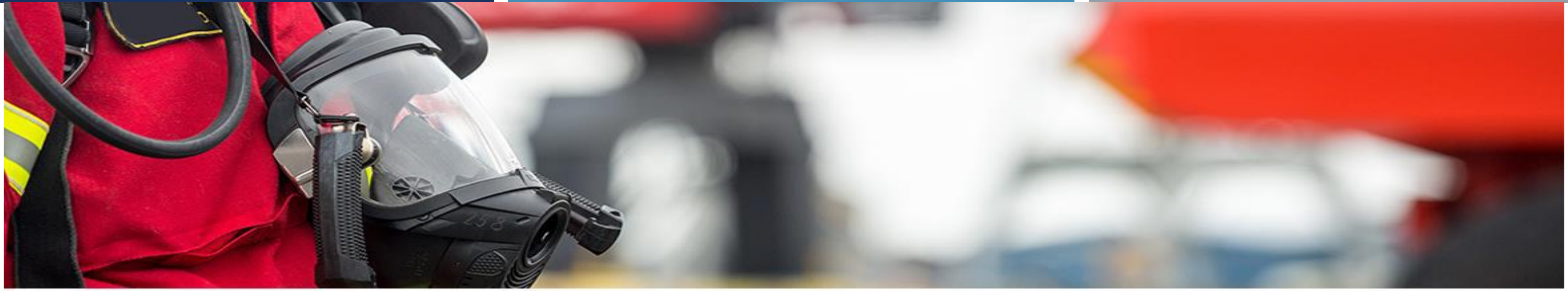

HAZARD REPORT

RISK MANAGEMENT IN SEAPORTS

PRESENTATION AT HAZARD WORKSHOP ORGANIZED BY PSRA ON 15.02.2019 IN GDYNIA

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INTRODUCTION

- It is estimated that currently maritime transport accounts for 80% of world cargo transport.
- The sea-land supply chains are gaining importance, especially between major global economic centres located in Asia, Europe and in the United States.
- Seaports act as a node in the logistics network and from this point of view are subjected to logistic management in sea-land supply chains and intermodal transport.

PORTS - GENERAL DESCRIPTION

The main business scope of the seaports with their industrial facilities is:

- activities of transhipment, storage and warehousing, mainly in the field of foreign trade cargo handling and transport vessels;
- support for tourism and passenger traffic, including marine shipping and ferry travel;
- support for sea water sports and leisure (eg. Marinas);
- industrial activities, especially the shipbuilding industry (including construction and repair of ships and cooperation), marine fisheries and the processing industry, including the refining and chemical industries;

PORTS - GENERAL DESCRIPTION

- distribution and logistics services, including services provided by the port logistics centres, especially cooperating with the container terminals;
- commercial and technical related, among others the services provided to ships (eg. towage and port, technical workshops) and trade in goods and services of inland transport (rail and road);
- security services for port facilities and industrial and rescue at sea;
- activity port administration institutions, providing services for the trading port and maritime and shipping and passenger traffic.

PORTS - GENERAL DESCRIPTION

Ports are land facilities constructed to transfer goods between sea and land. They consist of major features such as:

- docks, quays or berths where vessels moor;
- port approach channels and roadsteads;
- equipment and personnel to load and unload vessels, i.e. cranes (gantry, self-propelled, stacking), conveyors, forklifts, Roll-on-Roll-off (RoRo) tractors and trailers, transport vehicles, equipment for monitoring port inland waters, equipment for ship’s bunkering (fuel and water), etc.;

PORTS - GENERAL DESCRIPTION

- connections to land transportation (such as highways, railways, and pipelines);
- telecommunications and management (internal and external);
- cargo storage areas, i.e. hangars, warehouses, storage yards and large reservoirs, such as for example silos.

PORTS - GENERAL DESCRIPTION

- The seaports are intermodal facilities, a place where rail, truck, barge, ship, and other transport methods converge.
- In this way, ports play a key role in moving products both to other countries and to the interior of the country.
- The port's terminal makes possible the docking and the handling, storage and transfer of cargo.
- Ports are designed to handle a wide variety of types of cargo: bulk or loose, breakbulk in packages (bundles, crates, barrels, pallets).
- Thus, the port as a whole is also important for the country economics and people.

