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ABSTRACT

Risk assessment links the likelihood of the occurrences of adverse events to their consequences. Such assessment is used in labour management and determining trade-offs in order to identify the security and impacts correlated with an interest. In the maritime sector, it is mainly used to raise safety standards, prevent environmental pollution and to maintain healthy marine ecosystem. Risk control itself is traditionally focused on the individual action-consequence relationships, which are later considered in groups for assessment of their acceptability in accordance with safety requirements. Thus, the risk assessment for extraordinary pollution of the Adriatic Sea as an economically important area for the Republic of Croatia will be described in this paper. Firstly, the area of analysis will be defined, along with a meteorological description of the eastern Adriatic coast. Risk assessment is carried out in three steps. The waterways will be described in the first step, along with the analysis of traffic density, regulations, and types of vessels in individual areas. The second step is a detailed analysis of statistical data of accidents in the Adriatic. The final analysis is that of the most probable and the most undesirable extraordinary pollution events and its effect on Croatian economy. In addition, examples and procedures for determining the risk acceptability and its control in the part of the Croatian coast are presented.

Keywords: **Risk assessment, Extraordinary event, Marine pollution, Adverse event, Economic importance of the Adriatic Sea.**

1. INTRODUCTION

Shipping is a mechanism for large deliveries of goods in the world trade and plays a key role in the development of human life. Billion tonnes of raw material and finished goods are economically, environmentally friendly, and safely transported daily from port to port. But maritime transport is also a high-risk area. Despite the modern high-precision satellite-era navigation, many accidents still occur [1,2].

Although the number of maritime accidents is attracting big media attention, statistics show a slight but stable decline in the last decade [3]. Credit is given to harmonized and strict international rules and requirements issued by the International Maritime Organisation (IMO). But despite progress, maritime accidents remain a major problem for the industry as they have an extremely strong impact on human life, the environment, property, and various social activities. The scale is measured from minor injuries and damages to the loss of life, complete loss of property and irreversible damage to the environment.

As maritime accidents, depending on their type, affect the environment differently, it is important to note that not only mechanical damage to the ship (collision, impact or stranding of the ship) can result in environmental pollution, but also various crew errors, such as accidental discharge of oily water, fuel displacement accidents, poor waste management, etc. According to National Response Corporation Environmental Service data, slightly more than million tonnes of petroleum products end up in the sea due to industrial processes, natural phenomena, and accidental human spills. In addition, catastrophic accidents, such as the sinking of the Prestige tanker off the coast of Galicia in Spain and the explosion of the Deepwater Horizon oil rig in the Gulf of Mexico, still pose a threat to the sea and the marine ecosystem [4]. While the recent past is promising, new concerns about potential environmental pollution arise from the need to exploit oil from increasingly demanding areas, such as the Arctic and unexplored depths.

The impact of human error in routine work is a strictly regulated area. Each shipping company must have an approved safety management system including elaborated and detailed procedures. Using a checklist ensures that all the necessary actions are followed and helps reduce the likelihood of risk of accident.

Risk assessment of extraordinary pollution of the Adriatic Sea, which plays a huge role in the Croatian economy, will be discussed in this paper. The goal is the analysis of the extraordinary risks of environmental pollution and its effects on Croatian economy. Penalties and corrective actions always require more effort, and the damage can never be completely removed.

This paper is organized as follows: Section 2 introduces the geographical area of the research. Section 3 expands on weather characteristics of researched area continued on the traffic condition of Adriatic Sea in Section 4. Section 5. contains the risk analysis of the study with two scenarios, risk acceptance and control criteria and real-life practice examples. Section 6. explores current practice of risk control in Adriatic Sea with emphasis on Croatian area and development. Section 7 concludes the impact of discussed scenarios in accordance with current economic data on Croatian coast.

In the first three sections, the descriptive method is used to establish the bases and conditions of the study area. As the meteorology, geographical and traffic data conditions the statistical data of the study, these factors are closely correlated to the nature of the risk and as such to accidents on the sea.

Onwards, the development analysis of the most probable event and the most unfavorable event are used to establish two basic scenarios to define the risks. Statistical analyses of the data collected through “Historical method” was made to define the most likely accident. Data is collected from official statistics of Croatian Ministry of the Sea, Transport and Infrastructure [16] as this data is most reliable.

