Kołowrocki Krzysztof
Maritime University, Gdynia, Poland

Conclusions from the workshop on Baltic Sea region critical infrastructure networks and next steps in EU-CIRCLE project research

Keywords

Baltic Sea region, critical infrastructure, networks

Abstract

The report is devoted to the next steps in the Gdynia Maritime University team EU-CIRCLE project "A pan – European framework for strengthening Critical Infrastructure resilience to climate change" research activity after preliminary analysis of main static and dynamic industry critical infrastructures existing in the Baltic Sea Region performed to classify them as either a single critical infrastructure network or a network of critical infrastructure networks.

1. Introduction

The analysis of industrial and other systems performing activities within the Baltic Sea area, including prognosis of their developments was performed and the specification of criteria determining particular systems as a critical infrastructure subsystems, reflecting climate influence on their operation were done in [2]. After that, 8 Baltic critical infrastructure networks for various existing in this region industrial installations were defined and analysed [1], [3]-[6], [94]-[95] and 1 network of 3 most natural and typical for Baltic Sea Region closely interacting critical infrastructure networks was defined and its operation process was primarily modelled [93].
Moreover, in [7], an effort was made in order to create a global network of all considered in this report critical infrastructures within the Baltic Sea Region in the form of Baltic critical infrastructure "network of networks" called the Global Baltic Network of Critical Infrastructure Networks (GBNCIN).
Intended further steps of the Gdynia Maritime University research in the EU-CIRCLE project activity are presented in the successive section below.

2. The first step in research

The first step in research will be focused on the essential developing of tools concerned with:

- the critical infrastructures operation processes (CIOP);
- the climate-weather changes processes (C-WCP);
- the climate-weather changes processes (C-WCP) influence on the critical infrastructures operation processes (CIOP);

and their applications to single critical infrastructure networks BSCIN considered in [5] and BOPCIN considered in [6] and to networks of critical infrastructure networks BNSSTPOICIN defined in [93] and BBNCIN defined in [7].
In this research step, after modelling Critical Infrastructure Operation Process (CIOP) including Operating Environment Threats (OET) performed in [9] and Modelling Climate-Weather Change Process (C-WCP) including Extreme Weather Hazards (EWH) performed in [10], the results will be join in [11] to construct the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH).
Similarly, after identification methods and procedures of Critical Infrastructure Operation Process (CIOP) including Operating Environment Threats (OET), presented in [16] and identification methods and procedures of Climate-Weather Change Process (C-WCP) including Extreme Weather Hazards (EWH) presented in [17] the results will be collected together in [18] to create the identification methods and procedures of unknown parameters of Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment

Threats (OET) and Extreme Weather Hazards (EWH).

Practical applications of the results of the above reports will be done in [13] to modelling a maritime ferry transportation system (BSCIN component considered in [5]) operation process at the Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region and in [20] to evaluation of unknown parameters of a maritime ferry transportation system operation process related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the Baltic Sea area.

Practical applications of the results of the above reports will be done in [12] to modelling port piping transportation system (BOPCIN component considered in [1]) operation process at the southern Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region and in [19] to evaluation of unknown parameters of a port oil piping transportation system operation process related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the southern Baltic Sea area.

Practical applications of the results of the above reports will be done in [14] to modelling port, shipping and ship traffic and port operation information critical infrastructures network operation process (BNSSTPOICIN considered in [93]) at the Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region and in [21] to evaluation of unknown parameters of port, shipping and ship traffic and operation information critical infrastructures network operation processes related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the Baltic Sea area.

Practical applications of the results of the above reports will be done in [15] to modelling the operation process of the Baltic Sea critical infrastructures global network of interconnected and interdependent critical infrastructures located within the Baltic Sea and ashore around that function collaboratively (GBNCIN) using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWE) in its operating environment ("network of networks" approach) and in [22] to evaluation of unknown parameters of the Baltic Sea critical infrastructures global network ("network of networks") of interconnected and interdependent critical infrastructures located within the Baltic Sea and ashore around that function collaboratively using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in its operating environment.

