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Critical infrastructure networks at Baltic Sea and its seaside

Keywords

critical infrastructure, critical infrastructure network, Baltic Sea Region, GBNCIN, natural hazards, dynamic installation, static industrial installation

Abstract

At the beginning, in the paper the basic definitions concerned with critical infrastructures and climate and weather impacts on their safety are given. Next, critical infrastructure networks operating at Baltic Sea Region, forming the Global Baltic Network of Critical Infrastructure Networks (GBNCIN), are distinguished. Dangerous events coming from/to critical infrastructures located in the Baltic Sea area are classified and described. Potential threats are divided into two groups i.e. threats associated with dynamic installations and those associated with various static industrial installations. Moreover, natural hazards associated with weather and climate change are considered.

1. Critical infrastructure and their operating environment methodology

Before the considerations on critical infrastructure installations at Baltic Sea Region, we refer to definitions of selected basic notions concerned with critical infrastructures and climate and weather impacts on their safety included in the report [10].

We start with the notion of the *complex system* that is defined as a set or group of interacting, interrelated or interdependent elements or parts, that are organized and integrated to form a collective unity or an unified whole, to achieve a common objective.

This definition lays emphasis on the interactions between the parts of a system and the external environment to perform a specific task or function in the context of an operational environment. This focus on interactions is to take a view on the expected or unexpected demands (inputs) that will be placed on the system and see whether necessary and sufficient resources are available to process the demands. These might take form of stresses. These stresses can be either expected, as part of normal operations, or unexpected, as part of unforeseen acts or conditions that produce beyond-normal (i.e. abnormal) conditions and behaviours. This definition of a system, therefore, includes not only the product or the process but also the influences that the surrounding environment (including human interactions) may have on the product's or process's safety performance.

The *system operating environment* is defined as the surroundings in which a system operates, including air, water, land, natural resources, flora, fauna, humans and their interrelations.

The *system operating environment threat* is an unnatural event that may cause the system damage and/or change its operation activity in the way unsafe for the system and its operating environment, for instance: another ship activity in the ship operating environment that can result in an accident with serious consequences for the ship and its operating environment, a human error or a terrorist attack changing the system operation process in an unsafe way.

The *climate related hazard* is a natural physical event coming out from climate change that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.

The *system inside dependencies* are dependencies within a system itself i.e. relationship between components and subsystems in a system causing state changes of other components and subsystems and in a consequence resulting in changes of the system state.

The *system outside dependencies* are dependencies coming from the system operating environment (external factors), including changes of the system state caused by outside this system conditions e.g. climate changes, changes of its functionality, location, other objects, government and human decisions (regulations, economic, public policy).

Now, we can define the *critical infrastructure* as a complex system in its operating environment that significant features are inside-system dependencies and outside-system dependencies that in the case of its degradation have significant and destructive influence on the health, safety and security, economics and social conditions of large human communities and territory areas.

Further, we may define the *country's critical infrastructure* as a complex system and assets located in the country which is essential (vital) for the national security, governance, public health and safety, economy and public confidence of this country.

More general notion is the *regional critical infrastructure* defined as the network of interconnected and interdependent critical infrastructures located in the considered region that function collaboratively in order to ensure a continuous production flow of essentials, goods and services.

And particularly, the *European Critical infrastructure* is the network of interconnected and interdependent critical infrastructures located in EU member states that function collaboratively in order to ensure a continuous production flow of essentials, goods and services.

To explain two last definitions, we need to be familiar with the following three notions, the *critical infrastructure network* which is a set of interconnected and interdependent critical infrastructures interacting directly and indirectly at various levels of their complexity and operating activity, the *interconnected critical infrastructures* that are critical infrastructures in mutually direct and indirect connections between themselves and the *interdependent critical infrastructures* that are critical infrastructures in mutually dependant relationships between themselves interacting at various levels of their complexity.

