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Risk Analysis of Seaport Construction Project Execution

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Abstract: This article concerns the assessment of the level of risk at the stage of construction of a seaport, with particular emphasis on selected adverse incidents that can significantly affect the timeliness of the investment. In this article, the matrix method was used to analyse and evaluate the level of risk, and statistical analysis and case studies were used to identify incidents occurring during the port construction project. This allowed the identification of incidents with the highest probability of occurrence during the port construction process and to determine their impact on environmental pollution and the timeliness and success of the investment. The risk analysis performed identified 15 typical incidents of technical nature. The determined risk level for these incidents is at a moderate level or lower, which can be considered acceptable. For all undesirable incidents the values of probability and loss levels have been averaged, because e.g., a fire can have an extremely different dimension and can cause a different scale of losses. Analysis presented in the paper indicate the need to develop procedures for proceeding during the implementation of significant technical tasks to minimize the level of risk of adverse incidents and their consequences.

Keywords: risk; seaport; threat; undesired event; reliability; transport systems; modelling; maintenance; exploitation

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1. Introduction

It is practically impossible to provide for technical object functioning in specific conditions and period of time without an occurrence of an undesired event. There are numerous hazard factors that cannot be eliminated. Increasing the level of sefety of transport systems is possible through improving their reliability [1–3].

Seaports, complex business systems, located at land-water interface, generally integrate four modes of transport: sea, rail, road and inland, and make up a cluster of spatial-functional facilities [4–6]. Improving the safety of transportation systems can be achieved by increasing the reliability and quality of system components. The goal is to reduce the possibility of failure or poor quality of system elements. Observations of the use of individual elements of transport systems in terms of their safety allow us to conclude that proper functioning depends not only on the reliability of the elements that make up the system, but also on the effective management of the operation process and quality management of the system.

Seaport site is determined by natural conditions, and allocated land and water areas must be equipped with appropriate infrastructure and facilities for providing services to ships, cargo, and transport vehicles of the hinterland [7,8].

At the seaport construction phase, technical, organizational, legal and economic aspects have to be considered, but first of all the proper level of safety and security of the natural environment has to be assured to avoid negative impact of such projects on the surroundings.

The first step in analysing the level of safety of the seaport construction project is to identify and then assess the factors initiating the occurrence of threats and to classify these threats. Since it is impossible to eliminate all hazard factors in a large investment project such as seaport, it is important to identify and examine both the origins of undesirable events and the conditions of their formation and possible consequences.

Given that a seaport territory includes land and water areas, it is important to consider these two environments and take them into account when classifying risks. In the traditional approach, the risk of construction investment project is defined as the combination of the probability of occurrence (P) and the magnitude of the consequences (S), whose values are assumed in practice on the basis of estimates [9–11]. Then the level of risk is evaluated in relation to the adopted risk criteria, most often distinguishing three levels: acceptable, correctible and unacceptable [12,13]. In order to maintain and regulate an appropriate level of safety, various risk management methods are used, which include, among others, identification of threats, risk assessment of their occurrence, etc.

This article deals with the assessment of risk level at the stage of seaport construction, with particular emphasis on selected adverse events that can significantly affect the timely completion of investment project. The authors aim to determine undesirable events that may occur during the construction of a seaport and the level of risk during seaport construction.

2. Literature Review

Various risk management approaches are used to maintain and regulate an adequate degree of safety, which include the following methods [14,15]:

- identification of threats,
- risk assessment,
- risk analysis,
- risk propagation,
- risk management policies.

Safety assessment is conducted using selected measures, with the level of safety usually expressed indirectly through risk measures [16–18]:

$$M_r = M_{zw} * M_{zg} \quad (1)$$

where: M_r—Risk measure, M_{zw}—Unreliabzility measure, M_{zg}—Hazard measure.

One of the most important measures of construction project risk is the relative frequency of events in the assumed unit of time, causing losses greater than a certain fixed level [19–21]. The value of this measure is one of the basic criteria on the basis of which social acceptance of the design, construction and operation of a particular system can take place. The acceptable level of the risk measure assumes different values depending on the assessor. Risk analysis and assessment form the basis of Formal Safety Assessment (FSA). It is a systematic methodology based on International Maritime Organization (IMO) recommendations, in order to develop or introduce new solutions that will contribute to higher safety level.

