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Joint Network of Port, Shipping, Ship Traffic and Port Operation Information Critical Infrastructure Network

Keywords

Critical Infrastructure Network, Baltic Sea Region, Baltic ports, shipping, information systems

Abstract

The main aim of the paper is to define the Baltic Port, Shipping, Ship Traffic and Port Operation Information Joint Critical Infrastructure Network (BPSIJN). The particular components of this joint network are firstly defined as the single critical infrastructure networks. Based on these, the BPSIJN is defined and described. Furthermore, the operation process for the network is initially introduced.

1. Introduction

In the sea-land transport chain the logistic integration process take place between a number of players like shipping, sea ports with their transportation facilities, waterways and system users to create the maritime transportation system represented by maritime transportation network. The maritime transportation network consists of the maritime transportation system with its structure and flow. The nodes of this network can be ports, terminals, goods storages, destination places and so on. The ship and port transportation facilities routes and can be interpreted as edges between the nodes of the network.

2. Baltic Port Critical Infrastructure Network

According to [1], there are 21 Baltic seaports are included in the port core network: 2 Danish ports (Aarhus, Copenhagen), 2 German ports (Lübeck, Rostock), 1 Estonian port (Tallinn), 2 Latvian ports (Riga, Ventspils), 1 Lithuanian port (Klaipėda), 4 Polish ports (Gdańsk, Gdynia, Szczecin, Świnoujście), 4 Finnish (Helsinki, Turku, Kotka, Hamina), 5 Swedish ports (Gothenburg, Luleå, Malmö, Stockholm, Trelleborg). However, among these ports, three pairs of ports are under a single port authority, namely Copenhagen-Malmö in Sweden and Denmark, Hamina-Kotka in Finland, and Szczecin-Świnoujście in Poland. These pairs of ports are treated as single ports and this way the number of Baltic core ports is fixed as 18.

The set of those 18 core ports with their facilities we call the Baltic Port Critical Infrastructure Network (BPCIN).

3. Baltic Shipping Critical Infrastructure Network

As it is highlighted in [3], ships are very important components of the maritime transportation system. Shipping is a maritime segment of the general transportation system. That’s why ships are so important components of critical infrastructure. Their condition, crew training, traffic safety are influential factors for the whole safety of transportation system. Further, the set of ships operating at the Baltic Sea waters at the fixed moment of time (or at the fixed time interval) is called the dynamic Baltic Shipping Critical Infrastructure Network (BSCIN).

4. Baltic Ship Traffic and Port Operation Information Critical Information

The maritime transportation system operates using information and communication systems (ICT systems). They play an important role in each of these links as a core platform for an information exchange and supporting the safety monitoring of people, vessels, equipment and cargo in ports and during the ship passage on the waterways. There can be distinguish two types of ICT systems:

- ship traffic information systems;

- port operation information systems.

The first group consists of the following systems: AIS, LRIT, DGPS, GNSS. They are used by MSSiS, SafeSeaNet and THETIS [9]. In the second group we can highlighted the Electronic Data Interchange (EDI) systems.
The above ICT systems form the Baltic Ship Traffic and Port Operation Information Critical Infrastructure (BSTPOICIN). As it is shown in *Figure 1*, the nodes of above critical infrastructure network can be base stations, satellites, VTS Centres, ports, terminals, Maritime Offices, data centres, vessels, goods storages and destination places. The routes of this network are single links between the nodes.

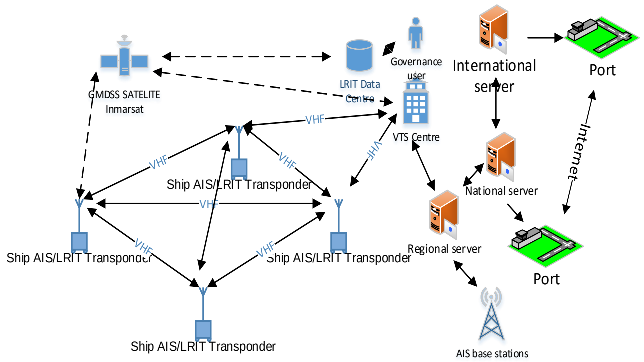

Figure 1. The schema of the BSTPOICIN [5]

5. Baltic Port, Shipping, Ship Traffic and Port Operation Information Joint Critical Infrastructure Network

The Baltic Port, Shipping and Ship Traffic and Port Operation Information Joint Critical Infrastructure Network (BPSIJCIN) is the network of critical infrastructure networks composed of three earlier defined Baltic critical infrastructures, namely the Baltic Port Critical Infrastructure Network (BPCIN) defined in Section 2, the Baltic Shipping Critical Infrastructure Network (BSCIN) defined in Section 3 and Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network (BPSTPOICIN) defined in Section 4.
The BPSIJCIN is exposed to various unfavourable factors, including its operating environment unnatural threats and climate/weather natural hazards. The BPSIJCIN is interacting and interconnected with other critical infrastructures networks that are operating in Baltic Sea Region.