Moreover, in the first year of research activity, the following practical reports fixing the assets of components of single critical infrastructure networks BSCIN and BOPCIN and networks of critical infrastructure networks BNSSTPOICIN and BBNCIN and reports identifying climate related hazards in their operating environment will be done:

- Port oil piping transportation critical infrastructure assets and interconnections [23];
- Maritime ferry critical infrastructure assets and interconnections [24];
- Southern Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network assets and interconnections [25];
- Baltic Sea area critical infrastructures global network assets and interconnections ("network of networks" approach) [26];
- Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters' exposure for port oil piping transportation critical infrastructure [27];
- Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters exposure for maritime ferry critical infrastructure [28];
- Identification climate related hazards at the Southern Baltic Sea area and their critical/extreme event parameters' exposure for port, shipping and ship traffic and port operation information critical infrastructures network [29];
- Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters' exposure for Baltic Sea critical infrastructures global network ("network of networks" approach) [30].

3. The second step in research

The second step in research will be focused on the essential developing of tools concerned with:

- the critical infrastructures safety modelling;
- the critical infrastructures safety prediction;
- the critical infrastructures safety optimization;

and their applications to single critical infrastructure networks BSCIN considered in [5] and BOPCIN considered in [6] and to networks of critical infrastructure networks BNSSTPOICIN defined in [93] and BBNCIN defined in [7].

In this step of research activity, after modelling safety of multistate ageing systems with independent components performed in [31] and modelling safety of multistate ageing systems with dependent components and subsystems in [32], the Integrated Model of Critical Infrastructure Safety (IMCIS) related to its operation process including operating environment threats (with other critical infrastructures influence, without climate-weather change influence) will be designed in [33] and the methods and procedures of identification of its unknown parameters will be proposed in [34]. Further, the adaptation of Integrated Model of Critical Infrastructure Safety (IMCIS) to critical infrastructure safety prediction will be done in [35] and the adaptation of Integrated Model of Critical Infrastructure Safety (IMCIS) to critical infrastructures network safety and "cascading effects" prediction (without climate-weather change influence) will be performed in [36].

Practical applications of the results of the above reports will be performed in [37] to the port oil piping transportation system (the preparatory approach to the Case Study 2, Scenario 1) safety modelling, identification and prediction (without climate-weather change influence), in [38] to the maritime ferry (the preparatory approach to the Case Study 2, Scenario 2) safety modelling, identification and prediction (without climate-weather change influence), in [39] to the ships operating at the Baltic Sea waters network safety modelling, identification and prediction (without climate-weather change influence), in [40] to the port, shipping and ship traffic and port operation information critical infrastructures at the Baltic Sea area network safety modelling, identification and prediction (without climate-weather change influence), and in [41] to the Baltic Sea area critical infrastructures global network ("network of networks") safety modelling, identification and prediction (without climate-weather change influence).

4. The third step in research

The third step in research will be focused on the essential developing of tools concerned with:

- the critical infrastructure operating environment threats and weather extreme hazards impacts assessment general model;
- the modelling critical infrastructure accident consequences;

and their applications to the chemical spill consequences generated by the accident of one of the ships of the shipping critical infrastructure network BSCIN.

At this stage, the impact assessment model will be created starting with the integration of the Integrated Model of Critical Infrastructure Safety (IMCIS) and the Critical Infrastructure Operation Process General Model (CIOPGM) into the General Integrated Model of Critical Infrastructure Safety (GIMCIS) related to operating environment threads (OET) and climate-weather extreme hazards (EWH) in [42]. Next, GIMCIS will be adapted in [43] to critical infrastructures network safety and "cascading effects" prediction related to climate-weather change influence and applied in [44] to the port oil piping transportation system safety modelling, identification and prediction (the preparatory approach to the Case Study 2, Scenario 1), in [45] to the maritime ferry safety modelling, identification and prediction (the preparatory approach to the Case Study 2, Scenario 2), in [46] to the ships operating at the Baltic Sea waters network safety modelling, identification and prediction (with climate-weather change influence), in [47] to the port, shipping and ship traffic and port operation information critical infrastructures at the Baltic Sea area network safety modelling, identification and prediction, and in [48] to the Baltic Sea area critical infrastructures global network ("network of networks") safety modelling, identification and prediction.