The analysis of scenario with worst possible consequence was done by “Generalization and Compilation methods” taking in to account collected historical information of traffic in Adriatic Sea. The results of such a scenario should therefore be seen as an attempt at representation rather than a rule. Risk acceptance and real-life examples are based on the “As Low As Practicably Possible (ALARP)” principle [26-27] and examples are based on “Compilation method: IAEA-TECDOC-727” [28]. ALARP principle categorizes risks according to the probability of occurrence and the severity of the consequence and IAEA-TECDOC-727 method contests such pre-determined probabilities of unwanted risk events occurring in the work process. Finally, the impact of the determined risks on Croatian economy are presented trough collected data from mentioned Croatian Ministry of Tourism and Sport and Ministry of Agriculture [35,37].

2. GEOGRAPHICAL REACH

The risk assessment of this paper is applicable to the entire Adriatic Sea area, but the analysis of the collected data is centred around the Croatian Adriatic coast.

Accordingly, the area of the Croatian economic zone is the most important subject of the analysis. It represents a complex and functionally related structure of various subsystems, such as natural resources, transport, maritime activities, political relations, and security systems. All maritime assets are thus of interest to the Republic of Croatia and are therefore used under its conditions. The economic zone is also called the exclusive economic zone, which indicates harmonized and controlled use of the public goods [5]. This means that in addition to the control of sea life exploits, concessions and other such activities, a security system must be established and implemented. Thus, the economic zone in the Adriatic Sea is composed of two parts of the same whole, starting from the midline of the Adriatic towards the Croatian coast, and from the midline towards the Italian coast.

The sea coast extends from the mean low water line and comprises a land belt bounded by the line reached by the largest waves during storms, along the part of the land intended for some maritime activity, which is at least six meters wide from the line of horizontal mean higher high waters [6]. Geographically, maritime good comprises sea waters of the territorial sea, with their bottom and underground, as well as the part of the land that is intended for public maritime use. Enviable natural resources and geographically strategic position make the Croatian coast the crown jewel of the Republic of Croatia.

3. METEOROLOGICAL AND OCEANOGRAPHIC CHARACTERISTICS OF THE ADRIATIC SEA

Small seas like the Adriatic are generally characterized by local weather development, which is mostly influenced by land distribution with its role of marine protection. Winds in the Adriatic generally depend on the barometric distribution of the wider area, while the direction and strength are defined by coastal masses. On the eastern side of the Adriatic, the climatic features and characteristics of the archipelago cause sudden contrasts in the weather.

Among other things, this creates gusts and winds. The prevailing winds in the Adriatic are “Bora” (NNE to ENE), “Jugo” (ESE to SSE), “Maestral” (WNW to NW) and westerly winds, which represent only a small part in the total number of days [7]. Winds of Beaufort force 6 or more blow up to 40 days a year, while the storm wind blows about 10 days a year and most commonly occurs as Bora. Generally, the southern part of the Adriatic is dominated by Jugo, and the north is subject to Bora. The impact of these winds differs significantly in summer and winter [7].

Bora creates a relatively small leeward area due to its nature of blowing from the mainland towards the sea. On the other hand, Jugo can create big waves because of its long leeward area. Important winds of the Adriatic are also Lebić, which blows from the SW direction and can be stormy, and Maestral, which marks the summer season.

As the Adriatic is a semi-enclosed sea, the generation of waves is caused by the surface influence of wind in its intense cyclonic activity. The most common wave formation in summer is caused by Maestral, and in winter by Bora and Jugo. The waves of the Adriatic are marked by repetition, 1.5 m height and, during stormy winds, an average period of 4.6 seconds and the height of up to 4 m. Waves up to 6 meters in height can be generated only in the wider Kvarner area during SE Jugo and in the Otran area during Jugo [7].

Freshwater inflow from the northern Adriatic rivers under the influence of the Coriolis force creates a flow along the Italian coast towards Otranto, thus causing the flow in the opposite direction. Such cyclic flow caused by the difference in density describes the surface sea currents of the Adriatic. The mean flow velocities are 0.5 knots and decrease drastically with depth. The difference in density during summer and winter, that is, the difference in temperature and salinity, create the input NW current along the east coast and the SE output on the west coast of the Adriatic. During very strong wind gusts, the speed of the surface current can reach 3-4 knots, but even at a smaller depth it can reach a maximum of 1.5 knots [7].

The tides of the Adriatic are of mixed type in the transitional phases of the moon and substantially unequal in height. Only during syzygy, they are of semidiurnal type, and during quadrants diurnal type. During syzygy, there is a delay in the growth of tides in a counter clockwise direction, while during quadrants, the growth is uniform along the entire length of the Adriatic. Amplitudes increase from south to north, with a range from 0.22 to 0.60 meters [7].