Risk is dependent of the measure of hazard. A hazard is a source of an undesirable event that can cause harm, i.e., loss of life, injury, loss of property or destruction. The origins of these threats are physical, chemical, organizational or human factors, etc., whose presence, condition or properties are the cause of undesirable events. The situation in which there are any threats is defined as dangerous [22].

One classification distinguishes between internal and external threats. External threats include all factors outside a technical facility that affect its safety, originating from: nature, products of human civilization or other people [23–25], traffic intensity, navigational conditions in a given area, etc. Although these are threats traditionally inscribed in the history of human experience, there is still a lack of sufficiently effective means to limit their negative effects [26].

Internal threats, on the other hand, are those that may occur within a given facility and result from activities and functions performed by this facility.

Statistical analysis based on the primary consequences of failures, accidents and disasters show that several types of threats exist. They may include operational threats, related to the life cycle of a facility or machine, fatigue and wear of its individual devices and mechanisms. The effects are, for example, corrosion damage, cracks or loss of strength of the structure.

Another type of hazard is technical threats or risk [27], which is the result of design and construction errors or violations of the regimes and conditions for the operation of facilities, machinery and technical equipment [28].

There are also thermal threats that cause fires. These can occur where there is an uncontrolled conversion of mechanical or electrical energy to heat or an uncontrolled flame, glow or sparks occur. Fire threats may occur when:

- there is a large accumulation of flammable materials,
- open fire or high temperature is used for technological purposes,
- flammable materials are used for technological purposes,
- there is a process of self-heating of materials,
- sparking tools are used,
- there is a possibility of static electricity discharge,
- heat energy is emitted as a result of friction of machinery elements,
- required distances of materials and equipment from lighting and heating elements are not maintained,
- exothermic reactions occur,
- electrical devices and installations are operated incorrectly,
- flammable waste is left unattended,
- lack of proper caution in dealing with fire (e.g., ignition of fire from cigarette butts) [14].

When discussing threats, it is also important to consider the human factor, the most common cause of accidents. Statistical studies emphasize that about 80% of all accidents and failures were caused by human error [29]. Most often these errors result from failure to perform or incorrect performance of operations required by a procedure, or performance of operations contrary to procedure. They can be caused by the action of one or several people, hence they can be of individual or collective nature. Any work performed by humans is strongly influenced by the external environment, therefore human error plays a significant role in the occurrence of adverse events [30].

Still another group of threats are natural threats, which include weather anomalies and other natural factors that make it impossible to perform work, including [31]:

- violent gusts of wind,
- heavy rainfall, lightning,
- heavy snowfall and blizzards,
- dense fog (with visibility restricted to less than 600 m),
- flood.

Among the main hazard factors during seaport construction are [32]:

- design errors (most often wrong calculations of the strength of materials or construction elements),
- manufacturing errors (using materials other than those designed, often inferior, excessive work pace, e.g., shortening the concrete setting time),
- skipping geodesic-geological procedures (e.g., lack of soil structure surveying)
- or disregarding natural threats,
- failure to take into account the specific nature of terrain, particularly water bodies.

Each of these errors is a factor that initiates the occurrence of a hazard and then an undesirable event, often with irreversible consequences and effects.

In accordance with the provisions of construction law and relevant regulations, as well as requirements of the Polish Standards, during the execution of the construction of any marine hydrotechnical structure, the following conditions must be met [33]:

- safety of structure load-bearing capacity and stability,

- fire safety,
- safety of use,
- appropriate service conditions corresponding to different types of structures.

The largest group of hazard factors are mechanical, including [34,35]:

- means of transport on both land and water sides that deliver essential construction materials, etc.,
- stationary and mobile construction machinery and equipment or tools for earthmoving, reinforcing, welding, lifting and moving of objects,
- limited work space and restricted access to facilities and equipment at construction sites,
- limited space for work and limited access to facilities and equipment on construction sites, obstructing the access of machinery or movement of workers,
- sharp protruding elements of unfinished buildings,
- falling objects from buildings on the site,
- uneven or slippery surfaces on the building site,
- electricity or gas.

