

AI-SUPPORTED MODERNIZATION OF THE CROATIAN COAST GUARD: MARINE POLLUTION RESPONSE IN EXCLUSIVE ECONOMIC ZONE

Ivona Balić Dorić¹, Robert Fabac^{2, *}, Goran Žanko³ and Ante Sršen¹

¹Croatian Navy
Split, Croatia

²University of Zagreb, Faculty of Organization and Informatics Varaždin
Varaždin, Croatia

³Institute for Research and Transfer of Advanced Defence Technologies
Zagreb, Croatia

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ABSTRACT

The maritime orientation of the Republic of Croatia significantly shapes its viability and overall existence. Beyond its cultural, historical, and natural significance, the Adriatic Sea also holds strategic importance for Croatia, serving as one of the country's vital economic resources. The evolving geopolitical landscape is driving substantial change, particularly in the energy supply through existing corridors, and may prompt European Union member states to expand maritime energy transport across the Adriatic Sea. Recognizing the high level of potential risk for marine pollution, due to increased maritime traffic in the Adriatic region, Croatia, Slovenia, and Italy have established a joint platform for prevention and response to potential incidents. In addition to outlining the current intervention management model for sudden marine pollution in the Republic of Croatia, this article presents the role and importance of the Croatian Coast Guard as the key authority for maritime security and a central organization in preventing, mitigating, preparing for, and responding to sudden marine pollution in Croatia's Exclusive Economic Zone. To assess its current response capabilities and future development and modernization needs, support was sought from the ChatGPT artificial intelligence model. By addressing a set of targeted questions about potential directions for the technological and organizational modernization of the Coast Guard, the artificial intelligence system proposed meaningful solutions in an exceptionally short period of time. Findings indicate that the widely accessible large language model used in this study provides useful suggestions for Coast Guard development and for supporting the strategic planning process as a whole, with the potential to significantly reduce the workload and time required by planning teams and decision-makers.

KEY WORDS

Croatian Coast Guard, marine pollution, prevention and response, modernization, artificial intelligence

CLASSIFICATION

JEL: C69, D89, H56, O31, Q58

*Corresponding author, *η*: rfabac@foi.unizg.hr; +385 42 390 854;
FOI, Pavlinska 2, HR – 42 000 Varaždin, Croatia

INTRODUCTION

The Mediterranean region represents one of the key areas for maintaining global stability and security, and the geopolitical and economic processes occurring there have multiple effects on the Republic of Croatia and its Adriatic area. The geographic position of the Adriatic Sea provides Croatia with a significant strategic advantage compared with continental states without direct access to the sea. Its geostrategic and geopolitical value stems from the Adriatic's role as a natural link between Croatia, Central Europe, and the Mediterranean [1]. This position enables Croatia to develop considerable transport, transit, and economic potential, which must be systematically enhanced and ultimately fully utilized.

The Adriatic Sea, as a semi-enclosed and relatively shallow marine system, holds exceptional importance for Croatia's national economic and security interests. Within this system, the Northern Adriatic stands out as an area of particular transport, economic, and environmental significance. This region is both an essential ecological resource, defined by a distinctive marine ecosystem, and an area of strategic interest for a range of economic activities taking place both on the sea surface and in the seabed. The hydrodynamic characteristics of the Northern Adriatic are shaped by its position within the Mediterranean basin, where water exchange occurs slowly and in a counterclockwise direction through the Strait of Otranto. These features make the area especially sensitive to pollution and other forms of environmental degradation, further emphasizing the need for systematic monitoring and protection of the marine ecosystem [2].

The dense population of the coastal zone, well-developed industrial infrastructure, and intensive maritime traffic, particularly traffic involving the transport of oil and other hazardous substances, further increase environmental risks in the Northern Adriatic. According to available data, 2 078 vessels carrying oil or other dangerous and harmful substances entered Croatian ports in 2017, rising to 2 888 in 2019 [3, 4]. The level of risk along maritime routes depends not only on the type of cargo but also on the technical characteristics and age of vessels, their compliance with international safety standards, and the crew's competence in handling cargo and managing ship-generated waste. Collectively, these factors determine the level of navigational safety and the potential threat to the marine environment within the Adriatic traffic system.