4. DIRECTION OF THE ADRIATIC SEA TRAFFIC

Waterways are nowadays conditioned by the position of ports, traffic, and hydrographic characteristics of an area. In the Adriatic, ports in the extreme north-western part define the waterways with their transhipment size [8]. The main traffic route passes through the central part of the Adriatic between the Otranto pass and ports of the north-western part, respectively towards the ports of Venice, Trieste, Ravenna, Koper, and Rijeka. It is the shortest way to sail the Adriatic

In addition to the main waterway, the Adriatic is also marked by other longitudinal waterways that are positioned closer to the coast for better connections with smaller ports. Such waterways follow the coastline along the east and west side. Longitudinal coastal waterways in the part of the eastern Adriatic coast (coasts of Albania, Montenegro, and the part of Croatia to the Dubrovnik area) extend in the immediate vicinity of the coast, within which inter-island waterways can be singled out as a special subgroup of nautical tourism waterways. They connect nautical centres with the most attractive tourist destinations on the Adriatic

In addition to longitudinal waterways in the Adriatic, there are numerous transverse waterways that connect ports of the east and west coasts and ports with longitudinal waterways. On the east side, these are the ports of Rijeka, Zadar, Šibenik, Split, Ploče, Dubrovnik, and on the west side, the ports of Ravenna, Ancona, Pescara, Bari [9-10].

All facilities, infrastructures and superstructures of international public transport are defined according to the term as a public good and their usage is equal for all. The importance of this concept is reflected in the fact that Croatia's geo-traffic position is characterized by an easy maritime approach to European traffic and is important for the general interest of the whole world [11].

5. RISK DETERMINATION

Risk determination scenarios can be explored through two basic approaches to the development analysis of the most probable event outcome and the most unfavourable event outcome. Risk assessment therefore boils down to a detailed and systematic evaluation of all actual and potential sources of danger, meaning it seeks to identify all foreseeable risks. The acceptability of a risk is very difficult to determine because of its association with the consequences for human life [12].

Therefore, the final values are not easy to represent mathematically, and the analysis of the results should be viewed as an attempt at presentation rather than a rule.

The fact that the occurrence of larger consequences in an event is lower, and that the occurrence probability of smaller consequences is higher, the rule of inverse proportionality is used. The consequence can thus be represented as the ratio of the sustained risk to the probability of its occurrence. However, statistical values from past events are used to determine these parameters. Due to the general progress of the industry standards, the data are often outdated and cannot reliably show the risk probability but can serve as an indication.

5.1. THE EVENT WITH THE HIGHEST PROBABILITY OF OCCURRENCE

In the case of risk assessment of the Adriatic Sea pollution, we consider the assessed risks in special circumstances, in which the first and the most important step is to analyse occurrences of the most probable adverse event.

Such analysis boils down to the study of past events and, accordingly, the calculation of the prognosis of the probability of occurrence. The disadvantage of this method is the unreliability of the data or their misrepresentation. Likewise, a maritime accident is caused by a series of events. As some of these events are related, conditional probabilities also need to be determined [13-14].

Traffic in the Adriatic Sea is constantly increasing, and with it, the probability of an accident increases. Especially during the tourist season, when there is an increased number of smaller vessels, there is also an increased number of minor accidents. Of course, such accidents are of lesser extent of damage, but their number cannot be ignored. The impact of such accidents, along with consequences for human life, can pose a high risk of environmental pollution. The reason are mostly traffic disturbances of larger ships, which can ultimately result in disaster.

Of all ship types, oil and chemical tankers pose the greatest danger in terms of the potential environmental damage and endangerment of human life. According to Maritime Transport and Possible Accidents in the Adriatic Sea data, tankers account for 20 % of traffic of the average number of merchant ships in the Adriatic. The traffic density is the highest on the main longitudinal waterway, i.e., the central part of the open sea of the Adriatic, where there are separate traffic systems. The problem generally pose access nodes to the ports of Rijeka, Bakar, Zadar, Split and Ploče, where there is no significant regulation of navigation [15].

As the majority of smaller vessels in the Adriatic do not have an AIS system (Automatic Identification System), the existing AIS based distributions of ships on voyages are not complete and cannot be a reliable source for traffic analysis.

The total number of accidents on the Croatian Adriatic coast is shown in Table 1 bellow, in accordance with the records of the Croatian Ministry of Transport, Maritime Affairs and Infrastructure [16].