3. Materials and Methods

The first step in the analysis of the safety level of a seaport construction project is the identification, then assessment of factors initiating the occurrence of threats and the classification of these threats. Since it is impossible to eliminate all the risk factors for such a large project as seaport construction, it is important to identify and investigate both the sources of adverse events and the conditions of their formation and possible consequences. In this article, the matrix method was used to analyze and evaluate the level of risk, and statistical analysis and case studies were used to identify events occurring during the port construction project. This allowed the identification of events having the highest probability of occurrence during the port construction process and the determination of their impact on environment pollution and the timely completion of the investment project.

The main objective of the article is to analyse the level of risk in the execution of seaport construction investment with particular emphasis on the causes and effects of adverse events that may have a significant impact on meeting the project deadline. To achieve the research objective, the research described herein has been divided into three stages, including the analysis of the research subject, as presented in Figure 1.

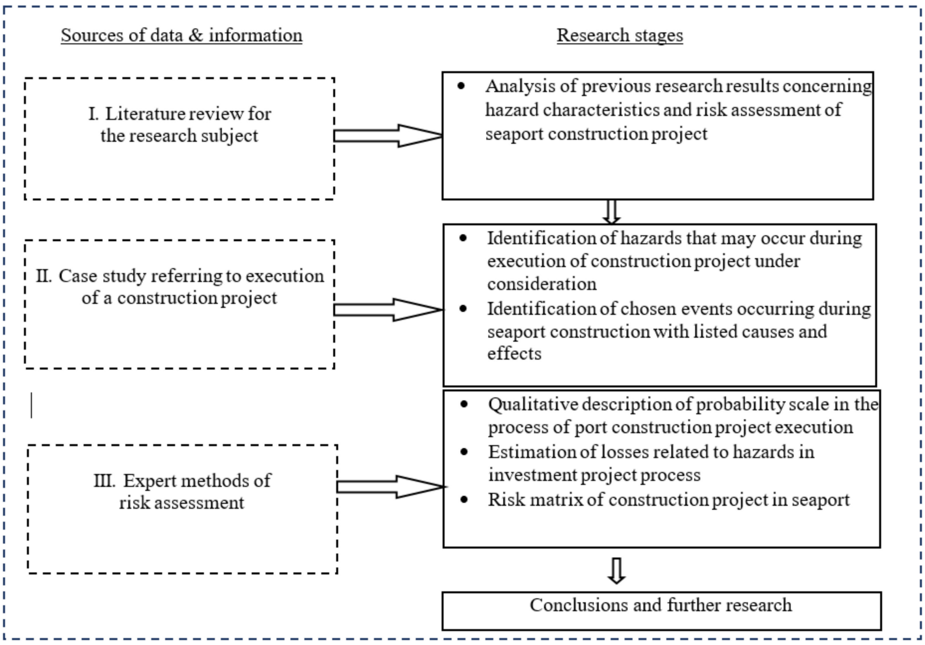

Figure 1. Research methodology diagram.

Source: Authors' Study

Stage I reviews publications addressing hazard identification, risk assessment, risk analysis, risk propagation and risk management policies. It has been found that most studies of risk analysis based on Formal Safety Assessment (FSA) methods deal mainly with ship operations (basically navigation) and existing port terminals. There is a research gap in the area of seaport construction or expansion.

In stage II, some events occurring during seaport construction were identified. Threats existing on land and in planned harbour basins were differentiated. Threats existing on land and in planned port were identified on the basis of expert research as part of research projects carried out by authors at the request of selected Polish ports.

Stage III included risk assessment of the seaport construction phase. Probability values for specific events were determined and then their effects were estimated. The results provided a quantitative assessment of construction project risk in the port area. At the current stage of the research, authors were only able to publish some of the results. The main goal was to introduce the method and procedures which should be prepared, as they have a great influence on the timely completion of the seaport construction project.

The authors used various techniques and tools for data collection and analysis. These included observation, analysis of source materials, and case studies. The analysis was carried out on the basis of data obtained from the State Marine Accident Investigation Commission regarding the threats and scale of losses that occur as a result of accidents in the port. Internal documents of the port security department were a valuable source of information, however, at the present stage of research, authors cannot make them available to the public.

The last part of the article presents conclusions from the research and indicates the directions of further studies focused on minimizing the risk of hazardous events during construction or expansion of a seaport. The elimination of risk factors has an impact on the profitability of the investment, and in particular on meeting the completion deadline.