The modelling critical infrastructure accident consequences will be done in [51] through designing the General Model of Critical Infrastructure Accident Consequences (GMCIAC) and the identification of its unknown parameters will be performed in [52]. Further, the GMCIAC adaptation to the prediction of critical infrastructure accident consequences will be done in [53] and its practical applications will be performed in [54] to the chemical spill consequences generated by the accident of one of the ships of the shipping critical infrastructure network operating at the Baltic Sea waters (the preparatory approach to the Case Study 2, Scenario 2).

Additionally, at this stage, the following 2 inventory reports will be done:

- Inventory and Comparison of the results of Reports D3.3-GMU7-11 and the results of reports D3.3-GMU14-18 [49];
- Inventory of Critical Infrastructure Assessment Models for Climate Hazards. Final report including the inventory of critical infrastructure assessment models for climate hazards [50].

5. The fourth step in research

The fourth step in research will be focused on the essential developing of tools concerned with:

- the critical infrastructure resilience;
- the critical infrastructure business continuity under climate pressures;
- the critical infrastructure Cost-Effectiveness Analysis;

and their applications to single critical infrastructure networks BSCIN considered in [5] and BOPCIN considered in [6] and to networks of critical infrastructure networks BNSSTPOICIN defined in [93] and BBNCIN defined in [7].

The procedures of operation and safety optimization of critical infrastructure without and with considering C-WCP influence are proposed to its resilience improving respectively in [55] and [56] by maximizing its lifetime in the set of safety states not worse than a critical safety state. Next, those procedures are applied in [57] to optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence (the preparatory approach to the Case Study 2, Scenario 1), in [58] to optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence (the preparatory approach to the Case Study 2, Scenario 2), in [59] to optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence, and in [60] to optimization of operation and safety of Baltic Sea area critical infrastructures global network (“network of networks”) without and with considering C-WCP influence.

The procedures of operation and safety optimization of critical infrastructure without and with considering C-WCP influence are proposed to its business continuity modelling respectively in [61] and [62] by minimizing its operation cost. Next, those procedures are applied in [63] to optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence (the preparatory approach to the Case Study 2, Scenario 1), in [64] to optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence (the preparatory approach to the Case Study 2, Scenario 2), in [65] to the optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence, and in [66] to the optimization of operation and safety of Baltic Sea area critical infrastructures global network (“network of networks”) without and with considering C-WCP influence.

The joint methods of maximizing critical infrastructure lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost without and with considering C-WCP influence are proposed to cost-effectiveness analysis respectively in [69] and [70]. Next those methods are applied in the following reports:

- Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost [71];
- Optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence – Maximizing maritime ferry technical system lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost [72];
- Optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence – Maximizing port, shipping and ship traffic and operation information critical infrastructures network lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost [73];
- Optimization of operation and safety of Baltic Sea area critical infrastructures global network (“network of networks”) of critical infrastructures operating at the Baltic Sea area without and with considering C-WCP influence – Maximizing critical infrastructures global network (“network of networks”) lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost [74].

Moreover, the method of critical infrastructure accident losses minimizing will be proposed in [75] and applied in [76] to the optimization of ships operating at Baltic Sea waters critical infrastructure network accident consequences.

Additionally, at this stage, the following 2 reports collecting and analysing resilience indicators:

- Collection and inventory of all resilience indicators introduced in GMU developed models of CI resilience to climate change [67];
- Analysis and quality evaluation of resilience indicators of Baltic Sea area CIs to climate change [68];

and 1 report on crisis management procedures:

- Methodology of crisis management procedures – Creating, and modelling of climate-weather change process influence on critical infrastructures resilience [77]

will be done.

6. The fifth step in research

The fifth step in research will be focused on practical adaptation and application of the developed in the project tools to the investigation of sea surge, extreme winds and coastal flooding in Baltic Sea Port influence on selected components of BPOCIN and BSCIN in the scope:

- Case study 2; Scenario 1;
- Case study 2; Scenario2.