PORTS - GENERAL DESCRIPTION

The European Programme for Critical Infrastructure Protection (EPCIP) has proposed a list of 11 European critical infrastructures based upon inputs by its Member States:

- Energy
- Information and communication technology (ICT)
- Water
- Food
- Health
- Financial
- Public and legal order and safety
- Civil administration
- Transportation
- Chemical and nuclear industry
- Space and research.

PORTS - GENERAL DESCRIPTION

- The seaports because of their importance for country economics and people are **Critical Infrastructures (CI)** and consist of the different types of assets.
- The assets can be categorized in many ways, including people, information, equipment, facilities and activities or operations.

PORTS - GENERAL DESCRIPTION

For the ports we can distinguish the assets like:

- passengers and goods,
- docks or berths,
- approach channels,
- roadsteads and inner pools,
- equipment for load and unload vessels,
- breakwaters,
- cargo storage areas,
- warehouses,
- piers,
- quays,
- roads and railways (internal and external),
- pipelines,
- navigational signs,
- means of transport.

RISK IN PORTS

We can give the following five risk categories:

- Human,
- Machinery,
- Environment,
- Security,
- Natural.

Every mentioned above categories have some sub-categories, which can be called ***hazard*** or ***threat***. The notation ***hazard*** is used in term of natural hazards classified as severe and extreme weather and climate events, while ***threats*** refer to events coming from human activity and other systems or infrastructures.

RISK IN PORTS

In case of **HUMAN** category we distinguish following selected sub-sectors (threat):

- ship collisions,
- grounding,
- sinking,
- navigation error,
- pilotage error,
- poor maintenance,
- falling of a cargo handling facilities (eg. crane, conveyors, etc.),
- falling of a container,
- error in cargo handling and storage.

RISK IN PORTS

In case of **MACHINERY** category we distinguish following selected sub-sectors (threat):

- damage to equipment,
- fire/explosion,
- machinery failure,
- system failure.

RISK IN PORTS

In case of **ENVIRONMENT** category we distinguish following selected sub-sectors (threat):

- ships emissions,
- dredging,
- oil spills,
- chemical contaminants,
- ballast waters,
- ship breaking /salvage activities,
- air toxics,
- noise pollution,
- alien species.

RISK IN PORTS

In case of **SECURITY** category we distinguish following selected sub-sectors (threat):

- security,
- war / political instability,
- terrorist,
- theft,
- smuggling,
- illegal trade,
- vandalism,
- illegal immigration,
- blockade.

RISK IN PORTS

In case of **NATURAL** category we distinguish following selected sub-sectors (hazard):

- earthquakes,
- volcanic eruptions,
- hurricane,
- strong winds,
- heavy swell and sea,
- floods,
- high temperature during working hours,
- heavy rain,
- heat waves, cold snaps,
- sea level rise,
- ice, frost, permafrost,
- storm surges, waves,
- lightning / thunderstorm,
- earth movement caused by climate drivers such as rain (landslide, erosion, avalanches, rock fall, soil subsidence, liquefaction, etc.).

HAZARD INFORMATION FOR PORTS

Hazards that can impact on ports:

- heat waves, cold snaps,
- floods / costal floods,
- sea level rise,
- ice, frost, permafrost,
- storm surges, waves,
- lightning / thunderstorm,
- earth movement caused by climate drivers such as rain (landslide, erosion, avalanches, rock fall, soil subsidence, liquefaction, etc.).

HAZARD INFORMATION FOR PORTS

A description of the impacts:

Hazard	Impacts on port and its assets
Heat waves, cold snaps	Damage to means of transport and suprastructure and infrastructure due to high temperature or frost wedging, depending on quality. Under the influence of high temperature damage of suprastructure are as follows: steel structural elements (steel thermal expansion - permanent deflection of steel structure), steel ropes (tensile - leading to break), rails of the gantry cranes (bent), overheating of engines. Under the influence of low temperature damage of suprastructure are as follows: cracking welded joints, brittleness of the steel structure)
Floods / costal floods	Impact of limited/short-term exposure: blocking of inner and outer roads, long-term: damage to means of transport and infrastructure.