4. Results

In the project environment, a hazard is anything that can affect the success of a particular phase or the entire project. Similarly, in the phase of construction project execution, when at each stage of ongoing work, both material assets, the environment and the public face threats. These threats can cause loss of life, be harmful to human health, damage to the environment, damage to facilities, machinery and equipment located in the port area under construction. The greater the hazard that may occur, the greater the safety measures that must be taken to neutralize it. The course of an event during construction is shown in Figure 2.

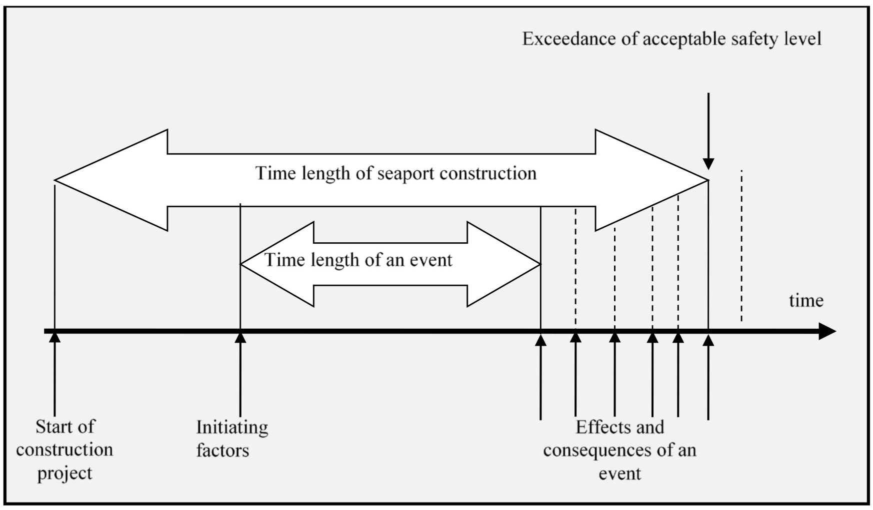

Figure 2. Schematic illustration of an event during a seaport construction.

An adverse event may be divided into stages presented in Figure 3. Initiating factors are e.g., human error or weather conditions. They cause a hazard to occur, which under unfavorable conditions will lead to an emergency situation. This, in turn, brings about an adverse event with different scale of effects and consequences. Eliminating or minimizing the initiating factors prevents the occurrence of the entire chain of events.

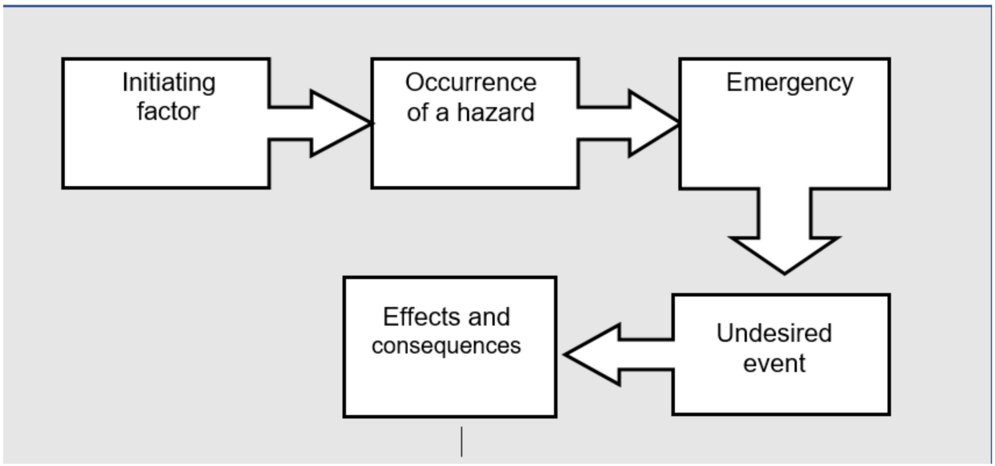

Figure 3. Flow chart of an adverse event.

Given that in any construction process there are many factors that can negatively affect the execution of specific works, the diversity and scope of the activities performed, the port is a place particularly vulnerable to the occurrence of all types of adverse events [36,37].