Figure 1. Density and directions of maritime traffic routes in the Adriatic [5].

Recognizing the significant potential risk of marine pollution (Figure 1), particularly within the Adriatic Sea region, Croatia, Slovenia, and Italy have established a joint platform dedicated to the prevention of and coordinated response to potential incidents. In addition to outlining the current intervention management model for sudden marine pollution in the Republic of Croatia,

this article concurrently acknowledges the pivotal role and importance of the Croatian Coast Guard as the key authority for maritime security and a central stakeholder integral to preventing, preparing for and responding to marine pollution within Croatia's Exclusive Economic Zone. Therefore, given the described critical context, the key research questions guiding this investigation have been identified as follows:

- RQ₁:** What are the key mechanisms and resources used to prevent pollution of the Adriatic Sea?
- RQ₂:** What is the importance and role of the Croatian Coast Guard in fulfilling the mission of preventing marine pollution?
- RQ₃:** Is artificial intelligence applicable in supporting the organizational development of the Croatian Coast Guard?

The following sections present: the mechanisms for preventing pollution of the Adriatic Sea; an overview of the Croatian Coast Guard; the Coast Guard's response capabilities in cases of marine pollution; the equipment and vessels used by coast guards for pollution prevention; and modernization and further development of the Croatian Coast Guard, including suggestions from the ChatGPT AI model; followed by the Conclusion.

MECHANISMS FOR PREVENTING POLLUTION OF THE ADRIATIC SEA

Croatia, Slovenia and Italy, as states sharing borders in the northern Adriatic Sea, are Parties to the Barcelona Convention and to the Protocol on cooperation in preventing and combating immediate threats of pollution from oil and other harmful substances in the Mediterranean Sea¹ [6, 7]. Given that the Adriatic Sea, particularly its northern part, is an exceptionally sensitive and vulnerable area due to its geostrategic significance, these states have recognized the need for a joint approach to preventing and mitigating potential threats to the marine environment. Based on the premise that effective reduction of the risk of accidental pollution can be achieved only through coordinated action at the subregional level and through the application of international regulations, an Initiative was launched to develop an optimal model of cooperation and joint response in the event of marine pollution emergencies [8].

SUBREGIONAL CONTINGENCY PLAN

Recognizing that a large-scale incident resulting in significant marine pollution could almost irreversibly jeopardize the Adriatic ecosystem and adversely affect economic activities in the region, particularly fisheries, energy, and tourism, representatives of Croatia, Italy, and Slovenia, with expert support of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea, developed the Subregional Contingency Plan for the Prevention of, Preparedness for, and Response to Major Marine Pollution Incidents in the Adriatic Sea [9]. This Plan provides that, within the framework of the Protocol Concerning Cooperation in Preventing and Combating Pollution of the Mediterranean Sea, which forms an integral part of the Barcelona Convention, and in accordance with the obligations of the Contracting Parties, a mechanism of mutual cooperation is to be established among the competent national authorities of Croatia, Italy, and Slovenia. The purpose of this mechanism is to ensure the coordination and harmonization of actions in preventing and responding to accidental marine pollution events that may affect the territorial seas, coastal zones, or interests of one or more states, as well as to incidents that exceed the capacity of an individual state to respond independently [10]. The signatory states consider the prevention of pollution incidents from ships an integral component of their national marine environmental protection policies in the Mediterranean, and particularly in the Adriatic Sea. In this context, they agreed to intensify joint activities, primarily through cooperation in implementing international regulations adopted under the auspices of the International Maritime Organization, as well as through the implementation of multilateral

agreements among the states sharing borders in the Adriatic Sea. The Contracting Parties further agreed that all measures aimed at preventing accidents that cause, or could cause, marine pollution within the area covered by the Plan must be fully aligned with the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) [8]. Despite the agreement reached, it should be noted that the Italian Republic has not yet ratified it, and therefore the Agreement has not formally entered into force [4]. At the same time, all three states have developed their own national systems for the prevention of, preparedness for, and response to major accidental pollution events in the Adriatic Sea. The Republic of Croatia, in accordance with the above, has established the Marine Pollution Contingency Plan (Contingency Plan) [8].