HAZARD INFORMATION FOR PORTS

A description of the impacts:

Sea level rise	**Complete loss**
Ice, frost, permafrost	Potentially reduced speed of operations in ports, because of bad navigational conditions.
Storm surges, waves	Potentially reduced speed of operations in ports, because of bad navigational conditions; Impact of limited/short-term exposure: blocking of inner and outer roads and railways, long-term: damage to substructures and inner structures (overturning crane, flooding the engine, etc.)
Lightning / thunderstorm	Operations limited or prohibited, damage to cranes
Earth movement caused by climate drivers	Damage to inner and outer infrastructure of roads and railways possible

INFORMATION ON DEPENDENCIES AND INTERDEPENDENCIES IN PORTS

There are different types of interdependencies and different ways of characterizing them. The categorization proposed by Rinaldi, Peerenboom, and Kelly [Rinaldi et al., 2001], [Rinaldi, 2004], is often used and distinguish four primary classes of interdependencies:

- physical interdependency – two infrastructures are physically interdependent if the state of each depends upon the material output(s) of the other. Physical interdependencies arise from physical linkages or connections among elements of the infrastructures;
- cyber interdependency – an infrastructure has a cyber interdependency if its state depends on information transmitted through the information infrastructure. The computerization and automation of modern infrastructures and widespread use of supervisory control and data acquisition (SCADA) systems have led to pervasive cyber interdependencies;

INFORMATION ON DEPENDENCIES AND INTERDEPENDENCIES IN PORTS

- geographic interdependency – infrastructures are geographically interdependent if a local environmental event can create state changes in all of them. This implies close spatial proximity of elements of different infrastructures, such as collocated elements of different infrastructures in a common right-of-way;
- logical interdependency – two infrastructures are logically interdependent if the state of each depends upon the state of the other via some mechanism that is not a physical, cyber, or geographic connection. For example, various policy, legal, or regulatory regimes can give rise to logical linkage among two or more infrastructures.

INFORMATION ON DEPENDENCIES AND INTERDEPENDENCIES IN PORTS

Dependent/interdependent sub-sector	Asset within dependent/interdependent sub-sector
Road: Roadways, crossings and intersections are connected to selected maritime subsector	- Inner roadways and crossings/intersections - Safety related systems - Public transport depots - Traffic control centre
Rail: Operation of roadways can be interrupted if level-crossings are not working or are blocked	- Commuter railway tracks, sidings, switches and crossovers - Long distance cargo and passenger railway tracks
Maritime: freight/passenger seaports are connected to all maritime subsector	- Marine terminal and berths - Warehouses - Port approach channels - Seawalls

INFORMATION ON DEPENDENCIES AND INTERDEPENDENCIES IN PORTS

Electricity: freight/passenger seaports are connected to all electricity subsectors	- **Control room* (to be specified if: IT services, monitoring equip., network communication equip.)** - **Step up Substations** - **Exposed Transmission high voltage Lines sea-river crossings** - **Transmission high voltage Substations** - **Distribution Substations** - **Transformers** - **Storage** - **Buildings* (for infrastructure operators)**
Public services: the maritime subsector is connected to all public services (depends on the country)	- Public buildings - IT equipment/network

INFORMATION ON DEPENDENCIES AND INTERDEPENDENCIES IN PORTS

Telecommunications: the maritime subsector is connected to selected telecommunication subsector assets sufficient for proper operation.	- **Network Switches** - **Trunk Line** - **Fibre Optic Cable** - **Cable Landing Stations** - **Base Stations** - **Masts** - **Antennae** - **Data Centers** - **Exchanges** - **Routers** - **Wireless Access Points**	- **SCADA Devices** - **Power Generators** - **SatCom Ground Stations** - **SatCom Ground Links** - **SatCom Antennae** - **HF Com Antennae** - **HF Com Ground Station** - **HF Com Masts** - **HF Com Radio Links** - **Carrier Hotels** - **Battery back-up**
Information systems: the maritime subsector is connected to selected telecommunication subsector assets sufficient for proper operation.	- Data Centers - End-Users Devices - Call Centers	