Tables 1 and 2 contain types of threats that may occur during the execution of seaport construction project.

Table 1. Threats in land area of the port.

	Types of Threats	Examples
1.	Weather conditions	– sudden gusts of wind, – heavy rainfall, – lightning, – heavy snowfalls and blizzards, hailstorms, – dense fog, – flood risk, – extreme (very low and very high) air temperatures,
2.	Technical threats	– hydrostatic and hydrodynamic pressure of water, – pressure of soil, – occurrence of slippage on or in the ground, – settlement or tilting of the structure, – exceeded bearing capacity of the ground,
3.	Operational threats	– chemical influence of sea water, – defects and improper operation of mechanical devices, – defects and improper use of electrical equipment and installations, – defects and incorrect operation of transport vehicles serving the construction site, – improper storage of materials, – lack of traffic routes or their incorrect designation, – failure to mark and separate hazardous areas, – carrying out work at height and by edges,
4.	Fire threats	– careless handling of flammable and pyrotechnic substances and naked flames, – defects in technological processes and failure to comply with technological regimes, – lack of care in fire hazard work, – spontaneous combustion, – improper storage of fire hazard materials, – intentional human activity,

Table 1. *Cont.*

	Types of Threats	Examples
5.	Human error	– mental and physical state due to consumption of alcohol, narcotics or psychotropic substances, – ignorance of health and safety procedures and regulations, – lack of qualifications, – negligence in performing work, – haste, routine, – work done not in compliance with technology and procedures.

Table 2. Threats in planned water area of the port.

	Types of Threats	Examples
1.	Weather conditions	– waves at different water levels in the sea, – tides and currents, – frozen bodies of water, – low or high water levels, – rapid wind gusts, – heavy rainfall, – lightning, – heavy snowfall, blizzards and hailstorms, – fog, – flood risk, – extreme (very low or very high) air temperatures,
2.	Technical threats	– possibility of liquefaction of the soil under the structure, – variable ground water levels, – ground pressure, – ground loads, – slippage on or in the ground, – settlement or tilting of the structure, – exceeded load-bearing capacity of the ground, – damage caused by impacts of ice floes or floating objects carried by waves,
3.	Operational threats	– chemical influence of sea water, – defects and improper operation of mechanical devices, – defects and improper operation of electrical equipment and installations, – defects and improper operation of transport vehicles serving the construction site, – conducting dredging works, laying cables and pipelines,
4.	Fire threats	– carelessness in handling flammable substances, – flammable and pyrotechnic substances and naked flames, – defects in technological processes and failure to observe technological regimes, – lack of care during welding works, – spontaneous ignition, – improper storage of flammable liquids,
5.	Human error	– mental and physical state caused by the consumption of alcohol, narcotics or psychotropic substances, – fatigue, failure to observe required rest periods, – ignorance of health and safety procedures and regulations, – lack of qualifications, – negligence in carrying out work, – haste, routine, – work done not in compliance with technology and procedures.

Table 3 presents the causes and effects of selected events that are most likely to occur during the seaport construction process.

Table 3. Identification of selected events occurring during seaport construction.