The delimitation of the Exclusive Economic Zones (EEZs) between the Republic of Croatia and the Italian Republic was completed by the treaty signed in Rome on 24 May 2022. After ratification by both parties, it entered into force on 15 April 2024. Within the EEZ, Croatia does not exercise territorial sovereignty but rather sovereign rights and jurisdiction in accordance with the 1982 United Nations Convention on the Law of the Sea (in force since 1994).

MARINE POLLUTION CONTINGENCY PLAN

The Contingency Plan establishes procedures and measures for forecasting, preventing, limiting, preparing for, and responding to sudden pollution incidents and extraordinary natural events at sea for the purpose of protecting the marine environment. The Plan applies exclusively to cases of sudden marine pollution by oil and/or oil mixtures in volumes exceeding 2 000 m³, hazardous and noxious substances, and extraordinary natural events at sea. It covers the maritime area, seabed, and subsoil of the Republic of Croatia, including the maritime domain, internal waters, territorial sea, and the EEZ, Figure 2 [11].

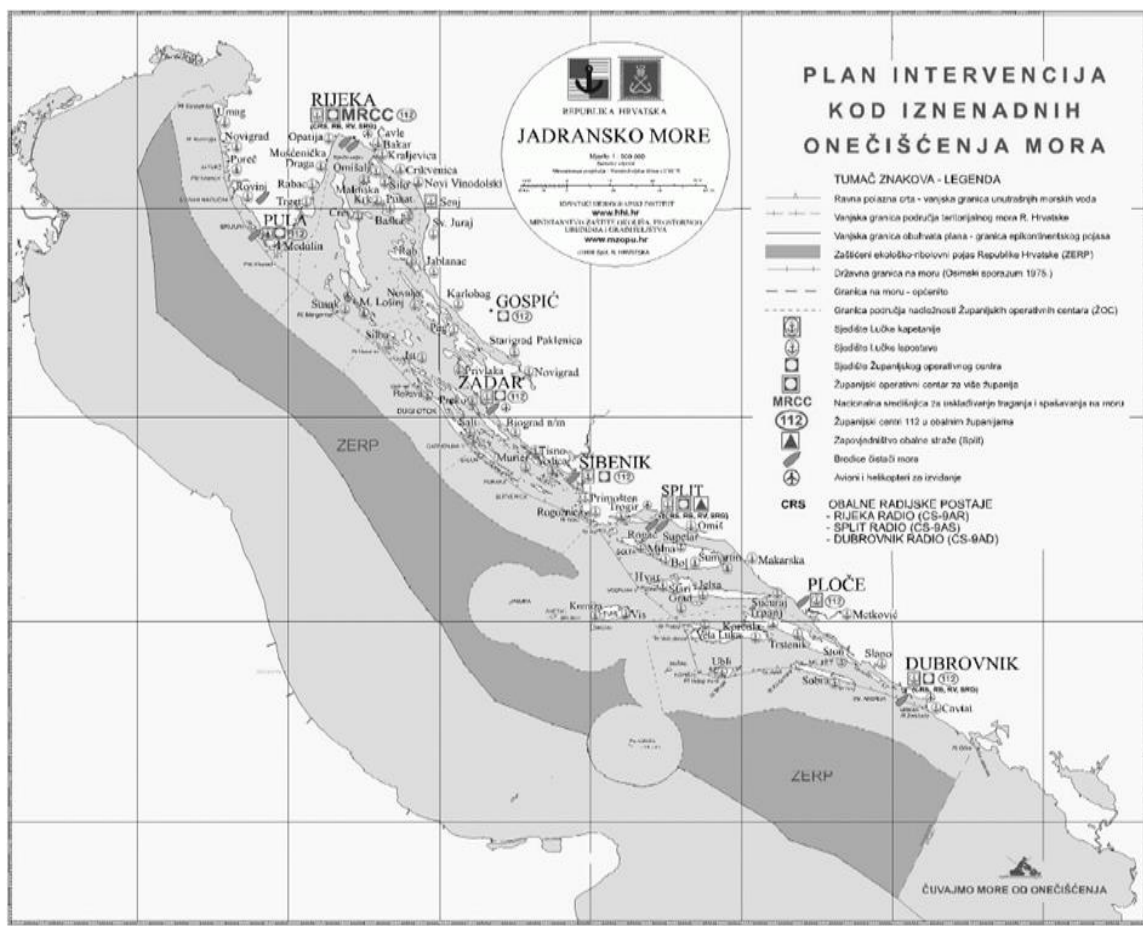


Figure 2. Map of the Contingency Plan scope [12].