In the scope of Case study 2: Scenario 1, the results of earlier performed preparatory approaches will be developed and applied to the port oil piping transportation system. Final results will be prepared in the following reports:

- Modelling port piping transportation system operation process at the Southern Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region [78];
- Evaluation of unknown parameters of a port oil piping transportation system operation process related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the southern Baltic Sea area [79];
- Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters' exposure for port oil piping transportation critical infrastructure [80];
- Port oil piping transportation system safety modelling, identification and prediction (without climate-weather change influence) [81];
- Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to port oil piping transportation system safety modelling, identification and prediction (with climate-weather change influence) [82];
- Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system lifetime in the set of safety states not worse than a critical safety state [83];
- Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost [84];
- Inventory and comparison of the results of reports D6.4-GMU4-7 [85];
- New strategy assuring high safety and resilience of port oil piping transportation system [89];

In the scope of Case study 2: Scenario 2, the results of earlier performed preparatory approaches will be developed and applied to the chemical spill consequences generated by the accident of one of the ship. Final results will be prepared in the following reports:

- Practical application of the General Model of Critical Infrastructure Accident Consequences (GMCIAC) to the chemical spill consequences generated by the accident of one of the ships of the ship critical infrastructure network operating at the Baltic Sea waters [86];
- Optimization of ships operating at Baltic Sea waters critical infrastructure network accident consequences - Losses minimizing, [87];
- Inventory and comparison of the results of reports D6.4-GMU9-10, [88];
- New strategy assuring low consequences of ships operating at Baltic Sea waters critical infrastructure network accident concerned with chemical spills [90].

The general conclusions coming from Case Study 2 will be summarized in the reports:

- New general strategy assuring high safety and resilience of critical infrastructure – Operation process and safety parameters of critical infrastructure components/assets modification related to maximizing its safety characteristics and minimizing its operation cost [91];
- New strategy assuring low consequences of critical infrastructure accident – Initiating events, environment threats and environment degradation processes modification related to minimizing critical infrastructure accident consequences [92].

7. Conclusion

The remaining research activity and resulting reports with descriptions are presented in [7].

The reports resulting from the research activity will be completed with the reports on the project dissemination, communication and exploitation including workshops, training courses and publications.

Acknowledgments

The paper presents the results developed in the scope of the EU-CIRCLE project titled "A pan – European framework for strengthening Critical Infrastructure resilience to climate change" that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653824. http://www.eu-circle.eu/.

References

[1] Blokus-Roszkowska, A., Bogalecka M., Dziula, P. et al. (2016). Gas Pipelines Critical Infrastructure Network. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 1-6.

[2] Blokus-Roszkowska, A., Bogalecka, M. & Kołowrocki, K. (2016). Critical Infrastructure networks at Baltic Sea and its seaside. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 7-14.

[3] Blokus-Roszkowska, A., Guze, S., Kołowrocki, K. et al. (2016). Port Critical Infrastructure Network. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 15-28.

[4] Blokus-Roszkowska, A., Kołowrocki, K. & Soszyńska-Budny, J. (2016). Baltic Electric Cable Critical Infrastructure Network. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 29-36.

[5] Bogalecka, M., Kołowrocki, K., Soszyńska-Budny J. et al. (2016). Shipping Critical Infrastructure Network. Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars 7, 1-2, 43-52.

[6] Drzazga, M., Kołowrocki, K. & Soszyńska-Budny, J. (2016). Oil Pipeline Critical Infrastructure Network. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 53-60.

[7] Dziula, P. & Kołowrocki, K. (2016). Global Baltic Network of Critical Infrastructure Networks. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 3, 15-20.

[8] EU-CIRCLE Report D1.4-GMU1. (2015). *Critical infrastructure safety and resilience to climate-weather change – An overall approach, 2015*.