	Stranding/ grounding and impact	Inability to navigate - failure	Sinking	Collision	Flooding	Fire	Total
2020	44	42	20	12	6	11	**139**
2019	67	56	23	15	18	8	**187**
2018	69	83	13	30	19	19	**233**
2017	61	59	12	19	13	18	**182**
2016	65	86	8	11	8	8	**186**
2015	47	48	11	11	8	9	**134**
2014	68	59	11	15	7	8	**168**
2013	45	60	17	8	11	12	**153**
2012	53	78	10	12	14	7	**174**
2011	49	64	9	7	11	7	**147**
2010	43	105	20	9	8	8	**193**
2009	59	104	8	3	10	8	**192**
2008	32	81	6	2	1	8	**130**
2007	72	92	7	10	8	8	**197**
2006	34	88	3	7	17	3	**152**
2005	43	61	12	15	15	7	**153**
2004	43	72	9	5	7	5	**141**
2003	37	70	9	0	6	6	**128**
2002	43	64	7	2	3	6	**125**
2001	28	72	3	1	5	3	**112**
2000	34	57	7	3	5	4	**110**
1999	17	52	3	0	4	11	**87**
Average	**48**	**71**	**10**	**9**	**9**	**8**	

Table 1 – Historical overview of maritime accidents in the Adriatic [16].

The *Table 1* shows that during the period from 2000 to this day, stranding accidents, and inability to navigate, predominate. The decrease of accidents in 2020 is the result of the Covid-19 pandemic.

According to the Search and Rescue statistics (SAR) from Ministry of the Sea, Transport and Infrastructure up to 60 % of accidents belong to vessels intended for entertainment during the tourist season. Research on such accidents has shown that the main cause of their occurrence is the lack of nautical experience, the lack of knowledge and inadequate equipment for boats and yachts [3].

According to the data abouve, on the distribution of accidents in the Adriatic, the port of Zadar records the most accidents with 35 %. The primary reason for this is the previously mentioned dominating traffic of small boats intended for entertainment, with unsatisfactory equipment and the operators' lack of nautical knowledge [3,16].

Therefore, the most probable adverse event is grounding and/or engine failure which leads to an inoperative vessel for entertainment and/or leisure in the coastal area of the major port junctions, with an emphasis on the Zadar area.

Furthermore, it is necessary to define the most probable environmental pollution that could result from these accidents.

By itself, grounding degrades the environment mechanically, but the extent of such degradation primarily depends on the location of the accident. If we refer to grounding on an underwater cliff, the pollution is reduced to the very contact surface of that cliff. Bigger pollution would cause puncture of the fuel tank and/or liquid cargo, in which case an oil spill would most likely occur.

On the other hand, a malfunction resulting in the inability to navigate can easily cause such grounding, collision and impact, or a combination of these. Thus, in the event of a collision, a liquid cargo spill and fire could be a probable outcome for tankers. In the worst-case scenario, a vessel can sink, resulting in complete spill of fuel and/or cargo from punctured tanks.

The greatest danger of collision of large ships is in the intersections of the main longitudinal waterway and the transverse waterways of the central Adriatic. Of course, the risk of collisions with smaller vessels is the greatest on waterways stretching along the coast and between the islands.

5.2. EVENT WITH THE WORST POSSIBLE CONSEQUENCES

The most unfavourable event in terms of pollution of the sea and the marine environment is the irreversible degradation of the marine environment, with the greatest efforts of eliminating the consequences. Such damage represents permanent or temporary changes to the affected area.

The advantage of such observation and risk analysis is the split process and sequence analysis, which results in the most unfavourable event. In this process, it is extremely important to understand the actions that cause the risk. On the other hand, it is important to know that such sequence has a very low probability of occurrence and often unrealistically high damages.

The greatest danger to the environment is oil spills. As there are numerous oilrigs for the exploitation of crude oil and natural gas in the Adriatic, the collision of an oil tanker and active platform could result in the most unfavourable event of pollution of the Adriatic. The sizes of tankers sailing the Adriatic are generally Aframax and Suezmax sizes. However, in determining the most undesirable event, it is interesting to note the exploitation of a 330 m long VLCC tanker with a capacity of 300 000 tons. For example, we have the tanker Houston, which is such VLCC that sailed to port of Omišalj for transhipment in 2018.

According to the EU and the Croatian Institute for Oceanography and Fisheries data, 70 million tonnes of oil and oil products are transported annually by tankers through the Adriatic [17]. This quantity of oil is about 100 times larger than the one spilled in the catastrophe of the Gulf of Mexico. Because of minor incidents, as per EU commission data, 100 000 tons of crude oil, oil products and other hydrocarbons are spilled into the Adriatic Sea every year.