	Type of Event	Selected Causes of Event	Possible Consequences
1.	Failure of equipment or electric installations	– improper handling of equipment, – leaking pipes and connections, – damage to the installation as a result of work carried out, – faulty control and measurement apparatus and safety devices, – improperly made and maintained electrical installations and devices, – human error	– suspension of work until failure is corrected, – delays in work execution, – material damage, – personal injuries, – environmental pollution,
2.	Explosion of pressurized devices (cylinders, boilers, tanks), gas pipes and intallations, gas-air mixtures	– improper handling of equipment, – leaking pipes and connections, – faulty control and measurement apparatus and safety devices, – damage to the installation as a result of work carried out, – human error	– suspension of work until failure is corrected, – delays in work execution, – material damage, – personal injuries and/or fatalities, – demolition and/or repair of damaged facilities, – environmental pollution,
3.	Settlement or tilting of the structure (building)	– uneven settlement or swelling of the soil under the foundations, – exceeding the load-bearing capacity of the foundation, – incomplete or incorrect static calculations (incomplete, incorrect soil examination), – human error	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delays in work execution, – material damage,
4.	Fire	– ignition of fire caused by man, – damage to the electrical installation, – damage to the gas installation, – damage to machinery and equipment, – carelessness in handling flammable, pyrotechnic substances – and open fire – defects in technological processes and failure to observe technological regimes, – lack of care – when working with fire hazard materials, – spontaneous ignition, – improper storage of fire hazard materials, – intentional human activity,	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delays in completion of work, – material damage, – injuries and/or fatalities, – environment pollution,
5.	Collisions with infrastructure facilities or other vehicles on land or water	– random events, – improper human behavior (inattention, negligence), – restricted visibility, – vehicle failure,	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delays in completion of work, – material damage, – injuries and/or fatalities, – environment pollution,
6.	Tilting or collapsing of heavy construction machinery	– incorrect spacing of side supports, – failure to provide proper footings, – using the equipment for purposes other than it is intended, – human error,	– suspension of work until failure is corrected, – delays in completion of work, – material damage, – injuries and/or fatalities,
7.	Sinking of construction machines and equipment	– strong wind, – collision with another object, – loss of stability, – impact of ice fields, – wave action, – human error	– suspension of work until failure is corrected, – delays in completion of work, – material damage, – injuries and/or fatalities, – environment pollution,
8.	Drop of cargo during transfer operations (materials or structural elements)	– wear of materials, – human error	– suspension of work until failure is corrected, – delays in completion of work, – material damage, – injuries and/or fatalities,
9.	Collapse of ceilings or roof structures	– incomplete or incorrect static calculations, – failure to observe process downtimes, – inadequate personnel competence of staff in supervising and execution of construction work,	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delay in completion of work, – material damage, – injuries and/or fatalities, – environment pollution,
10.	Collapse of piles driven into the ground due to local changes in the soil structure	– incorrect identification of geotechnical conditions of pile foundation,	– delay in completion of work, – material damage,
11.	Falling of excavations during excavation works	– incorrectly secured excavations,	– delay in completion of work, – injuries and/or fatalities, – material damage,
12.	Flooding of excavations	– rise in groundwater level – intense precipitation,	– delay in completion of work, – material damage,
13.	Destruction of or damage to overground equipment and installations	– human error, – strong wind, – lightning, – thermal loads,	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delay in completion of work, – material damage,
14.	Destruction of or damage to underground equipment and installations	– human error, – thermal loads	– suspension of work until failure is corrected, – demolition and/or repair of damaged facilities, – delay in completion of work, – material damage,
15.	Technical failure of equipment	– human error, – incorrect work technology, – material fatigue or loss of material properties, – failure to observe the required periods of maintenance, repairs, inspections and controls of machinery and equipment, – use of equipment contrary to its purpose.	– suspension of work until failure is corrected, – replacement and/or repair of damaged facilities, – delay in completion of work, – material damage, – injuries.

Each construction project must be carried out in accordance with applicable standards, procedures, health and safety regulations and under constant supervision of the site manager. This risk analysis identified 15 typical events of technical nature. The determined risk level for these events is moderate or lower, which can be considered as acceptable. For all adverse events, the values of risk probability level and losses were averaged, because e.g., a fire can have an extremely different size and can cause a different scale of losses. For selected events such as failure of technical equipment, collapsing of heavy construction machine or sinking of floating construction machinery, procedures should be prepared, as they have a great influence on the timely completion of the seaport construction investment.

The authors created their classification of works based on construction practice. In each construction process there are five basic stages: preparatory works, tender, design, construction works, commissioning of the facility and settlement of payments. Typical building works consist of:

– preparatory work,
– groundwork,
– assembly work,
– finishing phase,
– commissioning of the facility or facilities.

Typical origins of risk associated with a construction project in water areas include, among others:

– efficiency, scope, quality and technology of construction works carried out,
– variability of environmental conditions,
– scope and uncertainty of work schedule, etc.

The analysis and assessment of the risk level using the matrix method is presented below. The risk matrix is a graphical method of assessing the level of risk using a two-dimensional matrix, in which one variable is the probability of the hazard occurrence and the other variable is its effects. When estimating the risk parameters (the likelihood of a given threats and its effects), the risk value is determined and then placed in a designated place in the matrix (Tables 4 and 5). The first step is to determine in tabular form the level of probability (Table 6) and the size and category of losses (Table 7). The assumed data that were the source material in the risk.