[9] EU-CIRCLE Report D2.1-GMU2. (2016). *Modelling outside dependences influence on Critical Infrastructure Safety (CIS) – Modelling Critical Infrastructure Operation Process (CIOP) including Operating Environment Threats (OET).*

[10] EU-CIRCLE Report D2.1-GMU3. (2016). *Modelling outside dependences influence on Critical Infrastructure Safety (CIS) – Modelling Climate-Weather Change Process (C-WCP) including Extreme Weather Hazards (EWH).*

[11] EU-CIRCLE Report D2.1-GMU4. (2016). *Modelling outside dependences influence on Critical Infrastructure Safety (CIS) - Designing Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) by linking CIOP and C-WCP models.*

[12] EU-CIRCLE Report D2.2-GMU1. (2016). *Modelling port piping transportation system operation process at the southern Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region.*

[13] EU-CIRCLE Report D2.2-GMU2. (2016). *Modelling maritime ferry transportation system operation process at the Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region.*

[14] EU-CIRCLE Report D2.2-GMU3. (2016). *Modelling port, shipping and ship traffic and port operation information critical infrastructures network operation process at the Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region.*

[15] EU-CIRCLE Report D2.2-GMU4. (2016). *Modelling the operation process of the Baltic Sea critical infrastructures global network of interconnected and interdependent critical infrastructures located within the Baltic Sea and ashore around that function collaboratively using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in its operating environment ("network of networks" approach).*

[16] EU-CIRCLE Report D2.3-GMU1. (2016). *Identification methods and procedures of Critical Infrastructure Operation Process (CIOP) including Operating Environment Threats (OET).*

[17] EU-CIRCLE Report D2.3-GMU2. (2016). *Identification methods and procedures of Climate-Weather Change Process (C-WCP) including Extreme Weather Hazards (EWH).*

[18] EU-CIRCLE Report D2.3-GMU3. (2016). *Identification methods and procedures of unknown parameters of Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazard (EWH).*

[19] EU-CIRCLE Report D2.3-GMU4. (2016). *Evaluation of unknown parameters of a port oil piping transportation system operation process*

related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the southern Baltic Sea area.

[20] EU-CIRCLE Report D2.3-GMU5. (2016). *Evaluation of unknown parameters of a maritime ferry transportation system operation process related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the Baltic Sea area*.

[21] EU-CIRCLE Report D2.3-GMU6. (2016). *Evaluation of unknown parameters of port, shipping and ship traffic and port operation information critical infrastructures network operation processes related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the Baltic Sea area*.

[22] EU-CIRCLE Report D2.3-GMU7. (2016). *Evaluation of unknown parameters of the Baltic Sea critical infrastructures global network ("network of networks") of interconnected and interdependent critical infrastructures located within the Baltic Sea and ashore around that function collaboratively using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in its operating environment*.

[23] EU-CIRCLE Report D3.1-GMU1. (2016). *Port oil piping transportation critical infrastructure assets and interconnections*.

[24] EU-CIRCLE Report D3.1-GMU2. (2016). *Maritime ferry critical infrastructure assets and interconnections*.

[25] EU-CIRCLE Report D3.1-GMU3. (2016). *Southern Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network assets and interconnections*.

[26] EU-CIRCLE Report D3.1-GMU4. (2016). *Baltic Sea area critical infrastructures global network assets and interconnections ("network of networks" approach)*.

[27] EU-CIRCLE Report D3.2-GMU1. (2016). *Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters exposure for port oil piping transportation critical infrastructure*.

[28] EU-CIRCLE Report D3.2-GMU2. (2016). *Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters exposure for maritime ferry critical infrastructure*.

[29] EU-CIRCLE Report D3.2-GMU3. (2016). *Identification climate related hazards at the Southern Baltic Sea area and their critical/extreme event parameters' exposure for port, shipping and ship traffic and port operation information critical infrastructures network*.

[30] EU-CIRCLE Report D3.2-GMU4. (2016). *Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters' exposure for Baltic Sea critical infrastructures global network ("network of networks" approach)*.

[31] EU-CIRCLE Report D3.3-GMU1. (2016). *Modelling inside dependences influence on safety of multistate ageing systems – Modelling safety of multistate ageing systems*.

[32] EU-CIRCLE Report D3.3-GMU2. (2016). *Modelling inside dependences influence on safety of multistate ageing systems – Modelling safety of multistate ageing systems with dependent components and subsystems*.

[33] EU-CIRCLE Report D3.3-GMU3. (2016). *Modelling inside and outside dependences influence on safety of complex multistate ageing systems (critical infrastructures) – Integrated Model of Critical Infrastructure Safety (IMCIS) related to its operation process including operating environment threats (with other critical infrastructures influence, without climate-weather change influence)*.