By the Decision on the Proclamation of the Exclusive Economic Zone of the Republic of Croatia in the Adriatic Sea, the previously established Ecological and Fisheries Protection Zone (ZERP) was repealed (OG 10/21) [13]. In accordance with this Decision, a new legal framework based on the UNCLOS was established in the part of the Adriatic Sea in which the Republic of Croatia had exercised its rights from 2003 to 2021 under the ZERP regime, thereby defining the regime of the Exclusive Economic Zone.

Where pollution by hazardous or noxious substances, or extraordinary natural events, may endanger the marine environment, human health, or economic uses of the sea, and simultaneously produce consequences in the territory of two or more counties, or where the quantity of pollution by oil and/or oil mixtures exceeds 2 000 m³, command activities are carried out by the Crisis Headquarters. Coordination is assumed by the National Maritime Rescue Coordination Centre (MRCC) in cooperation with County Operational Centers [14-20]. For smaller-scale pollution, up to 2 000 m³, county contingency plans apply. These are adopted by county representative bodies with the prior consent of the central state administration authority responsible for environmental protection.

An analysis of the available capacities for combating marine oil pollution in the Republic of Croatia indicates that the majority of operational activities are carried out by private companies engaged in accordance with the provisions of the Marine Pollution Contingency Plan. Prominent among these are Cian d.o.o. Split, Ciklon d.o.o. Zadar, Dezinsekcija d.o.o. Rijeka, Jadranski pomorski servis d.d. Rijeka, Ind-Eko d.o.o. Rijeka, DVD Kaštel Gomilica d.o.o. and several smaller entities. They own approximately twenty smaller vessels, about 9 500 m of inflatable booms with a height of 0,6 m, and a total of 1650 m of offshore booms with a height of 1,2 m (300 m in Split and 1350 m in Rijeka). The operational equipment is distributed along the entire Croatian coastline, from Rijeka to Dubrovnik [3].

The central state administration authority responsible for the sea provides the necessary resources for implementing urgent pollution-prevention measures, including towing, fire-fighting, the use of storage tanks and other technical equipment, as well as assessing the costs associated with renting or using vessels and specialized equipment. At the same time, the central state administration authority responsible for nature protection is tasked with financing rapid-response activities aimed at removing pollution and restoring affected areas.

ENTITIES RESPONSIBLE FOR IMPLEMENTING THE CONTINGENCY PLAN

In the event of sudden marine pollution, the Contingency Plan is implemented by the Crisis Headquarters, the National MRCC in Rijeka, and the County Operational Centres. The Crisis Headquarters is a body appointed by the Government of the Republic of Croatia and is composed of representatives of state authorities responsible for the sea, environmental protection, nature protection, internal and external affairs, finance, civil protection, defense, and a representative of the MRCC. In emergency situations requiring immediate action, the Head of the Crisis Headquarters may activate the Contingency Plan without prior approval from the Headquarters. The MRCC serves as the central coordinating body between the Crisis Headquarters and County Operational Centres in cases of accidental marine pollution occurring within the territory of the Republic of Croatia. If marine pollution endangers the marine environment, human health, or the economic use of the sea in multiple counties, or exceeds the operational capacity of a single county operational center, MRCC Rijeka assumes coordination among the County Operational Centres. When pollution occurs within the EEZ, the territorial sea, or internal waters, MRCC Rijeka may propose to the Crisis Headquarters the activation of the Croatian Coast Guard [21, 22]. The National Centre in Rijeka also conducts surveillance of potential marine pollution through the CleanSeaNet satellite system, managed at the European level by the European Maritime Safety Agency (EMSA) [23]. When pollution is suspected, EMSA² forwards satellite images to

the National Centre, which then conducts on-site verification in cooperation with the Croatian Coast Guard, subordinate centres, and merchant vessels.