The *critical infrastructure accident* is defined as an event that causes changing the critical infrastructure safety state into the safety state worse than the critical safety state that is dangerous for the critical infrastructure itself and its operating environment.

The *critical infrastructure network cascading effects* are called degrading effects occurring within a critical infrastructure and between critical infrastructures in their operating environment, including situations in which one critical infrastructure causes degradation of another ones, which again causes additional degradation in other critical infrastructures and in their operating environment.

The *critical infrastructure threat* is the occurrence of an unwanted circumstance or event that may cause damage, functioning disruption or service interruption to critical infrastructures.

The *resilience* is the sufficient ability of an object to continue its operational objective in the conditions including harmful impacts and the ability to mitigate and/or to neutralize those harmful impacts.

The *critical infrastructure resilience* is the ability of a critical infrastructure to continue providing its essential services when threatened by a harmful event as well as its speed of recovery and ability to return to normal operation after the threat has receded.

The *critical infrastructure vulnerability* is the critical infrastructure feature that makes it easily influenced by some external threat and hazards coming from its operating environment.

The *critical infrastructure exposure* is the fact or the condition of being exposed to something (of being subjected to an action or an influence), for instance being exposed to severe weather.

To be able to consider fluently the climate change impacts on critical infrastructures behaviour, we introduce definitions of some notions related to those interactions.

The *climate* is defined as dynamic interactions of several components including atmosphere, hydrosphere, cryosphere, land surface and biosphere.

The *weather* is a short-term dynamically changing the states of atmosphere characterised by the values of several parameters including temperature, pressure, humidity and direction and force of wind.

The *climate change* is defined as any changes in climate over time, either due to natural variability or as a result of human activity.

The *extreme weather event* is defined as meteorological conditions that are dangerous and happen at a particular place and time and can generate severe hazards.

The *hazard caused by weather change* is an event associated with extreme weather that may cause the loss of life or severe injury, property damage, social and economic disruption or environmental degradation. For instance: a dangerous chemical realise into the sea water as a result of ship accident cause by severe storm.

The *critical infrastructure resilience to climate change* is the ability of a critical infrastructure to continue providing its essential services when it is exposed to hazards associated with coming out from the climate change harmful events as well as its speed of recovery and ability to return to normal operation after those threats has receded.

A bit different definition to the above is the following one.

The *critical infrastructure resilience to climate change* is a critical infrastructure capacity being able to absorb and to recover from hazardous events appearing as a result of climate change.

The *critical infrastructure strengthening to climate change* is an increasing critical infrastructure capacity through its components and subsystems parameters improving and its operating environment parameters modification to achieve its characteristics stronger what allows its functioning in its operating environment to be able to absorb and to recover from hazardous events appearing as a result of climate change.

The *critical infrastructure natural disaster resilience* is a critical infrastructure capacity being able to absorb and to recover from hazardous events appearing as a result of natural disaster impacts.

The *critical infrastructure adaptation to climate change* is a modification of critical infrastructure structure, its components and subsystems parameters and its operating environment parameters to achieve its characteristics that allows its functioning in its operating environment changed by climate change impacts.

The *critical infrastructure natural disaster impacts risk* is defined as the possibility of occurrence over the specified time period and area of dangerous alterations in the critical infrastructure normal functioning due to hazardous events coming out as a result of natural disaster impacts and interacting with critical infrastructure, leading to its and its operating environment degradation.

The *critical infrastructure natural disaster vulnerability* is a critical infrastructure feature that makes it easily influenced by some external factors and hazards coming from its operating environment dangerous changes forced by natural disaster impacts.

The *critical infrastructure natural disaster impacts reduction* is defined as efforts and actions to reduce effects of potential hazards coming from natural disaster influence on critical infrastructure by the reduction of their occurrence frequency and intensity, changing their interactions with people and their support systems.