Therefore, as the results of the most probable adverse event are stranding, collision and impact, it is necessary to analyse the worst-case scenario of such an accident.

When it comes to VLCC tankers, according to the general calculations of stability in damaged condition, the worst-case event from the point of view of environmental pollution would follow the penetration of the two largest tanks (usually in the middle of the ship – tanks No. 3 and 4). As oils have a lower density than the sea, by nature they float on the surface of the water. Therefore, the worst-case scenario would be the penetration of these tanks at the top, near the main deck, and the complete sinking of the ship. In the event of sinking, all the cargo in these tanks would float to the surface of the sea. The largest tanks can typically receive 10 % of the total payload, which in our case of VLCC would mean about 58,800 tons of oil. A possible explosion and fire could result in more tanks breaking and a larger spill.

As the sea currents on the eastern side of the Adriatic move from south to north, the most adverse location of oil spill for the Croatian coast would be in the south-eastern part of the Adriatic [18-22].

As another example, we can consider the LNG terminal on the island of Krk. The liquefied gas is converted into a cold vapor cloud during uncontrolled release into the environment. Such cloud is called an aerosol and is heavier than air. As it warms, this cloud mixes with the surrounding air and equalizes with its density. Furthermore, droplets of liquefied gas that have not completely evaporated can create smaller pools that evaporate on the surface.

Methane concentration in a mixture with air of 5-15 % and contact with an ignition source will result in ignition. The form of ignition can be a fire-jet from a pipeline, burning of steam above a pool of liquefied gas and, the most undesirable scenario, a sudden ignition of a cloud of vapor, or in other words, explosion. A gas explosion in the terminal area is unlikely, but possible, and can be divided into detonation or deflagration. The detonation is extremely aggressive and creates a shock wave faster than the speed of sound (1500 m / s). As natural gas is not reactive enough for this type of explosion, it is more likely to expect a shock wave slower than the speed of sound (about 250 m / s), in which case the explosion is described by deflagration [23].

Also, as steel becomes brittle at -45 ˚C and liquefied natural gas is transported at -162 ˚C, it can be assumed that droplets of liquefied gas that suddenly come in contact with a metal surface (unprotected by water shower curtains) could easily cause a large constructive damage to the ship.

The damage caused by such an event in the worst case could, except for the loss of human life, result in the complete loss of the ship, the loss of the entire cargo at the terminal and the loss of the terminal infrastructure, consequently resulting in the irreversible environmental degradation of the area.

5.3. RISK ACCEPTANCE AND RISK CONTROL

An acceptable risk is one for which all consequences are known and controlled with a series of preliminary actions. Such preliminaries represent several barriers to prevent their occurrence. Risk and uncertainty are characterized by situations where the actual result for a particular event or activity has more than one possible value, leading us to the question of acceptability.

Risk acceptance can be qualitative or quantitative in relation to categorization and evaluation. The comparison itself can be made without and in relation to other risks within an action.

The development of an acceptable model depends primarily on the existence of appropriate traffic data for the area under assessment, the satisfactory technological conditions available and the rules and regulations governing navigation safety. An acceptable risk is one for which all consequences are known and controlled with a series of preliminary actions that have multiple barriers for preventing their occurrence [23-25].

As the consequences of accidents in the environment primarily depend on the type of the vessel and other maritime facilities involved in the accident, the best way to present the pollution risk assessment is in a table. Since risk is defined as the result of the probability of occurrence and the severity of the consequence, both items are valued separately.

The following categorization is modelled by the “As Low As Practicably Possible (ALARP)” principle, i.e., the categorization of risks according to the probability of occurrence and the severity of the consequence [26-27].

	CONSEQUENCES FOR				LIKELIHOOD OF OCCURRENCE				
	SEA	COAST	ECO-SYSTEM	SEABED	VERY SMALL	SMALL	MEDIUM	HIGH	VERY HIGH
C1	NO POLLUTION	WITHOUT DEGRADATION	WITHOUT INFLUENCE	NO POLLUTION	1	2	3	4	5
C2	NEGLIGIBLE POLLUTION	NEGLIGIBLE DEGRADATION	NEGLIGIBLE IMPACT	NEGLIGIBLE POLLUTION	2	3	4	5	6
C3	LITTLE POLLUTION	SMALL DEGRADATION	SMALL IMPACT	LITTLE POLLUTION	3	4	5	6	7
C4	MEDIUM POLLUTION	MEDIUM DEGRADATION	MEDIUM IMPACT	MEDIUM POLLUTION	4	5	6	7	8
C5	GREAT POLLUTION	GREAT DEGRADATION	GREAT IMPACT	GREAT POLLUTION	5	6	7	8	9
					L1	L2	L3	L4	L5

Table 2 – Overview of risk categorization in safety impact assessment [Author].

