GDYNIA MARITIME UNIVERSITY CONTRIBUTION TO THE EU PROJECT
"A PANEUROPEAN FRAMEWORK FOR STRENGTHENING CRITICAL INFRASTRUCTURE RESILIENCE TO CLIMATE CHANGE"

Project Acronym: EU-CIRCLE

It is presently acknowledged and scientifically proven that climate related hazards have the potential to substantially affect the lifespan and effectiveness or even destroy of European Critical Infrastructures (CI), particularly the energy, transportation sectors, buildings, marine and water management infrastructure with devastating impacts in EU appraising the social and economic losses. The main strategic objective of EU-CIRCLE is to move towards infrastructure network(s) that is resilient to today's natural hazards and prepared for the future changing climate. Furthermore, modern infrastructures are inherently interconnected and interdependent systems; thus extreme events are liable to lead to "cascade failures". EU-CIRCLE scope is to derive an innovative framework for supporting the interconnected European Infrastructure's resilience to climate pressures, supported by an end-to-end modelling environment where new analyses can be added anywhere along the analysis workflow and multiple scientific disciplines can work together to understand interdependencies, validate results, and present findings in a unified manner providing an efficient "Best of Breeds" solution of integrating into a holistic resilience model existing modelling tools and data in a standardised fashion. It will be open & accessible to all interested parts in the infrastructure resilience business and having a confirmed interest in creating customized and innovative solutions. It will be complemented with a web-based portal. The design principles, offering transparency and greater flexibility, will allow potential users to introduce fully tailored solutions and infrastructure data, by defining and implementing customised impact assessment models, and use climate/weather data on demand.

Keywords: Risks modelling, assessment and impact reduction; Risks and vulnerabilities assessment; European infrastructures.

INTRODUCTION

Currently, the newest trends in the safety investigations of complex technical systems analysis are directed to the critical infrastructures. In general, a critical infrastructure is a single complex system of large scale or a network of complex large systems (set of hard or soft structures) that function collaboratively and synergistically in order to ensure to a continuous production flow of essentials goods and services. These are complex systems that significant features are inside-system dependencies and outside-system dependencies, that in the case of damage have significantly destructive influence on the health, safety and security, economics and social conditions of large human communities and territory areas. These systems are made of large number of interacting components and even small perturbations can trigger large scale consequences in critical infrastructures that may cause multiple treats in human life and activity. For the above reasons, as an
extended failure within one of these infrastructures may result in the critical incapacity or destruction and can significantly damage many aspects of human life and further cascading across the critical infrastructure boundaries, they have the potential for multi-infrastructural collapse with unprecedented and transnational dangerous consequences.

The models and the results originally developed in the previous GMU research team publications [2–17] are high reasonable to be used as the essential tools starting the novel investigations of safety of critical infrastructures impacted by climate changes. The project models, methods, procedures and algorithms will be based on the well known in the scientific world achievements of the main GMU participants of the project established in theory of reliability closely convergent with the theory of safety and included in the monographs “Reliability and Safety of Complex Technical Systems and Processes: Modelling – Identification – Prediction – Optimization”, Krzysztof Kołowrocki, Joanna Soszyńska-Budny, Springer 2011 [16] and “Reliability of Large and Complex Systems”, Krzysztof Kołowrocki, Elsevier 2014 [8], that are the source of scientific inspirations for GMU contributions to the project. The proposed approaches to the problems of safety of complex critical infrastructures are innovative and very important aspects of the project as in the world science there are no comprehensive and general solutions concerned with the safety of critical infrastructures related to their operation processes determined partly by climate changes and their inside and outside dependencies considered simultaneously.

The linking of the inside and outside the critical infrastructures dependencies and including other outside dangerous events and hazards coming from the environment and from other dangerous processes, under the assumed their structures multistate models, is the main idea of the project methodology. This joint considering of all these elements is a main innovative aspect of this project and the basis for the formulation and development of the new solutions concerned with the modelling, identification, prediction, improvement and optimization of the safety of the complex critical infrastructures related to their operation processes and their inside and outside interactions. Including into the project the risk modelling, identification, prediction and optimization of critical infrastructure accidents consequences also is of great added value.

The scientific experiments expanding the knowledge, testing and primary practical applications of the created theory of safety and developed methods to the real critical infrastructures of maritime and port transport sector and to maritime critical accidents consequences risk analysis are also an important reason for the realization of this project.