Within its activities, EMSA supports EU Member States by providing technical and expert assistance in implementing EU legislation related to navigational safety and the prevention of pollution from ships. The Agency also monitors the implementation of these regulations and assesses the effectiveness of measures applied at the national level. As part of its operational support, EMSA has established a network of stand-by oil spill response vessels through contracts with commercial ship operators. In the Republic of Croatia, EMSA has concluded a contract with a domestic commercial company for a stand-by vessel capable of responding to oil spills in the Adriatic Sea. These contracted vessels are equipped for the containment and recovery of oil slicks and remain in a state of constant readiness while conducting their regular commercial activities. In the event of an oil spill, the selected vessel suspends regular operations and is made available to the competent authorities, fully equipped and ready for deployment within a maximum of 24 hours from the request for intervention. All vessels in the EMSA network may be mobilized for deployment in any part of European waters or shared maritime basins. EMSA currently maintains a fleet of seventeen fully equipped oil spill response vessels across Europe, all equipped with dual systems for containment and mechanical recovery of oil pollution, adapted to various weather conditions and types of pollution. In addition, EMSA operates the Equipment Assistance Service³ (EAS), which provides stockpiles of specialized oil spill response equipment positioned at strategic locations throughout Europe. This equipment is maintained in a state of constant readiness and can be mobilized at any time, day or night, to any location across Europe. At present, EMSA maintains four EAS equipment warehouses, Figure 3: in Frederikshavn (Denmark – EAS Baltic Sea), Rotterdam (Netherlands – EAS North Sea), Tolkkinen (Finland – EAS Northern Baltic Sea), and Ravenna (Italy – EAS Adriatic Sea).



Figure 3. Projection of EMSA's operational services [24].

THE COAST GUARD OF THE REPUBLIC OF CROATIA

The Coast Guard of the Republic of Croatia is a unit within the Croatian Navy (HRM) whose mission is to conduct surveillance and protect the rights and interests of the Republic of Croatia. It consists of the Coast Guard Command, the 1st Squadron (based in Split) and the 2nd Squadron (based in Pula). Its operational structure includes ships and boats, and for the performance of maritime surveillance tasks it also employs aircraft from the Croatian Air Force and unmanned aerial systems from the Intelligence Regiment of the General Staff of the Armed Forces [25].

TASKS OF THE COAST GUARD

The Croatian Coast Guard, as defined by law, is responsible for monitoring and overseeing activities at sea and ensuring uniform enforcement of control measures across the entire maritime area under the jurisdiction of the Republic of Croatia. In addition to this core function, the Coast Guard plays a central role in the system for preventing, limiting, preparing for, and responding to accidental marine pollution. Its tasks also include monitoring compliance with regulations governing marine fisheries; combating and preventing transnational organized crime; and countering the proliferation of weapons of mass destruction.

Its mandate further encompasses activities aimed at suppressing piracy and preventing other uses of the high seas that are incompatible with the principles of peaceful conduct. The Coast Guard also oversees compliance with regulations governing safety zones surrounding facilities and installations at sea used for the exploration and exploitation of the seabed and sub-soil on the continental shelf of the Republic of Croatia. Additionally, it is responsible for monitoring the movement of foreign warships in the internal waters and territorial sea of the Republic of Croatia, as well as countering and eliminating security threats relevant to national security [25-27].