The *critical infrastructure natural disaster impacts mitigation* is defined as efforts and actions to prevent and reduce effects of potential hazards coming from natural disaster influence on critical infrastructure by their elimination or reduction of their occurrence frequency and intensity, changing their interactions with people and their support systems and making alters the way people live and the systems they create.

The *critical infrastructure resilience to natural hazard* is the critical infrastructure capacity being able to absorb and to recover from natural hazards.

The *critical infrastructure preparedness to climate change* is the critical infrastructure ability to ensure effective response to the impact of climate change related hazards, including the critical infrastructure operating organizational reactions to the issuance of timely and effective early warnings.

The *strengthening critical infrastructure resilience* is defined as efforts, like policies, procedures and actions, taken to prolong the proper and effective functioning of a critical infrastructure and providing its essential services when it is exposed to unnatural threats and natural hazards.

The *strengthening critical infrastructure resilience to climate change* is an increasing the critical infrastructure capacity through its components and subsystems parameters improving and its operating environment parameters modification to achieve its characteristics stronger what allow its functioning in its operating environment to be able to absorb and to recover from hazardous events appearing as a result of climate change.

Finally, to be familiar to the notions concerned with the critical infrastructure water environment, we introduce definitions of selected terms related to this environment.

The *basin* is a lake or river and its drainage area [1].

The *brackish* is a water body that it is neither fresh water nor fully marine water, but with a salt concentration in between [1].

The *bottom water* (*deep water*) is the water beneath the thermocline [1].

The *epicontinental sea* is a sea situated on, rather than between, continents [1].

The *exclusive economic zone* (*EEZ*) is an exclusive part of the continental shelf, taken to be a band extending 200 miles from the country shore where this country exploration and exploitation of marine resources is allowed [22].

The *halocline* is a rapid increase in salinity that occurs at a water depth of about 70-90 m in the Baltic Sea [1].

The *redoxcline* is the oxygen gradient from water depth of about 60-7- m to about 140 m in the Baltic Sea [1].

The *surface water* is the water above the thermocline [1].

The *thermocline* is the temperature gradient between a water depth of 20 m and about 70 m in the Baltic Sea [1].
The *water exchange* is the time water stays in a given area, or the retention time; water exchange varies in time and space in any given coastal area [1].

2. Critical infrastructure installations at Baltic Sea Region

Considering definitions of main notions from the above methodology concerned with critical infrastructures and their networks and the nature and features of the industrial installations at the Baltic Sea Region, we are convinced to distinguish the following 8 main critical infrastructure networks operating in this region:

- port critical infrastructure network [3], [11];
- shipping critical infrastructure network [5], [11];
- oil rig critical infrastructure network [11], [20];
- wind farm critical infrastructure network [11], [21];
- electric cable critical infrastructure network [4], [11];
- gas pipeline critical infrastructure network [2], [11];
- oil pipeline critical infrastructure network [9], [11];
- ship traffic and port operation information critical infrastructure network [11], [17].

We classify the above distinguished shipping critical infrastructure network to the class of so called dynamic installations and the remaining distinguished 7 critical infrastructures to the class of so called static installations.
We also distinguish, in our opinion, the most natural and important in this region the network of networks composed of the port critical infrastructure network, the shipping critical infrastructure network and the ship traffic and operation information critical infrastructure network.
Moreover, we suggest call the network of all those distinguished 8 networks operating at Baltic Sea Region the Global Baltic Network of Critical Infrastructure Networks.
The elements of those critical infrastructures and their networks, on the one hand, may be vulnerable to damage caused by external factors (threats from) and on the other hand, they may pose actual or potential threats to other critical infrastructures and networks. The dangerous events coming from/to critical infrastructures located in the Baltic Sea area can be divided into:

- the threats associated with dynamic installations, like shipping and port operations,
- the threats associated with various static industrial installations, like listed above,
- the natural hazards associated with weather and climate change.