1. OBJECTIVES

The main purpose of the GMU contributions to the project is to propose new and to develop existing methods and tools supporting intelligent modelling and decision systems, in controlling and optimizing the safety of critical infrastructures
and in the critical infrastructures accidents consequences risk analysis. Its main focus is on the creation and usage of new techniques, procedures and strategies to improve and to optimize safety of real complex infrastructure systems related to the inside – among their subsystems and components and the outside – coming from their operation environment and other systems operation processes dependences and climate change hazards. The main expected final effect is to integrate these issues into new coherent theory of safety of critical infrastructures, to develop practically useful packages of tools in the form of the Critical Infrastructure Safety Training System – CISTS and to create the Critical Infrastructure Safety Internet Training Centre – CISITC.

The particular objectives of the proposed project are as follows:

- to conduct a systematic safety and security study of complex industrial networks, systems and processes;
- to develop new and innovative models for safety and security improvements for complex industrial networks, systems and processes;
- to continue and to intensify long-term interdisciplinary research resulting in safer, more effective and more competitive people engaging in industrial activities;
- to develop an integrated package of practical tools (guidebooks, procedures, regulations), inclusive of new safety methods in investigating, improving and optimizing complex industrial networks, systems and processes;
- to provide and implement techniques for the design of safety decision support systems for various critical infrastructures, like complex maritime transportation, large piping oil transportation systems, complex ship and port operation processes, complex offshore platform oil industry infrastructures, large logistics networks, complex water supply networks and other;
- to offer education and training courses, addressing safety and security knowledge and technology enhancement within current critical infrastructures and processes.

2. CONCEPT AND APPROACH

Many technical systems belong to the class of complex critical infrastructure systems as a result of the large number of interacting components and subsystems they are built of and their complicated operating processes having significant influence on their safety. This complexity and the inside-infrastructure and outside-infrastructure dependencies and hazards cause that there is a need to develop new comprehensive approaches and general methods of analysis, identification, prediction, improvement and optimization for these complex system safety. We meet complex critical infrastructure systems, for instance, in piping transportation of water, gas, oil and various chemical substances, in port and maritime transportation. Optimization of the structures and operation processes of critical infrastructures with respect to their safety and costs of their accidents consequences is very important and very often also complicated and often not possible to perform by
practitioners because of the mathematical complexity of the applied methods. In addition, analyzing the critical infrastructures in their variable operation conditions and considering their changing in time safety structures and their among components and subsystems dependability resulting in changes of their safety characteristics becomes much more complicated. Adding to this analysis, the outside of the critical infrastructures hazards coming from other systems, from natural cataclysms and from other dangerous events makes the problem essentially more difficult to become solved in order to improve and to ensure high level of these systems safety.

From the point of view of more precise analysis of the safety and effectiveness of critical infrastructures, the developed methods will be based on a multistate approach to these complex systems safety analysis instead of normally used two-state approach. This will enable different critical infrastructure inside and outside safety states to be distinguished, such that they ensure a demanded level of the system operation effectiveness with accepted consequences of the dangerous accidents for the environment, population, etc. In most safety analyses, it is assumed that components of a system are independent. But in reality, especially in the case of critical infrastructures, this assumption is not true, so that the dependencies among the critical infrastructure systems components and subsystems should be assumed and considered. It is a natural assumption, as after decreasing the safety state by one of components in a subsystem, the inside interactions among the remaining components may cause further components safety states decrease. In reality, in the critical infrastructures, it may even cause the whole system safety state dangerous degradation. In the project, the new methods of the safety investigations of the multistate complex systems with dependent components and subsystems will be significantly developed. The multistate safety functions of the complex critical systems with dependent components will be determined for as wide as possible class of complex critical infrastructures. In the developed models, it will be assumed that the systems components are dependent and have the multistate exponential safety functions with interdependent departures rates from the subsets of the safety states. Moreover, in the case of very large numbers of components in the system, the asymptotic approach to the safety evaluation of these systems will be also applied and the classes of limit safety functions for the considered critical large infrastructure systems will be fixed. To tie the results of investigations of the critical infrastructures inside-dependences together with the results coming from the assumed in the critical infrastructures outside-dependencies, the semi-Markov models will be used to describe the complex systems operation processes. Furthermore, generalizations and developments based on the methods included in the GMU project participants’ publications, concerned with effective and cost efficient strategies and multi-objective optimization advanced methods for critical infrastructures, will be performed in the project. In this aspect, the project is aimed on the entire elaboration of the methods of evaluation and improvement of safety of as wide as possible class of critical infrastructures composed of dependent components and related to their operation
processes impacted by climate changes and other outside dependencies and on the pointing out of the possibility of these methods practical applications to complex maritime and coastal transportation infrastructure systems and to analysis and optimization of maritime accidents consequences concerned with rescue actions and with chemical spills at sea.