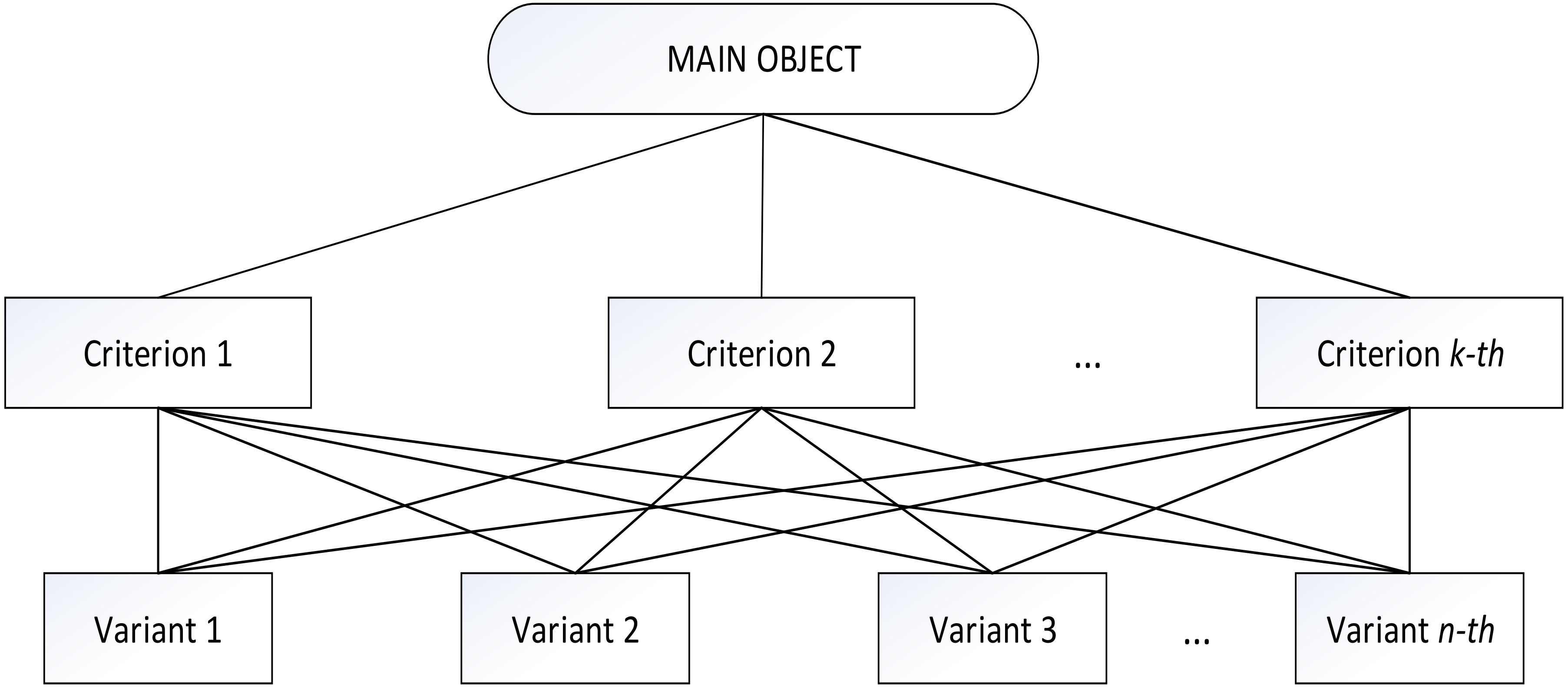
IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

- The risk assessment and risk management play both crucial roles in mitigating the effects of different disruptive events or activities.
- There are several risk assessment methods comprehensive for seaports.
- Usually, it is very complex and multiple criteria problem.
- The useful tool is multiple criteria decision analysis (MCDA), which helps in the evaluation of policy decision considering possibly not commensurate criteria.
- One of the proposed risk assessment methods for port risk assessment is scenario analysis.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

- Many insurance companies use scenarios (scenarios methods) to assess and identify threats and hazards in seaports.
- This method allows both qualitative and quantitative assessment of risk or vulnerabilities.
- These possibilities are extended when the combination of MCDA and scenario analysis is used. It can be applied to solve the risk optimization problem for seaports. According to **<u>the Analytical Hierarchy Process Method</u>** (AHP).
- This method requires to define:
  - the set of the *n*-variants (options) to consider and every one of these components takes the value for *k*-criteria.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS



General diagram of the AHP method

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

The steps of the AHP algorithm are as follows:

Step 1. Hierarchization of the problem.

Step 2. Paired comparison of the objectives being on the same level – matrixes of the paired comparisons.

Step 3. Definition of the mutual weight of the criteria and decision variants.

Step 4. Choosing the best options.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

Step 1 is followed by a detailed description of a problem and definition of the primary goal and expectations of them.

The decomposition of the problem in the form of the principal criteria and the main options considered, which generate a certain degree of fulfillment of objectives of the function at different levels of the hierarchical model is defined.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

In *step 2*, the decision maker compares together in pairs criteria about the primary goal and the options to the specific guidelines. A subjective determination does this that the criteria and options, and to what extent are more important than the other.