The model of area-picture of potential dangerous events coming from/to critical infrastructures in the Baltic Sea area is shown in *Figure 1*. This model can be used to construct a global network of interconnected and interdependent critical infrastructure networks existing in the Baltic Sea Region what is highly reasonable as usually the critical infrastructures are not isolated and they create a system of interconnected and interdependent critical infrastructures [22]. Often, one industrial sector activities concerned with one critical infrastructure may be in conflict of interest with the activities of a number of other critical infrastructures of other industrial sectors. Some sectors are quite stable while others are still changing, thus the global model of network on critical infrastructures needs to consider time-dependent behaviour of critical infrastructures it is to be composed. The proposed approach, taking into account layers of "dynamic threats" (threats associated with dynamic installations), "static threats" (threats associated with static installations) and natural climatic hazards (hazards associated with climate/weather change), in a holistic and dynamic way, can help to indicate critical infrastructures which can be affected and can affect other critical infrastructures in fixed area of the Baltic Sea Region.
Similar ideas of schemes showing the connections and interdependencies between critical infrastructures have been presented in [7] and [24]. In [24], in *Figure 1*, individual infrastructure networks are represented on a single plane, whereas the parallel lines represent individual sectors or sector subsets within the particular infrastructure. In this report, there are considered ties and dependencies existing within each infrastructure (internal dependencies) and between the different sectors (infrastructure interdependencies). A scheme showing the interconnection of critical infrastructures and their qualitative dependencies and interdependencies has been presented in the report prepared by Committee on the Peaceful Uses of Outer Space [7]**.**