[34] EU-CIRCLE Report D3.3-GMU4. (2016). *Identification of unknown parameters of critical infrastructure safety integrated model*.

[35] EU-CIRCLE Report D3.3-GMU5. (2016). *Adaptation of Integrated Model of Critical Infrastructure Safety (IMCIS) to critical infrastructure safety prediction*.

[36] EU-CIRCLE Report D3.3-GMU6. (2016). *Adaptation of Integrated Model of Critical Infrastructure Safety (IMCIS) to critical infrastructures network safety and "cascading effects" prediction (without climate-weather change influence)*.

[37] EU-CIRCLE Report D3.3-GMU7. (2016). *Port oil piping transportation system safety modelling, identification and prediction (without climate-weather change influence)*.

[38] EU-CIRCLE Report D3.3-GMU8. (2016). *Maritime ferry safety modelling, identification and prediction (without climate-weather change influence)*.

[39] EU-CIRCLE Report D3.3-GMU9. (2016). *Ships operating at the Baltic Sea waters network safety modelling, identification and prediction (without climate-weather change influence)*.

[40] EU-CIRCLE Report D3.3-GMU10. (2016). *Port, shipping and ship traffic and port operation information critical infrastructures at the Baltic Sea area network safety modelling, identification and prediction (without climate-weather change influence)*.

[41] EU-CIRCLE Report D3.3-GMU11. (2016). *The Baltic Sea area critical infrastructures global network ("network of networks") safety modelling, identification and prediction (without climate-weather change influence)*.

[42] EU-CIRCLE Report D3.3-GMU12. (2017). *Integration of the Integrated Model of Critical Infrastructure Safety (IMCIS) and the Critical Infrastructure Operation Process General Model (CIOPGM) into the General Integrated Model of Critical Infrastructure Safety (GIMCIS) related to operating environment threads (OET) and climate-weather extreme hazard (EWH).*

[43] EU-CIRCLE Report D3.3-GMU13. (2017). *Adaptation of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to critical infrastructures network safety and "cascading effects" prediction (with climate-weather change influence)*.

[44] EU-CIRCLE Report D3.3-GMU14. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to port oil piping transportation system safety modelling, identification and prediction (with climate-weather change influence)*.

[45] EU-CIRCLE Report D3.3-GMU15. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to maritime ferry safety modelling, identification and prediction (with climate-weather change influence)*.

[46] EU-CIRCLE Report D3.3-GMU16. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to ships operating at the Baltic Sea waters network safety modelling, identification and prediction (with climate-weather change influence)*.

[47] EU-CIRCLE Report D3.3-GMU17. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to port, shipping and ship traffic and port operation information critical infrastructures at the Baltic Sea area network safety modelling, identification and prediction (with climate-weather change influence).*

[48] EU-CIRCLE Report D3.3-GMU18. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to the Baltic Sea area critical infrastructures global network ("network of networks") safety modelling, identification and prediction (with climate-weather change influence)*.

[49] EU-CIRCLE Report D3.3-GMU19. (2017). *Inventory and Comparison of the results of reports D3.3-GMU7-11 and the results of reports D3.3-GMU14-18*.

[50] EU-CIRCLE Report D3.3-GMU20. (2017). *Inventory of Critical Infrastructure Assessment Models for Climate Hazards*. *Final report including the inventory of critical infrastructure assessment models for climate hazards*.

[51] EU-CIRCLE Report D3.3-GMU21. (2016). *Modelling critical infrastructure accident consequences - Designing the General Model of Critical Infrastructure Accident Consequences (GMCIAC)*.

[52] EU-CIRCLE Report D3.3-GMU22. (2016). *Identification of unknown parameters of the General Model of Critical Infrastructure Accident Consequences (GMCIAC)*.

[53] EU-CIRCLE Report D3.3-GMU23. (2016). *Adaptation of the General Model of Critical Infrastructure Accident Consequences (GMCIAC) to the prediction of critical infrastructure accident consequences*.

[54] EU-CIRCLE Report D3.3-GMU24. (2017). *Practical application of the General Model of Critical Infrastructure Accident Consequences (GMCIAC) to the chemical spill consequences generated by the accident of one of the ships of the ship critical infrastructure network operating at the Baltic Sea waters*.