The analytical methods proposed will be complemented with the Monte Carlo simulation methods and the statistical methods for safety data processing that will include an innovative and original approach to the methods of safety evaluation and optimization on the basis of the existing rough and incomplete empirical data for the processing.

Thus, these all approaches will fulfil a comprehensive solution of problems the project is concerned with. The activities also performed in the project will be research and technology development, innovation and demonstration, experiments and newly developed tools practical testing, education and training.

3. PROJECT ORGANIZATION

The project is organized into the following 9 Workpackages:
WP 1. Setting the Operational Environment,
WP 2. Climatic Data Capture and Processing,
WP 3. Critical Infrastructure Risk Model for Climate Hazards,
WP 4. Critical Infrastructure Resilience and Adaptation to Climate Change,
WP 5. Climate Infrastructure Resilience Platform,
WP 6. Case Studies and EU-CIRCLE Assessment,
WP 7. Simulating Interconnected Critical Infrastructures – SimICI: Reference Simulated Network of Interconnected Critical Infrastructures,
WP 8. Dissemination and Exploitation,

The GMU research team intended participation and activity in the above workpackages is as follows.

At the stage 1 of the project (months 1–12), after reviewing the current state of the art, the general models and methods of the critical infrastructures environment influence on their operation processes will be developed. Namely, new general analytical models of complex infrastructure systems’ operation processes related to their environment will be constructed (WP 2: Task 2.3, Task 2.4, Task 2.5). Also, originally new and universal tools for safety of critical infrastructures evaluation will be developed (WP 3: Task 3.2).

At the stage 2 of the project (months 13–24), the integration of the general analytical models of critical infrastructures safety evaluation with the general models of their operation processes related to their environment will be made (WP3: Task 3.3). This integrating environment and safety models of critical infrastructures will be the basis for the preliminary building, at the project activity stage 3, such integrated particular models for complex transportation systems from
selected maritime and coastal transport sectors considered in the project (WP 6: Task 6.2) and for all further tasks developed at the stages 3 and 4 of the project. Modeling the critical infrastructure accident consequences will also be performed at this stage (WP 3: Task 3.4). Moreover, the data mining methods for identification of safety general models unknown parameters of complex critical infrastructures and the critical infrastructure accident consequences will be developed at this stage (WP 3: Task 3.3, Task 3.4). The models of the critical infrastructure safety and the critical infrastructure accident consequences prediction and will be developed at this stage as well (WP 3: Task 3.5).

At stage 3 of the project (months 25–36), the model of the critical infrastructure safety optimization related to safety lifetime maximizing and the optimization model of the critical infrastructure accident consequences related to accident consequences cost minimization (WP 4: Task 4.1) will be developed and considered together with organizational and management aspects. In addition, these topics of investigation are to be the essential points in the construction of the system ensuring much safer and reliable people industrial activity and implementing it to maritime and coastal transport sectors (WP6: Task 6.2). At this stage, the integrated particular safety models for complex transportation systems from selected maritime and coastal transport sectors are constructed and applied to safety modeling, identification, prediction and optimization of maritime, shipyard and port complex transportation systems and to risk of chemical spills an pollution at sea modeling, identification and optimization (WP 6: Task 6.2). After that experimental testing, the modification of the developed integrated general and particular safety models of critical infrastructures and the model of the critical infrastructure accident consequences will be modified and new strategies assuring high safety of critical infrastructures and low risk of critical infrastructure accidents will be developed (WP 6: Task 6.2).

Moreover, at the stage 3 of the project, all the results of project activity after their modifications and final improvements will be used to creating the integrated Critical Infrastructure Safety Training System – CISTS (WP 8: Task 8.1, Task 8.4, Task 8.5, Task 8.6). The activity at this stage will result in a new general theory of safety of critical infrastructures and in integrated methods and procedures addressed to safety practitioners allowing them to identify safety data, to evaluate and to optimize safety and operation processes of critical infrastructures. The CISTS including user-friendly guidebooks and procedures developed using the methods and algorithms at the project stages 1, 2 and 3 for the modeling, identification, prediction and optimization of safety of the critical infrastructures as whole and of specific processes occurring therein will be created and practically tested in Gdynia Port transport sectors and in selected shipping systems of the Baltic Sea region and its quality and accuracy will be evaluated. Also, the Critical Infrastructures Safety Internet Training Centre – CISITC will be designed and practically applied and tested (WP 8: Task 8.7. Task 8.8) in order to initiate its every day work as the fully operational internet service to all safety related resources and knowledge coming from the project.
The potential of the project is in its ability to mobilize a critical mass of research and development resources and competence in the field of safety of critical infrastructures, which will improve current safety, effectiveness and competitiveness in this field. It will have positive impact on the sustainable development of knowledge in safety of complex industrial critical infrastructures. The project brings together theoretical and applied research, which includes research in the natural, technical, social, economical sciences and industry practice with an inclination towards practical applications. Linking theoretical scientific activity with experiments extending knowledge, testing and practical applications is particularly important for increasing complex industrial systems and networks safety and operation procedures optimization. The development of new knowledge applications will result in safer, more reliable and more effective people engaging in current industrial activities.