6. Operation process of BPSIJCIN

To simplify notations in modelling the BPSIJCIN operation process, we numerate three critical infrastructure networks this joint network is composed of and we mark them respectively as follows:
- the Baltic Port Critical Infrastructure Network (BPCIN) by $CIN^{(1)}$;
- the Baltic Shipping Critical Infrastructure Network (BSCIN) by $CIN^{(2)}$;
- the Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network (BSTPOICIN) by $CIN^{(3)}$.

These three Critical Infrastructure Networks have to be consider commonly. Each of them has strong influence on the another one. They are the complex network with strong inner and outer dependencies. Moreover, we suppose that the operation processes of these critical infrastructure networks have an influence on their safety and depend on their operating area within the Baltic Sea Region.
To take the last fact into account, we can divide the considered part of the Baltic Sea Region D into a grid of rectangles D_{ab}, $a = 1,2,...,m$, $b = 1,2,...,n$, $m,n \in N$, such that

$$D = \bigcup_{a=1}^{m} \bigcup_{b=1}^{n} D_{ab}. \tag{1}$$

The grid dimension denoted by mxn depends on the assumed accurancy of geographical coordinates (*Figure 2*).

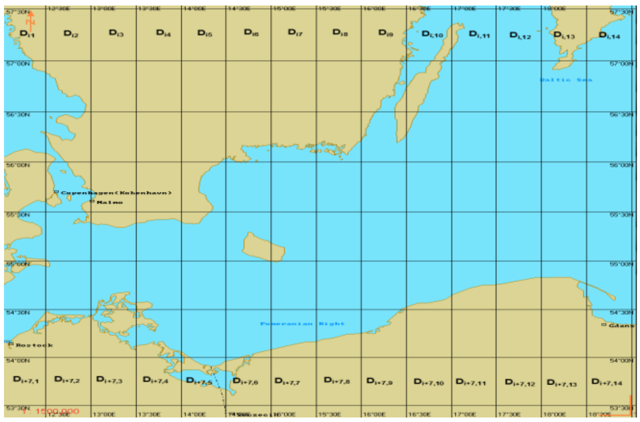

Figure 2. An exemplary grid [5]

Next, we assume that the critical infrastructure networks $CIN^{(i)}$, $i = 1,2,3$, during their operation processes is taking a fixed number of different operation states defined in the following forms:

- for the critical infrastructure network $CIN^{(1)}$ the operation states are

$$[Z^{(1)}]_{1\times\nu^{(1)}} = [z_1^{(1)},\ z_2^{(1)},\ \ldots,\ z_{\nu^{(1)}}^{(1)}], \tag{2}$$

where $z_a^{(1)}$ are the numbers of ships in the port P_a, $a = 1,2,...,,\nu^{(1)}$, creating the network defined in [1], $\nu^{(1)}$, $\nu^{(1)} \in N$, is the number of ports in the of ports under the consideration in the Baltic Sea Region D ($\nu^{(1)} = 18$ for the network defined in [1]);

- for the critical infrastructure network CIN$^{(2)}$ the operation states are

$$[Z^{(2)}]_{m\times n} = \begin{bmatrix} z_{11}^{(2)} & z_{12}^{(2)} & \cdots & z_{1n}^{(2)} \\ z_{21}^{(2)} & z_{22}^{(2)} & \cdots & z_{2n}^{(2)} \\ \cdots & & & \\ z_{m1}^{(2)} & z_{m2}^{(2)} & \cdots & z_{mn}^{(2)} \end{bmatrix}, \tag{3}$$

where $z_{ab}^{(2)}$ are the numbers of ships in the regions D_{ab}, $a = 1,2,...,m,$ $b = 1,2,...,n,$ $m,n \in N;$

- for the critical infrastructure network CIN$^{(3)}$ the operation states are

$$[Z^{(3)}]_{1\times\nu^{(3)}} = [z_1^{(3)},\ z_2^{(3)},\ \ldots,\ z_{\nu^{(3)}}^{(3)}], \tag{4}$$

where $z_a^{(3)}$ are the numbers of ships in the range of the information systems I_a, $a = 1,2,...,\nu^{(3)}$, creating the network defined in [9], $\nu^{(3)}$, $\nu^{(3)} \in N$, is the number of information systems under the consideration in the the Baltic Sea Region D ($\nu^{(3)} = 146$ for the network defined in [9]).