Relations between the elements can be determined based on a 9-point scale:

- 1 – the same significance;
- 3 - a small advantage;
- 5 - a strong advantage;
- 7 – a very strong advantage;
- 9 – an absolute advantage;
- 2, 4, 6, 8 – an intermediate value.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

This step completes the formation of a matrix $\mathbf{B}^{level}$, $level = 2,3$, size $k \times k$ and $n \times n$ in case of the second and third levels, respectively, which is made of $k(k-1)/2$ and $n(n-1)/2$ of these comparisons. The general structure of this matrix is given as

$$\mathbf{B}^{level} = \begin{bmatrix} 1 & b_{12} & \cdots & b_{1n} \\ b_{21} & 1 & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \cdots & 1 \end{bmatrix}. \qquad (1)$$

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

The characteristic feature of this matrix is diagonal equal to 1, which consists of the following property

$$b_{ij} = \frac{1}{b_{ji}}, \qquad (2)$$

where b_{ij} is an element in an i-th row and j-th column and b_{ji} is an element in a j-th row and i-th column.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

Step 3, is the stage of the AHP algorithm in which the mutual weights for criteria and variants (options) are calculated. The normalized rows of the matrix $\mathbf{B}^{level}$, $level = 2,3,$ are summed, and the eigenvector of it is found. The matrix $\mathbf{B}^{level}$, $level = 2,3,$ satisfies:

$$\mathbf{B}^{level} \cdot \mathbf{w} = \lambda \cdot \mathbf{w}, \tag{3}$$

where $\mathbf{w}$ - the eigenvector of a matrix $\mathbf{B}^{level}$, λ - the eigenvalue of a matrix $\mathbf{B}^{level}$, $level = 2,3.$

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

The experts' assessments are not always completely neutral, so it is necessary to introduce the inconsistency coefficient IF defined as follows:

$$IF = \frac{CR}{RI}, \qquad (4)$$

where CR - consequence ratio, RI - random index. This number should be less than or equal to 0.2. In the case when $CI = 0$ then the value of the coefficient IF is calculated respect to the random index RI. It is the average CI for a large number of a randomly generated matrix of comparisons.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

The consequence ratio CI for matrix size n is given by:

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \qquad (5)$$

where $\lambda_{\max}$ is a maximal eigenvalue of a matrix $\mathbf{B}^{level}$, $level = 2,3$, calculated with equation (3).

It is believed that the data are consistent that the value of the ratio CI, given in (5), is less than 0.1.

IMPROVING RISK ASSESSMENT METHODS FOR SEAPORTS

Finally, in *Step 4*, the decision-maker chooses the optimal option for established criteria based on the ranking vector for the choosing option/scenario.

It should be noted that this is a helpful method when the expert opinions are collected during the research, i.e., build the scenarios.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

Risk management does not have to relate to risk assessment directly.

It may also rely on finding vulnerabilities in the port organization and operation.

The proposed method can be used to find measure port components vulnerability to a variety of disruption scenarios or risk measure.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

We take into account the following transportation sectors operating in the port area, which are impacted by initial disruption:

- rail transportation,
- water transportation (sea and inland),
- truck transportation,
- transit and ground passenger transportation,
- pipeline transportation,
- other transportation and support activities,
- warehousing and storage.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

The following scenarios for port disruptions can be considered:

- ***Scenario 1***: Port/terminal worker strike at the port facility resulting in a work stoppage,
- ***Scenario 2***: Strong wind/hurricane,
- ***Scenario 3***: Terrorist attack on the port facility,
- ***Scenario 4***: Baseline scenario.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

In ***Scenario 1*** we assume, that the direct impact comes from labor shortages or its slowdowns, what is harmful to the port operations.

- This scenario should base on historical data about the operations done by dockworkers within the port industry.
- The largest inoperability is related to cargo handling responsibilities of dockworkers and slowing of shipping activities (water transportation).

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

- Port operations also include rail transportation, truck transportation, and storage to handle intermodal transportation services. Thus, for these sectors, we assume a lower inoperability within this scenario.
- Furthermore, we can assume, that port disruptions traditionally extend from 5 to10 days, followed by an operational recovery period extending another 5 to 10 days.
- Finally, we can assume that the mean time to restore full port operability is 20 days in this scenario.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

The direct impact of a natural disaster such as a strong wind or hurricane, consider as ***Scenario* 2**, leads to conditions unsuitable for shipping activities.