The project aims to deliver the followings effects:

- a general safety model of critical infrastructures relating to their inside and outside dependencies and hazards;
- a general model of risk assessment of critical infrastructure accident consequences;
- a statistical study of current critical infrastructures to evaluate unknown parameters of these general models using empirical data mining techniques;
- a systematic study of methods for safety that includes an evaluation of current complex critical infrastructures;
- a systematic study of operation strategies for critical infrastructures;
- general theory of safety of critical infrastructures (monograph published internationally);
- modeling safety of complex technical systems and processes (monograph published internationally);
- risk analysis of chemical spills at sea (monograph published internationally);
- user-friendly guidebooks for practitioners, which includes methods, procedures, descriptions, applications, like:
  - Integrated Critical Infrastructure Safety System,
  - Safety of Transport and Information Critical Infrastructures;
- Baltic Sea Area Critical Infrastructures Protection Related to Climate Changes;
- Critical Infrastructures Safety Training System – CISTS;
- Critical Infrastructure Safety Internet Training Centre – CISTC;
- contributions to scientific seminars and conferences, organizing training courses and fully operational internet service.
4. CONSORTIUM

4.1. List of participants

Table 1

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<thead>
<tr>
<th>Participant No</th>
<th>Participant organisation name</th>
<th>Country</th>
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<tbody>
<tr>
<td>1. (Coordinator)</td>
<td>National Center for Scientific Research “Demokritos”</td>
<td>Greece</td>
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<tr>
<td>2.</td>
<td>Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V</td>
<td>Germany</td>
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<td>3.</td>
<td>Meteorologisk Institutt</td>
<td>Norway</td>
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<td>4.</td>
<td>University of Exeter</td>
<td>UK</td>
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<td>5.</td>
<td>Gdynia Maritime University</td>
<td>Poland</td>
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<td>6.</td>
<td>ARTELIA Eau et Environnement SAS</td>
<td>France</td>
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<td>7.</td>
<td>SATWAYS Ltd</td>
<td>Greece</td>
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<td>8.</td>
<td>Entente pour la forêt Méditerranéenne</td>
<td>Valabre</td>
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<td>9.</td>
<td>D’Appolonia S.P.A.</td>
<td>Italy</td>
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<td>10.</td>
<td>Državni Hidrometeorološki Zavod – Meteorological And Hydrological Service</td>
<td>Croatia</td>
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<td>11.</td>
<td>XUVASI Ltd</td>
<td>UK</td>
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<td>12.</td>
<td>MRK Management Consultants GmbH</td>
<td>Germany</td>
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<td>13.</td>
<td>European University of Cyprus / Center for Risk and Safety in the Environment</td>
<td>Cyprus</td>
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<td>14.</td>
<td>Center for Security Studies</td>
<td>Greece</td>
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<td>15.</td>
<td>University of Salford</td>
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<td>18.</td>
<td>Torbay City Council</td>
<td>UK</td>
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<td>19.</td>
<td>Hellenic National Meteorological Service</td>
<td>Greece</td>
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<td>20.</td>
<td>University of Applied Sciences Velika Gorica</td>
<td>Croatia</td>
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<td>21.</td>
<td>Patuakhali Science and Technology University</td>
<td>Bangladesh</td>
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4.2. GMU Research Team

The GMU will involve into the project 8 researchers from its 3 Departments, Prof. Krzysztof Kołowrocki (Person in Charge), Prof. Joanna Soszyńska-Budny (Deputy Person in Charge), Dr. Agnieszka Blokus-Roszkowska, Dr. Sambor Guze, MSc. Ewa Kuligowska and MSc. Mateusz Torbicki from Department of Mathematics, Dr. Magdalena Bogalecka from Department of Chemistry and Industrial Commodity Knowledge and Dr Przemysław Dziula from Department of Navigation. GMU will also involve into the project 4 industry and administration
consultants, Michał Drzazga from the Baltic Oil Terminal in Dębogórze, Marek Reszko from the Maritime Search and Rescue Service in Gdynia, Ewa Jakusik from Institute of Meteorology and Water Management in Gdynia and Marek Ledóchowski from Maritime Office in Gdynia.

