaver, M. 2008. Modeling dependencies in critical infrastructures. *Critical Infrastructure Protection II, IFIP International Federation for Information Processing, Series* 253. Springer, Boston, 205–213.

Ouyang, M. 2014. Review on modelling and simulation of interdependent critical infrastructure systems. *Reliability Engineering & System Safety* 121, 43–60.

Piperopoulos, E., Calabrese, L., Mastronardo, E., Proverbio, E. & Milone, C. 2020. Sustainable reuse of char waste for oil spill recovery foams. *Water, Air, and Soil Pollution* 231(6), 293.

Ramirez-Marquez, J.E. & Coit, D.W. 2007. Multi-state component criticality analysis for reliability improvement in multi-state systems. *Reliability Engineering & System Safety* 92, 1608–1619.

Rinaldi, S., Peerenboom, J. & Kelly, T. 2001. Identifying, understanding and analyzing critical infrastructure interdependencies. *IEEE Control Systems Magazine* 21(6), 11–25.

Svedsen, N. & Wolthunsen, S. 2007. Connectivity models of interdependency in mixed-type critical infrastructure networks. *Information Security Technical Report* 12(1), 44–55.

Szymkowiak, M. 2019. *Lifetime Analysis by Aging Intensity Functions*. Monograph in series: *Studies in Systems, Decision and Control* (196). Springer International Publishing.

Tang, H., Yin, B.Q. & Xi, H.S. 2007. Error bounds of optimization algorithms for semi-Markov decision processes. *International Journal of Systems Science* 38(9).

Torbicki, M. 2018. Longtime prediction of climate-weather change influence on critical infrastructure safety and resilience. *IEEE International Conference on Industrial Engineering and Engineering Management* 996–1000.

Torbicki, M. 2019a. An approach to longtime safety and resilience prediction of critical infrastructure influenced by weather change processes. *IEEE International Conference on Information and Digital Technologies*. Žilina, Slovakia.

Torbicki, M. 2019b. *Safety of a Critical Network Infrastructure Exposed to Operation and Weather Condition Changes*. PhD Thesis, Polish Academy of Science, System Research Institute, Warsaw.

Torbicki, M. 2019c. The longtime safety and resilience prediction of the Baltic oil terminal. *IEEE The International Conference on Information and Digital Technologies* 2019 – *IDT* 2019. Žilina, Slovakia.

Torbicki, M. & Drabiński, B. 2020. An application determining weatherimpact on critical infrastructure safety and resilience. K. Kołowrocki et al. (Eds.). *Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2020*. Gdynia Maritime University, Gdynia, 231–242.

Wang, Z., Huang, H.Z., Li, Y. & Xiao, N.C. 2011. An approach to reliability assessment under degradation and shock process. *IEEE Transactions on Reliability* 60(4), 852–863.

Xue, J. 1985. On multi-state system analysis. *IEEE Transactions on Reliability* 34, 329–337.

Xue, J. & Yang, K. 1995a. Dynamic reliability analysis of coherent multi-state systems. *IEEE Transactions on Reliability* 4(44), 683–688.

Xue, J. & Yang, K. 1995b. Symmetric relations in multi-state systems. *IEEE Transactions on Reliability* 4(44), 689–693.

Yingkui, G. & Jing, L. 2012. Multi-state system reliability: a new and systematic review. *Procedia Engineering* 29, 531–536.

Zaitseva, E. & Levashenko, V. 2017. Reliability analysis of multi-state system and multiple-valued logic. *International Journal of Quality & Reliability Management* 34(6), 862–878.

Zieja, M., Migus, P., Wójcik, J. & Zieja, M. 2019. A Method for estimation and prediction of the efficiency of the proactive prevention applied in the aircraft transport. *Proceedings of the 29th European Safety and Reliability Conference*, 3040–3047.

Zieja, M., Żyluk, A., Adamski, M. & Kawka, K. 2019. Maintaining a continuous readiness for military pilot flights by using mobile technology. *Journal of KONBiN* 49(4), 511–519.

Zieja M., Szelmanowski A., Pazur A. & Głyda K. 2020. Studying the dynamic properties of an amplifier board execution block in terms of false tripping of an aircraft fire suppression system. *Mechanisms and Machine Science* 70, 121–137.