- The largest inoperability is related to shipping activities.
- The direct impact on non-water transportation sectors is contingent upon the severity of the strong wind or hurricane. In severe cases, there may be a potential reduction in available resources (workers and technology) and potential damage to transportation infrastructure.
- Therefore, this scenario assumes inoperability directly impacts all transportation sectors. For fixing the time needed to recover transportation operations after hurricane events, the risk manager should study the historical data about time of restoration all damages after a strong wind/hurricane.
- We can assume, exemplary, the time needed to resume status quo operations as 30 days.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

The implications of ***Scenario 3*** across sectors can vary widely depending on the specific event.

- In order to maintain generality, this scenario assumes inoperability directly impacts all studied transportation sectors equally.
- Consistent with related work that assumes a one-month port closure, this scenario assumes the restoration time equal to 30 days.

Baseline ***Scenario 4*** assumes inoperability directly impacts all transportation sectors. As this scenario models minor disruptions requiring minimal recovery time, this scenario assumes the time of full restoration is seven days.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

According to the above scenarios, we can consider three different approaches to port risk management:

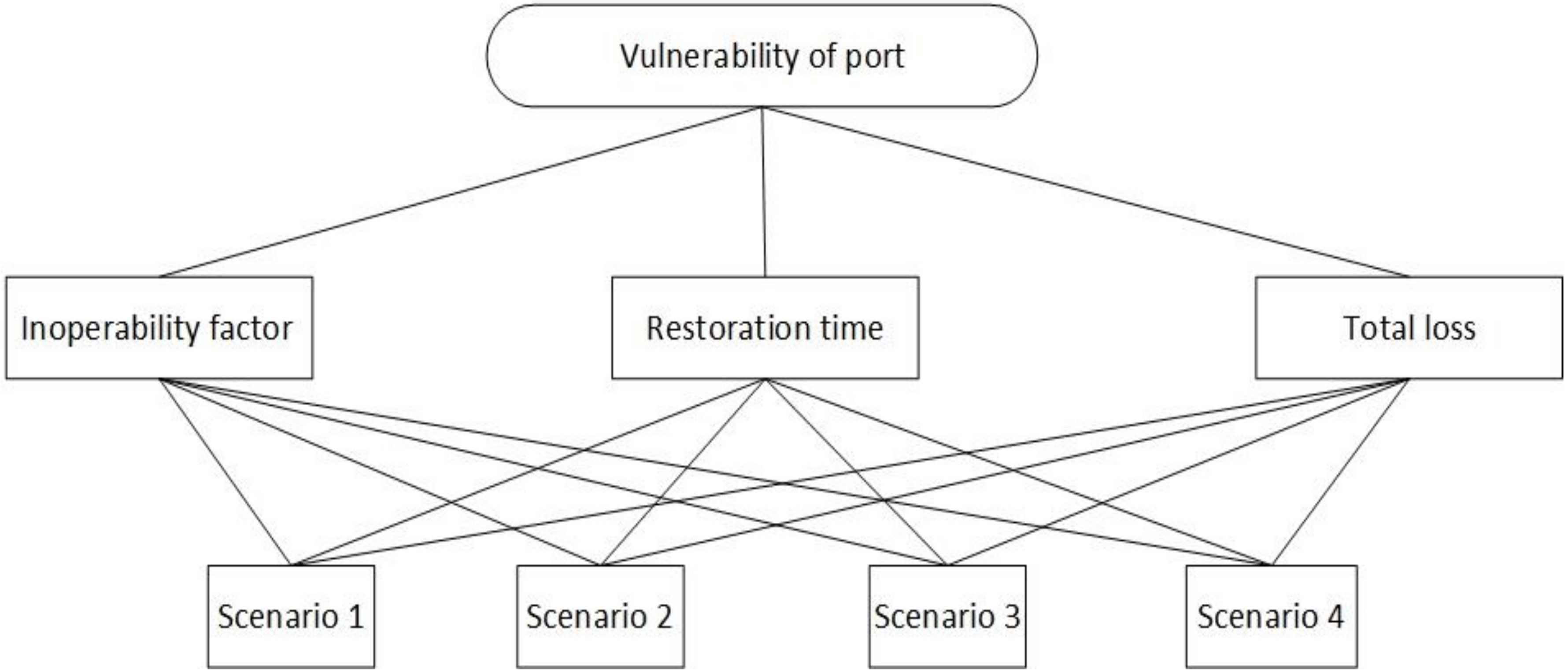
- vulnerability of distinguishing scenarios, i.e., it is searching the weakest link;
- two approaches take into account the risk measures for different criteria.