**SUMMARY**

The GMU participants will contribute to the project with its scientists’ extensive experience in safety and reliability analysis of complex industrial systems and processes with dependent components and subsystems. The researchers from GMU will contribute with their experience in developing of methods and models of safety analysis and optimisation of maritime and port and shipyard transportation systems and processes. GMU will contribute their scientists experience in risk analysis of chemical spills and pollutions at sea as well. The know-how and experience of the GMU team will also be used work to propose statistical data mining tools for the identification and prediction of safety parameters and characteristics of complex maritime and coastal transportation systems.

The GMU research team will particularly contribute in the following areas:

- methods and procedure to assess critical infrastructures safety;
- methods and procedures of critical infrastructures accident consequences modelling;
- methods of safety of critical infrastructures statistical data processing;
- methods of port and maritime transportation infrastructures safety modelling;
- methods of critical infrastructures safety optimizing with respect to their operation processes and inside and outside dependences and hazards;
- methods for the safety of critical infrastructures and their operation processes and inside and outside dependences optimal management;
- methods for optimising safety characteristics of ship transportation systems;
- methods of risk analysis of chemical spills and pollutions at sea;
- methods of safety analysis of other various real critical infrastructures (commonly with project participants and consultants from industry).

The GMU research team together with the industry partners will conduct research in safety analysis of critical infrastructures subjected to climate change and risk analysis of critical infrastructure accidents. The role of the industrial partners will be based on the collecting and delivering data and cooperating in research tools testing in the Case Study.

**BIBLIOGRAPHY**


WKŁAD AKADEMII MORSKIEJ W GDYNI DO EUROPEJSKIEGO PROJEKTU „OGÓLNOEUROPEJSKIE RAMY WZMACNIANIA ODPORNOŚCI INFRASTRUKTUR KRYTYCZNYCH NA ZMIANY KLIMATYCZNE”

Streszczenie

Obecnie potwierdzono i udowodniono naukowo, że zagrożenia klimatyczne mają możliwość znacząco wpływać na żywotność i efektywność europejskich infrastruktur krytycznych (CI), w szczególności takich jak energetyka, sektory transportu, budownictwa i morski, a także infrastrukturę zarządzania zasobami wodnymi, a nawet je niszczyć. To wszystko ma destrukcyjny wpływ na UE, powodując straty ekonomiczne i społeczne. Głównym celem strategicznym projektu UE-CIRCLE jest pojście w kierunku sieci infrastruktur, które są odporne na codzienne zagrożenia oraz na przyszłe zmiany klimatu. Ponadto, ponieważ nowoczesne infrastruktury są połączonymi i wzajemnie zależnymi systemami, zdarzenia ekstremalne mogą prowadzić do „uszkodzeń kaskadowych”. Zakresem projektu UE-CIRCLE objęte jest wyprowadzenie innowacyjnych ram wspierających odporność wzmiannie połączonych europejskich infrastruktur na presje klimatyczne, połączonych z kompletnym modelowaniem środowiska, dzięki któremu nowe analizy można dodać w dowolnym miejscu w czasie postępu badań. Dzięki temu wiele dyscyplin naukowych może pracować razem, aby zrozumieć wzajemne zależności, oceniać wyniki i przedstawiać konkluzje w ujednolicony sposób zapewniający skuteczne „najlepsze z wykreowanych” rozwiązania scalające istniejące narzędzia modelowania oraz znormalizowane dane w holistycznym model odporności. Model ten będzie otwarty i dostępny dla wszystkich podmiotów zainteresowanych sprawami odporności infrastruktury i posiadających potwierdzone zainteresowanie w kreowaniu wykonanych na zamówienie i innowacyjnych rozwiązań. Będzie on również uzupełniany poprzez portal internetowy. Zasady projektowania oferujące przejrzystość i większą elastyczność pozwolą przedstawić potencjalnemu użytkownikowi kompletnie dostosowane rozwiązania i dane infrastruktury poprzez zdefiniowanie i wdrożenie zamawianych modeli oceny wpływu oraz wykorzystanie danych klimatyczno-pogodowych zgodnie z życzeniem.

Słowa kluczowe: modelowanie, ocena oraz redukcja wpływu ryzyka, ocena zagrożeń i podatności, infrastruktury europejskie.