THE ROLE OF THE CROATIAN COAST GUARD IN MARINE POLLUTION EVENTS

In the event of accidental marine pollution, including oil spills, discharges of oil mixtures, releases of hazardous and noxious substances, or extraordinary natural disasters, the Croatian Coast Guard acts in accordance with the provisions of the Contingency Plan for Accidental Marine Pollution in the Republic of Croatia. Within the implementation of the Plan, the Coast Guard may engage, as needed, legal entities specialized in offshore operations, including towing, firefighting, deployment of protective booms, and other activities aimed to pre-venting and limiting the spread of marine pollution, upon the order of the Head of the Crisis Headquarters. A member of the Croatian Coast Guard is appointed to the Crisis Headquarters as the representative of the Ministry of Defence. Cooperation between the Coast Guard and other competent authorities is regulated in detail by the Regulation on the Cooperation of the Coast Guard of the Republic of Croatia with Authorities Responsible for the Surveillance of Accidental Marine Pollution [2, 8]. A Central Coordination Body for the Surveillance and Protection of Rights and Interests of the Republic of Croatia at Sea has also been established within the legal framework. Its membership includes representatives of ministries responsible for defence, maritime affairs, internal affairs, fisheries, environmental protection, the economy, finance, and foreign affairs. The Coordination Body also includes the Director of the Navigation Safety Directorate of the Ministry of the Sea, Transport and Infrastructure; the Director of the Customs Administration; the Director of Civil Protection; the Chief of Police; the Chief of the General Staff of the Armed Forces of the Republic of Croatia; the Commander of the Croatian Navy; and the Commander of the Croatian Coast Guard [20, 27].

According to the Law on the Croatian Coast Guard (OG 125/19), in force since 28 December 2019, the duties of the Croatian Coast Guard (Article 5 Par. 3) include [2]:

- Surveillance and protection of the Exclusive Economic Zone and the continental shelf over which the Republic of Croatia exercises sovereign rights and jurisdiction.

- Exercise of jurisdiction of the Republic of Croatia in the areas of marine scientific re-search and marine environmental protection within the Exclusive Economic Zone and continental shelf of the Republic of Croatia.
- Exercise of jurisdiction of the Republic of Croatia on the high seas in accordance with international law.
- Search and rescue at sea in accordance with special regulations.
- Prevention, limitation, preparedness, and response in cases of accidental marine pollution, in accordance with special regulations.
- Surveillance of the implementation of fisheries regulations in internal waters, the territorial sea, and the Exclusive Economic Zone.
- Combating and preventing transnational organized crime and the proliferation of weapons of mass destruction, in accordance with international law.
- Suppression of piracy and other uses of the high seas incompatible with peaceful purposes, in accordance with international law.
- Surveillance of the implementation of regulations concerning established safety zones around offshore installations and devices for the exploration and exploitation of the seabed and subsoil in the continental shelf of the Republic of Croatia.
- Suppression and elimination of security risks significant to national security, in accordance with legislation governing the homeland security system, as well as execution of other tasks in accordance with special laws.

In addition to these duties, the Croatian Coast Guard conducts continuous maritime surveillance within its zone of responsibility; exchanges information; provides support to civil institutions during natural and technological disasters; prepares, equips, and trains naval forces for independent or joint operations; maintains and enhances combat functions in operational planning, logistics, command, and control; and maintains and develops capabilities for participation in joint, combined, and international NATO, EU, and UN-led operations, with emphasis on meeting NATO standards applicable to the Croatian Coast Guard.

To fulfil these tasks, the Croatian Coast Guard must possess a sufficient number of vessels specialized for operations in territorial waters and the Exclusive Economic Zone. The analysis that follows focuses exclusively on Point 5: the prevention, limitation, preparedness, and response to accidental marine pollution, in accordance with special regulations. For an area as large as the EZZ, specialized vessels are especially necessary.

CAPABILITY OF THE CROATIAN COAST GUARD TO RESPOND TO MARINE POLLUTION

Through joint action with the authorities responsible for monitoring and protecting the rights and interests of the Republic of Croatia at sea, and by applying the principles of economy and efficiency in accordance with international law and national regulations, the Coast Guard of the Republic of Croatia has carried out a range of activities within its scope of work aimed at ensuring readiness and an effective response to marine pollution incidents in internal sea waters, the territorial sea, and the Exclusive Economic Zone. For the purpose of implementing the Contingency Plan for Accidental Marine Pollution, the Coast Guard of the RC designated the patrol vessel OB SB-73 Faust Vrančić for use, as it possesses the technical characteristics required for sea pollution-control operations. Over the past several years, numerous reconstruction and technical modifications have been carried out on vessel OB SB-73 Faust Vrančić to enable it to effectively perform the tasks set out in the Contingency Plan, Figure 4.