Table 4. Risk matrix.

Probability					Consequences
Level 1	Level 2	Level 3	Level 4	Level 5	
Very Low	Low	Medium	High	Very High	
1	2	3	4	5	Level 1
2	4	6	8	10	Level 2
3	6	9	12	15	Level 3
4	8	12	16	20	Level 4
5	10	15	20	25	Level 5

Table 5. Risks in construction project.

Assessment of Severity	Risk	Description
1	Slight	Does not require preventive actions.
2–4	Low	Does not require any preventive actions. After an event occurs, monitoring of changes is recommended.
5–12	Moderate	Plans and procedures are required for control actions to reduce the probability of event occurrence.
13–20	High	Risk management plans need to be prepared. Works may be performed only under constant supervision.
21–25	Unacceptable	Risk is at unacceptable level. Technology and/or design need to be changed as well as the scope of works performed simultaneously within a given area.

Table 6. Qualitative description of the probability scale in port construction project.

Level	Probability	Description
Level 1	very low	will occur not more than once during construction
Level 2	low	will occur twice during construction
Level 3	medium	will occur 3–5 times during construction
Level 4	high	will occur 6–10 times during construction
Level 5	very high	will occur more than 10 times during construction

For this purpose, the data in Table 3 have been used. In risk assessment, probability values were assigned to specific events, then effects were estimated in four categories (material losses, human injuries and fatalities, environmental damage, and timeliness of work completion). The study adopted a 5-point probability scale (Table 6) and a 5-point impact scale (Table 7). The results are presented in Table 8.

Table 7. Estimation of losses associated with threats in the investment project.

Category of Loss	Assigned Value	Loss Values
Material damage	Level 1	insignificant, less than 50,000 PLN,
	Level 2	small, 50,000 PLN to 200,000 PLN,
	Level 3	Medium, 200,000 PLN to 500,000 PLN,
	Level 4	large, 500,000 PLN to 1,000,000 PLN,
	Level 5	catastrophic, over 1,000,000 PLN,
Injuries and fatalities	Level 1	No fatalities or injured persons. Nobody or few persons require medical aid.
	Level 2	Few injured persons, no fatalities. First aid required.
	Level 3	Medical assistance required, no fatalities. Some require hospital transfer.
	Level 4	Numerous injuries, people require hospital transfer, few fatalities (max 3).
	Level 5	Many people with numerous injuries. Many require hospital transfer. More than three fatalities.
Environmental losses	Level 1	Immeasurable effect on the natural environment.
	Level 2	Minor impact on the natural environment, short-term effect.
	Level 3	Some effects in the environment but short term or small effects with long term effect.
	Level 4	Long term effects in the environment.
	Level 5	Large impact on the environment and/or permanent damage.
Delays of work completion	Level 1	Insignificant, no impact on meeting the deadline (timely completion)
	Level 2	Minor time delay (project completion deadline may be met).
	Level 3	Considerable delay of one to two weeks (It may be necessary to shift the deadline, depending on the project phase).
	Level 4	Major delay of two weeks to a month (project completion date is very likely to be postponed, particularly in the final phases).
	Level 5	Enormous, over one month (completion date must be postponed).

Statistical studies of accidents, including those on water, show that among the causes of accidents during construction projects, incidents and accidents caused by humans have the largest share. They account for 70% of the total number of accidents that occurred due to careless behaviour of injured workers. About 17% are events caused by improper organization of work or poor organization of the workplace. Technical causes account for 13% of the total number of events, originated by structural defects, improper operation of machinery or equipment [30].

Table 8. Risk assessment of in-port construction project.