Further, we define the critical infrastructure networks $CIN^{(i)}, i = 1,2,3$, operation processes $Z^{(i)}(t)$, $t \in < 0,+\infty)$, i = 1,2,3, as follows:

- for the critical infrastructure network CIN$^{(1)}$ the operation process is the matrix

$$Z^{(1)}(t) = [Z^{(2)}(t)]_{1\times\nu^{(1)}}$$
$$= [z_1^{(1)}(t), z_2^{(1)}(t),..., z_{\nu^{(1)}}^{(1)}(t)] \tag{5}$$

with discrete operation states from the set defined by (2), where the operation subprocesses $z_a^{(1)}(t)$ assume the values equal to the numbers $z_a^{(1)}$ of ships in the ports P_a, $a = 1,2,...,,\nu^{(1)}$, at the moment $t \in < 0,+\infty$);

- for the critical infrastructure network CIN$^{(2)}$ the operation process is the vector

$$Z^{(2)}(t) = [Z^{(2)}(t)]_{m\times n}$$
$$= \begin{bmatrix} z_{11}^{(2)}(t) & z_{12}^{(2)}(t) & \cdots & z_{1n}^{(2)}(t) \\ z_{21}^{(2)}(t) & z_{22}^{(2)}(t) & \cdots & z_{2n}^{(2)}(t) \\ \cdots & & & \\ z_{m1}^{(2)}(t) & z_{m2}^{(2)}(t) & \cdots & z_{mn}^{(2)}(t) \end{bmatrix}, \tag{6}$$

with discrete operation states from the set defined by (3), where the operation subprocesses $z_{ab}^{(2)}(t)$ assume the equal to the numbers $z_{ab}^{(2)}$ of ships in the rectangles D_{ab}, $a = 1,2,...,m,$ $b = 1,2,...,n,$ $m,n \in N,$ at the moment $t \in < 0,+\infty)$, $m,n \in N;$

- for the critical infrastructure network CIN$^{(3)}$ the operation process is the vector

$$Z^{(3)}(t) = [Z^{(3)}(t)]_{1\times\nu^{(3)}}$$
$$= [z_1^{(3)}(t), z_2^{(3)}(t),..., z_{\nu^{(3)}}^{(3)}(t)] \tag{7}$$

with discrete operation states from the set defined by (4), where the operation subprocesses $z_a^{(3)}(t)$ assume the values equal to the numbers $z_a^{(3)}$ of ships in in the range of the information systems I_a, $a = 1,2,...,\nu^{(3)}$, at the moment $t \in < 0,+\infty)$.

In detailed definitions of the states and the operation process $Z^{(1)}(t)$ of the Baltic Port Critical Infrastructure Network $CIN^{(1)}$, consisted of all ports with their facilities, where the operation states are defined by the numbers of vessels in ports P_a, $a = 1,2,...,\nu^{(1)}$, either waiting for port services or being under port services, the impacts of those numbers of ships and their port operations interactions should be including.

Considering interactions between ships creating the Baltic Shipping Critical Infrastructure Network $CIN^{(2)}$, we assume that there are strong inner and outer dependencies between the ships operating in a single fixed rectangle D_{ab}, $a = 1,2,...,m,$ $b = 1,2,...,n,$ $m,n \in N,$ and that ships in each two adjacent rectangles influence each other as well. These influences that should be included in detailed definitions of this network operation process $Z^{(2)}(t)$ and its states strongly depend on the operation states of this network defined by the numbers of ships in these rectangles and those ships technical operations.

The Ship Traffic and Port Operation Information Critical Infrastructure Network $CIN^{(3)}$ is a platform to exchange the information about ships' operations and their cargo. Due to the fact that all informations are given mainly in electronic form, this network is very sensitive for any disruption, especially cyber attacks, but also for natural hazards. Thus, in detailed defining this network operation process and its states those features should be taken into account.

The next steps in modelling the BPSIJCIN operation process, considering taking into account just defined processes $Z^{(1)}(t)$, $Z^{(2)}(t)$ and $Z^{(3)}(t)$ interactions and interdependences, the joint operation process of this network of critical infrastructure networks can be defined in the form of the vector

$$Z(t) = [Z^{(1)}(t), Z^{(2)}(t), Z^{(3)}(t)], \qquad t \in < 0, +\infty). \tag{8}$$

The results of this section will be developed in next papers where BPSIJCIN will be finally defined and modelled.

Modelling, parameters' identification, characteristics' prediction of the above process and its characteristics optimization with respect to the BPSIJCIN safety and its resilience to climate/weather change are going to be done in the next EU-CIRCLE GMU reports based on [4], [6] – [8].

7. Conclusion

The three critical infrastructures for the Baltic Sea Region, i.e. Baltic Port Critical Infrastructure Network, Baltic Shipping Critical Infrastructure Network, Ship Traffic and Port Operation Information Critical Infrastructure Network have been defined. Subsequently, the Baltic Port, Shipping, Ship Traffic and Port Operation Information Joint Critical Infrastructure Network (BPSIJN) has been proposed. Furthermore, the operation process for this network has been initially introduced.

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