The vessel's speed is 13 knots, with an endurance of six days at sea and a range of 1650 NM. Nevertheless, it remains questionable whether the vessel, if engaged in a routine task in the

southern Adriatic, would be able to sail to Dubrovnik or Split, embark the modular equipment, and reach a pollution site exceeding 2 000 m³ near the western boundary of the EEZ in time to prevent the pollution, under unfavourable meteorological conditions, from spreading beyond the scale at which it can be controlled or remediated?



Figure 4. Croatian Navy's Vessel Faust Vrančić [28].

Analysis of specialized vessels operated by other Coast Guards, intended for responding to marine pollution, has shown that patrol vessel OB SB-73 Faust Vrančić must be additionally equipped with an infrared (IR) camera or a specialized radar system for detecting oil slicks on the sea surface. The installation of such equipment would enable early detection of oil pollution within the area of responsibility of the Republic of Croatia, precise localization of the pollution, identification of the vessel that is the source of the pollution, and the production of reliable evidence on the quantity and characteristics of the oil substances required for the prosecution of responsible parties.

The CG of the Republic of Croatia may, as needed, employ other available vessels in order to ensure rapid and effective intervention and to maintain the safety of maritime navigation in the incident zone. Awareness of the complexity of procedures, the need for coordination, and the high level of training required of all participants in the Contingency Plan when responding to marine pollution incidents, particularly those of greater scope, has prompted the implementation of numerous interdepartmental exercises and international workshops in which Croatian Coast Guard personnel participated as equal partners.

During national exercises such as ADRIATIC 2017, ADRIATIC 2018 and NAMIRG Pula 2019, communication systems, coordination mechanisms, and operational readiness for conducting sea and shoreline clean-up activities in the event of accidental marine pollution were tested [8, 20]. The Croatian Coast Guard, with vessel OB SB-73 Faust Vrančić, also participated in the interdepartmental exercise JADRAN 20 held in 2020, during which the capability to combat oil pollution at sea using EAS equipment from the Danish manufacturer TRAWEL NET-1500-DESMI was demonstrated in the waters surrounding the island of Vis.

The objective of the exercise was to verify the readiness of the intervention system for accidental marine pollution incidents and the effectiveness of the response mechanisms set out in the Contingency Plan. During the exercise, the crew's level of proficiency in handling the equipment was assessed, along with the functionality of the technical and material resources.

The results demonstrated a high level of training and operational readiness of the crew, while vessel OB SB-73 Faust Vrančić proved capable of independently performing most tasks, except for the temporary storage of collected oily water until arrival at a discharge port. In this segment, it is necessary to ensure a floating storage unit or the support of another vessel that would sail alongside and receive the collected oily substances.

In addition to the aforementioned equipment, the Norwegian Nofi Current Buster 6 system was also used within the Croatian Navy during 2019 and 2020. Both systems, being container-type, were embarked on vessel OB SB-73 Faust Vrančić for the purpose of crew training. The oil pollution response equipment is owned by the EMSA and was assigned to the Republic of Croatia for temporary use under the Agreement on Temporary Transfer of Assets between EMSA and the Croatian Ministry of the Sea, Transport and Infrastructure (MMPI). Pursuant to the Cooperation Agreement between MMPI and the Ministry of Defence of the Republic of Croatia, this equipment was assigned to the Coast Guard from July 2019 until October 2020.

As part of the 13th Plenary Conference of the Coast Guard Forum, chaired in 2022 by the Coast Guard of the Republic of Croatia, the interdepartmental COASTEX 22 exercise was conducted. The objective of this exercise was to enhance interoperability and mutual understanding among European agencies operating in the field of marine protection and the safe-guarding of marine resources. The deputy commander of the Croatian Coast Guard served as the exercise director, and the exercise consisted of several scenarios, one of which included a collision between two vessels resulting in marine pollution. During the execution of this scenario, particular attention was devoted to the accurate and timely flow of information to all competent bodies and services in accordance with their respective responsibilities.