Taking into account the vulnerability, we assume that the optimization criteria in AHP method are fixed in the following way:

- C1 – inoperability factor – a number from 0 to 1,
- C2 – restoration time [days],
- C3 – total loss [USD].

A suitable example diagram for the AHP method in vulnerability approach is presented in figure.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS



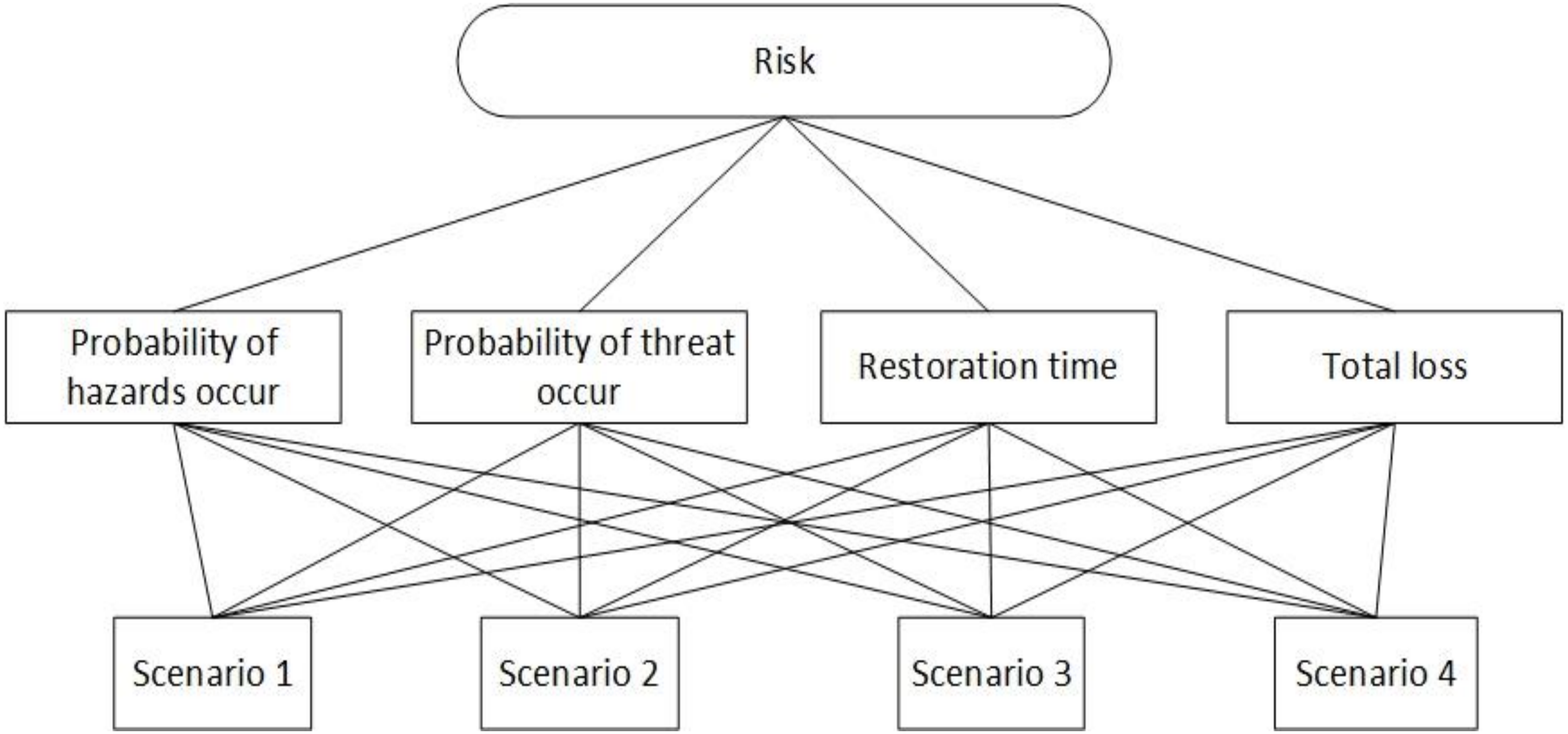
APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

Taking into account the risk measures, we assume that the optimization criteria in AHP method are fixed in the following way:

- C1 – the probability of hazards occur – a number from 0 to 1,
- C2 – the probability of hazards occur – a number from 0 to 1,
- C3 – restoration time [days],
- C4 – total cost [USD].