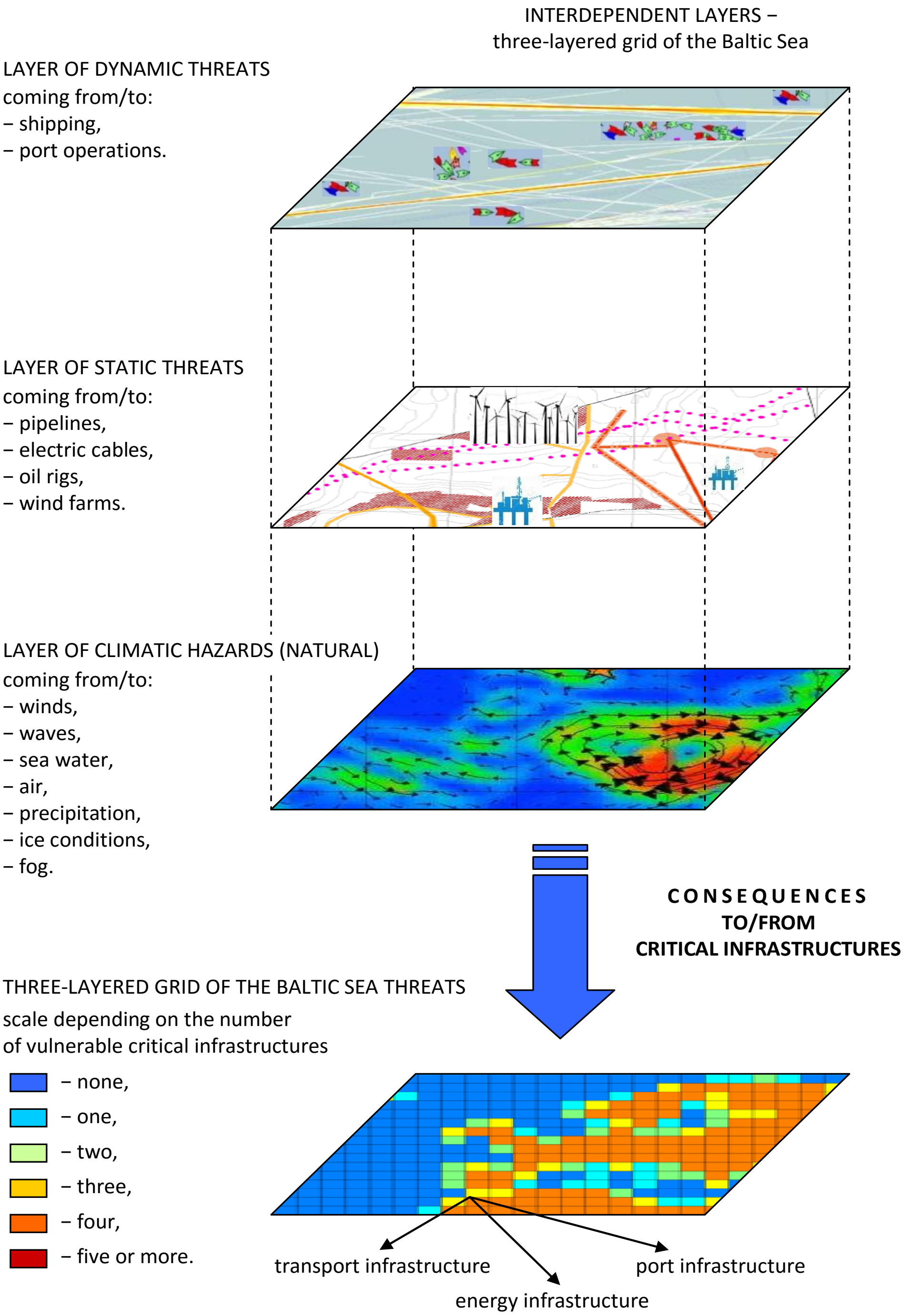

Figure 1. The model of area-picture of potential threats from/to critical infrastructures in the Baltic Sea Region

Among the "static threats" we can distinguish:

- the elements, which are merely obstacles and pose a threat such as shipwrecks and sunken chemical weapons,
- physical structures which are part of critical infrastructure and can have negative impact on other sectors or cannot co-exist in the same area (e.g. wind farms),
- and components of critical infrastructures, which constitute a threat to other sectors and at the same time they are themselves threatened with disturbances in their functioning.

The latter group of threats can include those coming from pipelines, electricity cables, oil rigs. For example failure of pipelines caused by anchors passing over the pipe, corrosion or breakage, can result in oil spills and affect both nature and many commercial sectors. The leakages can be also caused by operational spills and discharges or blowouts from oil wells [27].

Large scale wind farms may result in conflicts with other sectors such as shipping, laying of cables and pipelines and military activities, as they block specific areas. Furthermore, wind farms can potentially cause interference with hydrological processes of the sea by altering water currents or transportation of sediments [23].

The shipping sector is a critical infrastructure network which collides with other sectors, for example with wind energy sector. Wind farms occupy more and more areas and there is usually safety zone of 500 meters around wind farms, with restrictions for shipping, and a buffer zone of 500 meters around the cables, which prohibits anchoring of vessels [27].

Each month there are around 3,500 to 5,000 ships on the waters of the Baltic Sea; around 2,000 sizeable ships are normally at sea at any given moment, including large oil tankers, ships carrying dangerous and potentially polluting cargoes, as well as many large passenger ferries [8]. According to HELCOM, there has been an increase in both groundings and collisions during the last years. Many accidents result in oil spills. A large oil accident in the Baltic Sea would have serious ecological effects [26].

The main environmental effects of shipping and other activities at sea include air pollution, illegal deliberate and accidental discharges of oil, hazardous substances and other wastes, and the unintentional introduction of invasive alien organisms via ships' ballast water or hulls. Shipping adds to the problem of eutrophication of the Baltic Sea with its nutrient inputs from sewage discharges and nitrogen oxides (NOx) emissions [18]. In our opinion, those facts are sufficient and reasonable to consider the set of operating in the Baltic Sea area as a shipping critical infrastructure network what currently is not clearly acceptable in critical infrastructure safety analysis. Our suggestion is to accept our approach without any objections.