Risk is then placed on the table by characterizing severity of consequence in the column (C1 to C5) and by characterizing likelihood of occurrence on scale (L1 to L5).

In this way, the values of the risk are presented in three categories:

• Low risk (Green) - Acceptable risk

• Medium risk (Yellow) - Tolerating the risk with additional safety measures that will reduce the likelihood of its occurrence and thus rank it in the green acceptable zone.

• High Risk (Red) - An unacceptable and intolerable risk that requires immediate corrective action. Such action cannot be carried out until the likelihood of such a risk has been reduced to an acceptable level.

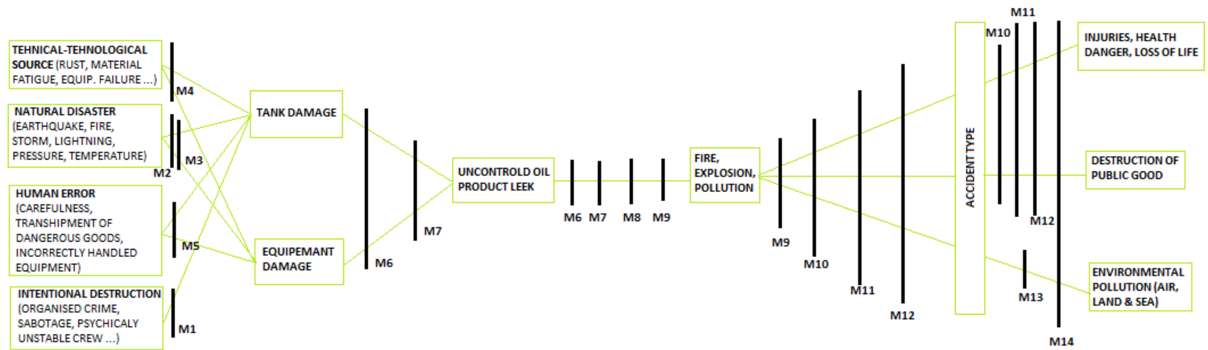
As seen from the table, risks whose occurrence is unlikely, both because of their nature and because of the actions that prevent its occurrence, can be accepted. Likewise, small risks that have a high probability of occurrence are accepted only if the consequences are insignificant.

Risk reduction and control is carried out in cases when their occurrence is unacceptable. In case the risks are analysed and included in the yellow zone, i.e., tolerable, it is up to us to choose whether to take any pre-treatment to reduce either the probability of its occurrence or/and its consequence. However, if the analysed risk is in the red zone, additional preliminary actions to reduce the likelihood of occurrence and/or consequences are mandatory. This means that by additional actions we would try to eliminate or reduce the consequences or minimize the probability of their occurrence so that they would be in the acceptable zone.

Risk mitigation is carried out according to the hierarchy: elimination, replacement, technical control (machines), implementation of signs / warnings, administrative control (checklists) and personal protective equipment. In addition, it is extremely important that all participants are well acquainted with the identified risks and the purpose of protection measures. Thus, before each work begins, a meeting must be held to discuss security measures.

As a real-life field example of risk control and acceptance of risk of extraordinary pollution events occurrence, let’s consider the Oil Storage Federation BIH Ltd. in the port of Ploče. The assessment of the probability of occurrence of risk is based on the IAEA-TECDOC-727 method [28], which goes through pre-determined probabilities of unwanted risk events occurring in the work process. Initial data on the area were collected from various historical sources and included according with the statistics of similar plants. Thus, the cause of the danger is considered to be a disturbance in the process due to which a harmful substance can be released into the environment uncontrollably (leakage of the tank, mechanical damage to the pipeline and / or tank, etc.).

For each foreseeable disturbance scenario, the amount of hazardous substance released, and possible consequences are assumed. From *Scheme 1* we can see the predicted sequence of events.



Scheme 1 – Overview of risk control at the Federation d.o.o oil terminal [29].

Between each event, protection measures are set, i.e., prevention and control of the risk that can cause the next undesirable event in the series is set.

For example, between the technical and technological cause of contamination on the tank, prevention measures include regular inspection and measurement of the wall thickness of the tank, while maintaining anti-corrosion protection. Furthermore, for early detection of uncontrolled discharge, protection measures are regular inspection rounds and regular measurement of the liquid level in the tank. Fire and explosion prevention is also carried out with regular rounds, early detection of a potential source of ignition, a tank inerting system and a fire alarm system.