A suitable example diagram for the AHP method in risk approach is presented in figure.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS



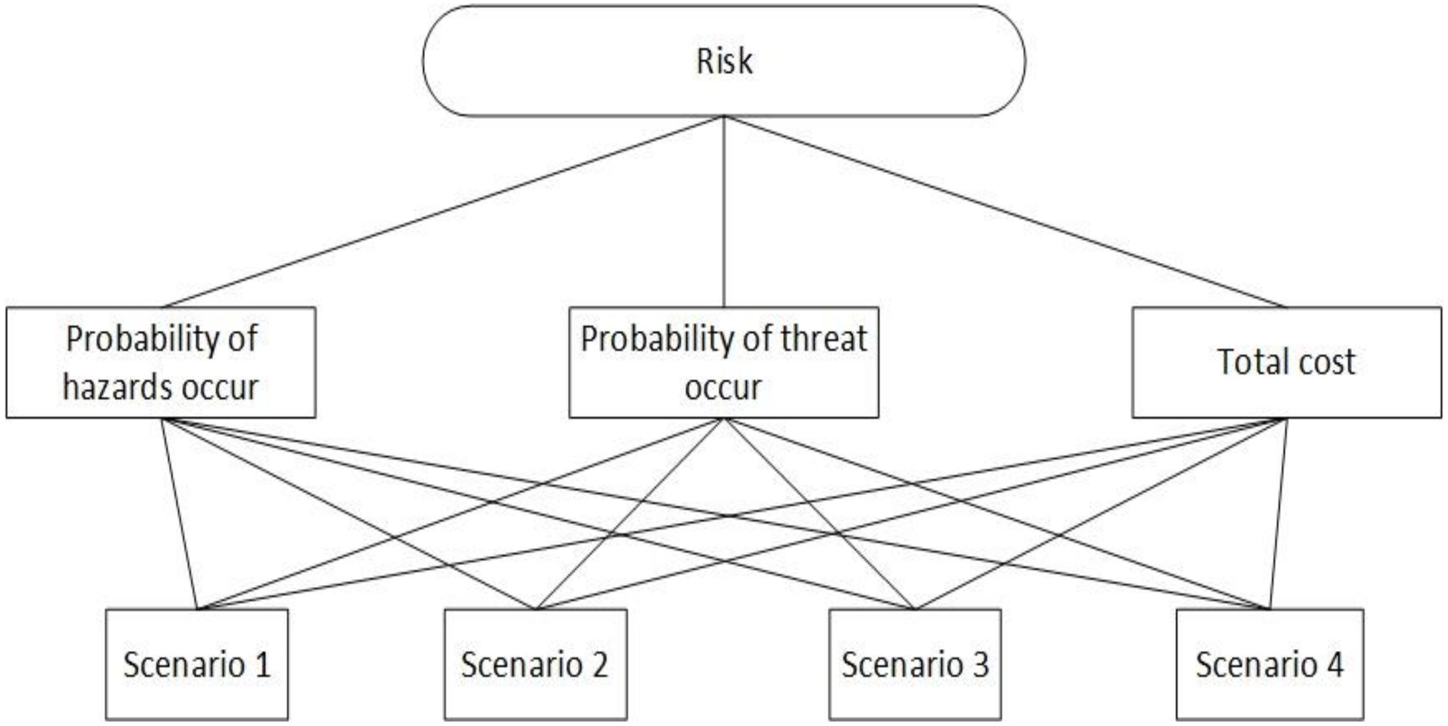
APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS

Taking into account the risk measures in the second case, we assume that the optimization criteria in AHP method are fixed in the following way:

- C1 – the probability of hazards occur – a number from 0 to 1,
- C2 – the probability of hazards occur – a number from 0 to 1,
- C3 – total cost [USD].

A suitable example diagram for the AHP method in second risk approach is presented in figure.

APPLICATION OF AHP METHOD FOR SCENARIO-BASED RISK AND VULNERABILITY ASSESSMENT FOR PORTS



CONCLUSIONS

- The report presents research on risk management in ports.
- In the report the general information about scope of the ports' activities and the risks possible in ports during their operation are presented.
- The methods for risk and vulnerability analysis in case of Baltic Ports is proposed.

ACKNOWLEDGEMENT

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Thank you for attention