(Scenarios)	Undesired Event during Port Construction	Probability	Results				Risk Assessment			
			Material Damage	Injuries and Fatalities	Environmental Losses	Timeliness of Work Execution	Material Damage	Injuries and Fatalities	Environmental LOSSES	Timeliness of Work Execution
1.	Failure of equipment or electric installations	5	1	1	1	1	5	5	5	5
2.	Explosion of pressurized devices (cylinders, boilers, tanks), gas pipes and installations, gas-air mixtures	2	2	4	2	3	4	8	4	6
3.	Settlement or tilting of the structure	1	5	1	1	5	5	1	1	5
4.	Fire	3	2	4	3	4	6	12	9	12
5.	Collisions:									
	(a) with infrastructure facilities	4	1	1	1	1	4	4	4	4
	(b) between land vehicles	2	1	1	1	1	2	2	2	2
	(c) involving a ship or other mobile offshore units	1	3	1	4	4	3	1	4	4
6.	Tilting or collapsing of heavy construction machinery	1	3	3	1	3	3	3	1	3
7.	Sinking of construction machines and equipment	1	5	3	4	4	5	3	4	4
8.	Drop of cargo during transfer operations (materials or structural elements)	2	2	2	1	3	4	4	2	6
9.	Collapse of ceilings or roof structures Collapse of ceilings or roof structures Collapse of ceilings and roof structures	1	5	4	1	5	5	4	1	5
10.	Collapse of piles driven into the ground due to local changes in the soil structure	3	1	1	1	2	3	3	3	6
11.	Falling of excavations during excavation works	2	1	4	1	2	2	8	2	4
12.	Flooding of excavations	3	1	1	1	1	3	3	3	3
13.	Destruction of or damage to overground equipment and installations	2	1	1	1	2	2	2	2	4
14.	Destruction of or damage to underground equipment and installations	2	1	1	1	2	2	2	2	4
15.	Technical failure of machinery	5	1	2	1	1	5	10	5	5

5. Discussion

In the article, in the first part, a case study was made in the implementation of a construction project that may affect the current functioning of the port. In the second part of the article, an expert risk assessment was carried out, and the level of the effects that may occur as a result of the occurrence of probable threats was determined.

This approach is fully justified as it allows:

- define the target condition of the investment and its functionality,
- organize and define the data needed for the final results.

In order to confirm the lack of negative impact of the construction and operation of the external port and to indicate the likelihood of a threat to the vicinity of the port, the following analyzes were carried out in the article relating to the current state of the port area, i.e.:

- analysis of undesirable (hazardous) events in the fairway area,
- analysis of the probability of occurrence of particular types of threats and their consequences.

The article shows that of all causes of accidents that occurred during execution of seaport construction projects, those caused by humans have the largest share in incidents and accidents, followed by those resulting from improper organization of work and workplace. Technical failures account for 13% of the total number of events. The presented analysis indicate the necessity of developing procedures for the implementation of significant technical tasks in order to minimize risks of undesirable events and their consequences.

In the analysis examining all undesirable events, the values of probability and losses were averaged, because e.g., fire can have an extremely different dimension and cause a different scale of losses.

For selected events, including: failure of technical equipment, tilting or overturning of heavy construction machinery, sinking of floating construction machinery and equipment, procedures should be prepared in the event of a major accident or damage, due to the potentially large impact on the timely completion of the investment project.

Lifting plans should be prepared for all significant lifting operations (which have a large impact on the timing of the project and may cause potentially large losses). The remaining scenarios require routine operation in accordance with occupational safety rules.

Throughout the construction process, the following risks can be distinguished during typical construction activities:

- risk of poorly identified soil structure;
- risk of equipment failure;
- risk of construction materials quality;
- risk of failing to maintain standards;
- risk of timely delivery of construction and operating materials;
- risk of inadequate employee qualifications (employee performance);
- risk of poor management of material, operating and human resources, etc.

It is important to bear in mind that the risks will be specific to each particular project and each project participant.

Despite the relatively low risk of a collision on water, which can result in extensive oil spills, an appropriate procedure must be in place. In order to prevent such events, it is necessary to introduce additionally:

- mandatory installation of AIS receivers (Automatic Identification System, on vessels and mobile offshore units during construction,
- procedures for traffic clearance granted by VTS/VTMS (Vessel Traffic Service) for avoiding collisions with passing vessels,
- approach channels for mobile construction units on the waterside,
- on land, GPS-based monitoring mobile machinery for surveying purposes and autonomous communication,
- standby vessel for oil spill combat.

The presented approach to risk management is important for the investor, although it will not guarantee the achievement of the planned investment efficiency, it can significantly minimize possible losses. A limitation may be, for example, a badly accepted probability scale or inadequate values of effects. Effective project and risk management is also influenced by the knowledge and scope of application of standards, methods and techniques in a given field. Only a risk matrix should not be used in the risk assessment of a construction investment in a seaport.

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