[55] EU-CIRCLE Report D4.3-GMU1. (2017). *Optimization of operation and safety of critical infrastructure without considering C-WCP influence – Maximizing CI lifetime in the set of safety states not worse than a critical safety state*.

[56] EU-CIRCLE Report D4.3-GMU2. (2017). *Optimization of operation and safety of critical infrastructure with considering C-WCP influence – Maximizing CI llifetime in the set of safety states not worse than a critical safety state*.

[57] EU-CIRCLE Report D4.3-GMU3. (2017). *Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system llifetime in the set of safety states not worse than a critical safety state*.

[58] EU-CIRCLE Report D4.3-GMU4. (2017). *Optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence – Maximizing maritime ferry technical system lifetime in the set of safety states not worse than a critical safety state*.

[59] EU-CIRCLE Report D4.3-GMU5. (2017). *Optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence – Maximizing port, shipping and ship*

traffic and port operation information critical infrastructures network lifetime in the set of safety states not worse than a critical safety state.

[60] EU-CIRCLE Report D4.3-GMU6. (2017). *Optimization of operation and safety of Baltic Sea area critical infrastructures global network ("network of networks") without and with considering C-WCP influence – Maximizing critical infrastructures global/general network ("network of networks") lifetime in the set of safety states not worse than a critical safety state*.

[61] EU-CIRCLE Report D4.4-GMU1. (2017). *Optimization of operation and safety of critical infrastructure without considering C-WCP influence – Minimizing CI operation cost*.

[62] EU-CIRCLE Report D4.4-GMU2. (2017). *Optimization of operation and safety of critical infrastructure with C-WCP influence – Minimizing CI operation cost*.

[63] EU-CIRCLE Report D4.4-GMU3. (2017). *Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Minimizing port oil piping transportation system operation cost*.

[64] EU-CIRCLE Report D4.4-GMU4. (2017). *Optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence – Minimizing maritime ferry technical system operation cost*.

[65] EU-CIRCLE Report D4.4-GMU5. (2017). *Optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence – Minimizing port, shipping and ship traffic and port operation information critical infrastructures network operation cost*.

[66] EU-CIRCLE Report D4.4-GMU6. (2017). *Optimization of operation and safety of Baltic Sea area critical infrastructures global network ("network of networks") without and with considering C-WCP influence – Minimizing critical infrastructures global/general network ("network of networks") operation cost*.

[67] EU-CIRCLE Report D4.5-GMU1. (2017). *Collection and inventory of all resilience indicators introduced in GMU developed models of CI resilience to climate change*.

[68] EU-CIRCLE Report D4.5-GMU2. (2017). *Analysis and quality evaluation of resilience indicators of Baltic Sea area CIs to climate change*.

[69] EU-CIRCLE Report D4.7-GMU1. (2017). *Optimization of operation and safety of critical infrastructure without considering C-WCP influence – Maximizing CI lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[70] EU-CIRCLE Report D4.7-GMU2. (2017). *Optimization of operation and safety of critical infrastructure with C-WCP influence – Maximizing CI lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[71] EU-CIRCLE Report D4.7-GMU3. (2017). *Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system llifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[72] EU-CIRCLE Report D4.7-GMU4. (2017). *Optimization of operation and safety of maritime ferry transportation critical infrastructure without and with considering C-WCP influence – Maximizing maritime ferry technical system lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[73] EU-CIRCLE Report D4.7-GMU5. (2017). *Optimization of operation and safety of Baltic Sea area port, shipping and ship traffic and port operation information critical infrastructures network without and with considering C-WCP influence – Maximizing port, shipping and ship traffic and port operation information critical infrastructures network lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[74] EU-CIRCLE Report D4.7-GMU6. (2017). *Optimization of operation and safety of Baltic Sea area critical infrastructures global network ("network of networks") of critical infrastructures operating at the Baltic Sea area without and with considering C-WCP influence – Maximizing critical infrastructures network ("network of networks") lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[75] EU-CIRCLE Report D4.7-GMU7. (2017). *Optimization of critical infrastructure accident consequences - Losses minimizing*.