If ignition occurs, there are fire extinguishing systems, fire spreading prevention systems, a tank boundary cooling system, along with means to prevent and stop environmental pollution [29].

As far as the risk control on board is concerned, according to the International Safety Management Code (ISM), each carrier is obliged to ensure satisfactory working conditions for its seafarers and all personnel on board, applying both risk assessment and the possibility of reducing them. Therefore, "each crew-member on the ship must inform the supervisors or other competent person, and they have to inform the owner, if there is a significant risk on human life, ship or environmental safety, and violation of working conditions and working procedures". Working principles must aim to improve the safety at work of their employees and to protect against the risks that exist when executing particular work. As an example of risk control, International Safety Guide for Tankers and Terminals (ISGOT) recommendations and approved checklists for routine on-board operations are carried out on crude oil and oil product tankers. Such checklists are usually divided into groups according to the type of work. We therefore have work at heights, operations with machinery, work below the waterline, enclosed space entry, contingencies (contingency planning - fire, stranding, failures, etc.) and others.

6. RISK CONTROL IN CASE OF EXTRAORDINARY POLLUTION IN THE REPUBLIC OF CROATIA

With the continuous growth of traffic and the proportional growth of accidents, it is necessary to increase preventive actions. From the above presented risk analysis, we see that the greatest attention should be paid to larger cargo ships carrying dangerous goods. Thus, as of July 1st, 2003, the use of the ATS (Adriatic Traffic System) reporting system is mandatory for participation in the Adriatic traffic. It applies to tankers over 150 GT and to other ships above 300 GT carrying dangerous goods and/or environmentally harmful goods. In addition, maritime traffic management supervision of Vessel Traffic Service (VTS) Croatia and navigation supervision based on the AIS device has been established at the access to the port of Rijeka [7].

Also, laws banning navigation and restrictive measures in sensitive areas, such as the Pelješac and Koločep Channels, the Murter Sea and the Žirjan Channel, were adopted, as well as a partially declared economic zone for countries outside Europe. In addition to the ban on navigation of ships transporting dangerous goods older than 25 years, the Law on the Coast Guard and the Rulebook on places of refuge were adopted.

The protection of the sea and maritime features in Croatia derives from the Barcelona Convention, National Contingency plan for intervention.

Furthermore, Croatia has about 650 shelters on the Adriatic, of which 380 are natural and 270 are ports and harbours [30-31]. Such shelters are extremely important in preventing major pollution. The threat of pollution from a ship, or the pollution itself, is much easier to control in a shelter. An oil slick in the open seas is almost impossible to stop from spreading, which can potentially endanger a large area, while in a port with a calmer sea surface and floating fences, such oil slick can be controlled. Also, pollution control in the port is possible even in the case of vessel sinking up to 15 m of depth.

In addition to the above-mentioned measures, the established new measures on traffic directing, with emphasis on the northern Adriatic, are to be pointed out.

Sudden marine pollution is the subject of an international plan of “Intervention for prevention, preparedness and response”. Accordingly, on September 16th, 1993, the Government of the Republic of Croatia adopted the “Contingency Plan for Sudden Marine Pollution in the Republic of Croatia”, which was renewed in 2008 on the basis of Article 50, paragraph 4 of the Environmental Protection Act (OG 110/07) and Article 63, paragraph 2 of the Maritime Code (OG 181/04 and 76/07). Procedures and measures for the implementation, prevention, limitation, and preparedness for sudden marine pollution, in addition to extraordinary natural events at sea for the purpose of protecting the marine environment, is defined in the plan. The plan is implemented by the Croatian headquarters, MRCC Rijeka and the County’s Operations Centres (Županijski operativni centri - ŽOC). Also, the plan is incorporated into the regional intervention plan for pollution prevention, preparedness, and response of the Adriatic in agreement with Italy and Slovenia. Sudden pollution of the marine environment is considered to be of a quantity greater than 2000 m^3.

On October 3rd, 2003, The Republic of Croatia has declared an ecological-fishing zone for the purpose of environmental protection and the use of living resources.

As already mentioned in the paper, the greatest threat to navigation safety is posed by sub-standard and old vessels with unqualified management. Therefore, regarding inspections on compliance with regulations and documentation, additional efforts were made during the tourist season. Under the development plan for the entire maritime system in the Republic of Croatia, the e-Maritime and e-Navigation system is being developed, with which the regulation of documents would be much more effective. The application of such “network related system” eliminates the possibility of falsification and misrepresentation, which drastically speeds up the control system and review of the vessel's fitness [31-34].