The Baltic Sea is facing an expansion in all sectors. This growth increases demand for the space and resources of the sea and can consequently lead to conflicts within maritime sectors and between sectors. The Baltic Sea is already one of the most densely trafficked sea regions in the world. In addition to the pressures from place-based maritime activities, the already stressed Baltic Sea ecosystem is exposed to further pressures from diffuse sources like agricultural and industrial pollution and climate change [27].

In the layer of climatic hazards we can take into account wind, temperature, humidity, cloudiness, precipitation or solar radiation as well as occurrence extreme weather events – hurricanes, storms, etc. – and changes in weather patterns. Sea-surface height is an important indicator of climate variability and long-term change. According to [19], a compilation of mid-range and high-range sea-level rise scenarios projected respectively a 0.6 m and 1.1 m sea-level rise in the Baltic Sea over the 21st century.

The results of multi-media ensemble simulations of projected changes in sea-level extremes caused by changes in the regional wind field indicated that at the end of the 21st century the largest changes in mean sea-surface height will occur during spring, amounting to up to 20 cm in coastal areas of the Bothnian Bay. The maximum change in the annual mean sea-surface height will be 10 cm. However, these results do not take into account large-scale sea-level rise or the land uplift in the Baltic Sea area. Another study that also took into account available global sea-level rise scenarios and simulated regional wind speed changes found that sea-level rise has a greater potential to increase storm surge levels in the Baltic Sea than does increased wind speed. This study projected large increases of storm surge levels at the entrance to the Baltic Sea, but the relative impact of changing wind speed on sea-level extremes may be even greater for areas in the eastern Baltic [19].

There is a complex relationship between climate change and maritime infrastructure sectors. This relationship can be considered in terms of how climate change impacts on the maritime industry, e.g. extreme weather events, erosion of coastal infrastructure and opening of new sea routes.

The most serious and costly water-related impacts of climate change are likely to be coastal flooding. Low-lying port facilities, roads, rail lines, tunnels, pipelines, ventilation shafts, and power lines are potentially subject to flooding, depending on the extent of sea level rise and storm surges. Global climate change is likely to require reengineered freight facilities that are better able to withstand storm surges and flooding. For example, stronger, higher, corrosion- and scour-resistant bridges will be needed in areas subject to storm surges and salt water contamination. Lift-on/lift-off port facilities may replace roll-on/roll-off port facilities in harbours that experience unusually large tidal variations [6].

Critical infrastructure components can be also installations or objects that cause danger for vessels. Oil rigs and wind farms are the best examples of such obstructions.

3. Conclusion

In the paper there are presented critical infrastructure networks at Baltic Sea Region that are creating the Global Baltic Network of Critical Infrastructure Networks (GBNCIN). Critical infrastructure installation belonging to GBNCIN and their elements on the one hand, may be vulnerable to damage caused by external factors and on the other hand,

they may pose actual or potential threats to other critical infrastructures and networks. The dangerous events coming from/to critical infrastructures located in the Baltic Sea area in this paper are divided into three categories, i.e. the threats associated with dynamic installations, the threats associated with various static industrial installations, and natural hazards associated with weather and climate change.
The global network GBNCIN of all considered in this paper critical infrastructures is formulated as the Baltic critical infrastructure "network of networks".
Next step of the research based on the concept presented in this paper and on the report [11] will focus on the essential developing of tools concerned with:
- the critical infrastructures operation processes (CIOP), [13],
- the climate-weather changes processes (C-WCP), [14],
- the climate-weather changes processes (C-WCP) influence on the critical infrastructures operation processes (CIOP), [15],
and their applications to single critical infrastructure networks, such as the Baltic shipping critical infrastructure network (BSCIN) considered in [5], [12] and the Baltic Oil Pipeline Critical Infrastructure Network (BOPCIN) considered in [9], [12], and to networks of critical infrastructure networks, i.e. the Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network defined in [12], [17] and the Joint Network of Port, Shipping and Ship Traffic and Operation Information Critical Infrastructure Networks defined in [11], [16].

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