[76] EU-CIRCLE Report D4.7-GMU8. (2017). *Optimization of ships operating at Baltic Sea waters critical infrastructure network accident consequences – Losses minimizing*.

[77] EU-CIRCLE Report D4.7-GMU9. (2017). *Methodology of crisis management procedures – Creating, and modeling of climate-weather change process influence on critical infrastructures resilience*.

[78] EU-CIRCLE Report D6.4-GMU1. (2017). *Modelling port piping transportation system operation process at the Southern Baltic Sea area using the Critical Infrastructure Operation Process General Model (CIOPGM) related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) in this region*.

[79] EU-CIRCLE Report D6.4-GMU2. (2017). *Evaluation of unknown parameters of a port oil piping transportation system operation process related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH) at the southern Baltic Sea area*.

[80] EU-CIRCLE Report D6.4-GMU3. (2017). *Identification climate related hazards at the Baltic Sea area and their critical/extreme event parameters' exposure for port oil piping transportation critical infrastructure*.

[81] EU-CIRCLE Report D6.4-GMU4. (2017). *Port oil piping transportation system safety modelling, identification and prediction (without climate-weather change influence)*.

[82] EU-CIRCLE Report D6.4-GMU5. (2017). *Application of the General Integrated Model of Critical Infrastructure Safety (GIMCIS) to port oil piping transportation system safety modelling, identification and prediction (with climate-weather change influence)*.

[83] EU-CIRCLE Report D6.4-GMU6. (2017). *Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system llifetime in the set of safety states not worse than a critical safety state*.

[84] EU-CIRCLE Report D6.4-GMU7. (2017). *Optimization of operation and safety of port oil piping transportation critical infrastructure without and with considering C-WCP influence – Maximizing port oil piping transportation system lifetime in the set of safety states not worse than a critical safety state and minimizing its operation cost*.

[85] EU-CIRCLE Report D6.4-GMU8. (2017). *Inventory and comparison of the results of reports D6.4-GMU4-7*.

[86] EU-CIRCLE Report D6.4-GMU9. (2017). *Practical application of the General Model of Critical Infrastructure Accident Consequences (GMCIAC) to the chemical spill consequences generated by the accident of one of the ships of the ship critical infrastructure network operating at the Baltic Sea waters*.

[87] EU-CIRCLE Report D6.4-GMU10. (2017). *Optimization of ships operating at Baltic Sea waters critical infrastructure network accident consequences – Losses minimizing*.

[88] EU-CIRCLE Report D6.4-GMU11. (2017). *Inventory and comparison of the results of reports D6.4-GMU9-10*.

[89] EU-CIRCLE Report D6.5-GMU1. (2018). *New strategy assuring high safety and resilience of port oil piping transportation system*.

[90] EU-CIRCLE Report D6.5-GMU2. (2018). *New strategy assuring low consequences of ships operating at Baltic Sea waters critical infrastructure network accident concerned with chemical spills*.

[91] EU-CIRCLE Report D6.5-GMU3. (2018). *New general strategy assuring high safety and resilience of critical infrastructure – Operation process and safety parameters of critical infrastructure components/assets modification related to maximizing its safety characteristics and minimizing its operation cost*.

[92] EU-CIRCLE Report D6.5-GMU4. (2018). *New strategy assuring low consequences of critical infrastructure accident – Initiating events, environment threats and environment degradation processes modification related to minimizing critical infrastructure accident consequences*.

[93] Guze, S. & Kołowrocki, K. (2016). Joint Network of Port, Shipping and Ship Traffic and Operation Information Critical Infrastructure Networks. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 61-64.

[94] Guze, S. & Ledóchowski, M. (2016). Ship Traffic and Port Operation Information Critical Infrastructure Network. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 65-72.

[95] Kołowrocki, K., Kuligowska, E. & Reszko, M. (2016). Methodology for oil rig critical infrastructure network safety and resilience to climate change analysis. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 187-195.

[96] Kołowrocki, K., Kuligowska, E. & Reszko, M. (2016). Methodology for wind farms critical infrastructure network safety and resilience to climate change analysis. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 179-186.