7. IMPACTS ON TOURISM AND THE ECONOMY

Assessing the damage of the most unfavourable event is very difficult to perform. That is mostly because its unknown strength, total cost and corrective efforts do not follow any regularities.

As the caterers’ annual earnings during the tourist season, along with the values of marine biomass and annual earnings from sales are known, the total value will represent the worst damage ratio for a certain area.

Thus, the consequences of pollution on the Croatian Adriatic coast are reflected in the economic damage. According to the Central Bureau of Statistics, in 2019 Croatia had 1.3 million visitors. Of that total number, 87 % belongs to the coastal area, which amounted revenues of 1.1 billion euros [35].

According to the Directorate of Fisheries of the Ministry of Agriculture, the Croatian fleet consists of over 200 vessels that catch over 60,000 tons of small pelagic fish a year, which represents 90 % of the total fish catch in Croatia and 56 % of the total catch. 350 trawlers make up about 6 % of the total catch and about 25 % of the total catch value of 60 million euros [36-37].

The analysis of the development of infrastructure of nautical tourism shows that the development related to the counties is uneven. Thus, the Primorsko-Goranska county records a decline in the number of ports, while the Šibensko-Kninska, Zadarska and Splitsko-Dalmatinska are in continuous growth. The main reason for this is the orientation of the port of Rijeka towards freight traffic. Furthermore, the Port of Rijeka marks a record number of large cruisers in 2019, the development of which was unfortunately interrupted by the pandemic. It is also important to note that in the last few years, the port of Rijeka has invested most funds in the development of infrastructure for the reception of this type of vessel.

The income from berth renting in nautical tourism has annually contributed around 69.3 million Euro to Croatia in the last ten years. In addition, through transit vessels with other catering services, Croatia generates around 106.6 million Euro in revenue, with a constant annual increase of around 5 % [38].

Ultimately, cleaning costs are subject to large value oscillations. They mostly depend on the technology used in cleaning, so it is impossible to estimate them beforehand. According to a well-known historical example of the Exxon Valdez tanker wreck, the total cost of cleaning up the 38,800 m^3 oil-spill was roughly 2.1 Billion US dollars [39].

Hence, the total possible damage is the sum of the losses from tourism, fish sales and breeding, imports that replace goods (quality) for the time needed for recovery and cleaning costs (efforts - human labour, equipment and means spent). It is also necessary to mention the violation of social value and coastal infrastructure.

8. CONCLUSION

This paper analysis shows that importance of oil pollution prevention plays a vital role for Croatian economy. In the case that the most unfavourable case analysed in the paper occurs, from the standpoint of economy and welfare, the impact would be catastrophic in all parts of Republic. Due to varied classifications and perceptions of risk of each individual making the assessment, the process is arguably very subjective. As so, it is important that for each process the risk assessment is done by team of professionals in regular interval. Re-analysing of the same process by the group will give us the higher chance of determining all the associated risks and hopefully all the prevention barriers would be established.

One of the biggest dangers in risk management is the illusion of security and it is certain that silencing and neglecting of the risk leads projects to ruin. Project risk management primarily depends on the level of risk tolerance of those responsible. According to some authors, risk perception is even considered one of the main areas for improvement in the development of risk management practices.

Knowing the characteristics of certain jobs, with the existence of information from similar ones, it is possible to predict what risks the project may be exposed to and what the consequences may be if these risky events occur. Better project management results are achieved by determining how to counter these risks as soon as possible and by implementing early activities to that end, because it is always more efficient and significantly cheaper than later repairing the damage from the consequences of the risk. Today, strong organizations set high standards of safety at sea. But with all the demands, there is always room for progress and new goals.

Criteria for determining acceptable risks are nowadays created through systemic elimination and risk evaluation. An accident is never the result of one wrongdoing and there are always several barriers on board that prevent an accident from occurring. Hence, with the omission of one of the barriers, we encounter the term avoided accident or "near miss".

Acceptable risk is difficult to describe objectively because it primarily depends on the perception of the consequence. However, with the application of risk control systems and their analysis, the industry standard is constantly raised to a higher level and the management of identified risks becomes routine.

The risk control is the most important action in accident prevention and thus the prevention of marine pollution. Further research should continue to focus on the control of compliance in constructional and technical requirements of smaller vessels intended for entertainment and the regulation of the operators' qualifications. The fact is that such vessels cause the most accidents in the eastern part of the Adriatic and can potentially cause extraordinary pollution with catastrophic consequences for the Croatian economy.

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