In October 2022, Croatian Coast Guard personnel participated in a regional workshop titled Enhancing Oil Spill Preparedness and Response in the Adriatic and Mediterranean Regions, held in Opatija. The aim of the workshop was to improve regional cooperation in the field of preparedness and response to accidental marine pollution, to present new technologies in the industry, and to encourage the exchange of experience and knowledge between equipment manufacturers and intervention authorities. During 2023 and 2024, Croatian Coast Guard personnel also participated in a series of international workshops held in Portugal and Italy, organized under the auspices of the EMSA. Participation in such activities increases the level of professional competence and awareness of contemporary trends in capability development related to the prevention of marine pollution, strengthens cooperation with related institutions domestically and abroad, and contributes to intersectoral coordination. In this way, interoperability is enhanced and a sub-regional operational cooperation mechanism is developed among the countries of the northern Adriatic.

In October 2025, the international maritime exercise, ADRIA 25, was conducted in the Dubrovnik maritime area, bringing together representatives of the competent authorities of the Republic of Croatia, the Republic of Slovenia, and the Italian Republic. The objective of the exercise was to enhance interoperability, coordination, and readiness among the services responsible for navigational safety, maritime search and rescue, and marine environmental protection. The Croatian Coast Guard participated with vessels OB SB-73 Faust Vrančić and OOB-31 Omiš as well as with two rigid-hulled inflatable boats. Within the framework of the exercise's complex scenario, a series of activities were carried out, including:

- a simulation of a maritime accident involving fire and missing persons,
- maritime search and rescue operations,
- response to accidental marine pollution, and
- aerial evacuation by helicopter.

The execution of the ADRIA 25 exercise confirmed the high level of capability and readiness of the participants, as well as the effectiveness of existing cooperation mechanisms between national ministries, agencies, and international organizations. The outcomes of the exercise contribute to the further development of the maritime safety system in the region and strengthen capacities for joint action in emergency situations at sea.

Recognizing the importance of the Croatian Coast Guard's role, its technical capabilities, human resources, and implemented activities, the State Audit Office conducted a performance audit for the period from 2017 to 2019. In the report published in 2021, several shortcomings were highlighted, including the excessively broad threshold of 2 000 m³ of spilled oil at sea as the criterion for activating county operational centres. It was also determined that although the Coast Guard has a vessel adapted for boom deployment, sea-surveillance craft, appropriate storage capacities, and qualified personnel, it still lacks sufficient technical equipment for the effective prevention and containment of marine pollution in the EEZ [8].

According to the Law on the Croatian Coast Guard, a Coast Guard vessel of the Republic of Croatia (OBS), as a "Croatian public vessel marked with the official insignia of the Coast Guard" (Article 2, paragraph 3, p.2) may be assigned, by decision of the Minister of Defence, a certain number of aircraft, helicopters, and unmanned aerial systems for the performance of Coast Guard duties (Article 8, paragraph 2, p.4). This provision raises challenging questions, such as the fact that the assigned aircraft do not carry Coast Guard markings, which in the area of operations could lead to misinterpretation or inappropriate actions by other parties, potentially resulting in international consequences [2].

Furthermore, according to national-level documents of the Republic of Croatia, in addition to atypical security challenges, the Armed Forces are being trained and equipped to achieve a sufficient level of deterrence capability along two operational axes. Given the rapid changes in real-world international conditions, it is possible that the Coast Guard may not have Croatian Air Force aircraft available. This raises doubts as to whether the Coast Guard's ability to meet its assigned tasks, in accordance with the Law and within the known operational area of 55 349 km², is thereby compromised.

EQUIPMENT ASSIGNED TO THE COAST GUARD

Rapid and effective intervention in the event of a marine pollution incident contributes to a more successful system for protecting and preserving the marine environment. Therefore, the MMPI has provided three sets of equipment (booms, floating tanks for collecting polluted seawater, skimmers, etc.) for Coast Guard operations. Skimmers are specialized devices used to remove pollutants, especially oil, from the surface of the water. They operate on the principle of collecting pollutants from the water surface through suction. Coast Guard personnel have carried out a series of training exercises with this equipment, which will enhance the response capability to sudden large-scale marine pollution in the EEZ, territorial sea, and internal waters. Procurement of the necessary equipment was completed during 2024, and the equipment is currently stored in Split. Its deployment is planned at military locations in Pula, Split, and the southern Adriatic area. Such spatial distribution ensures a higher level of operational readiness and enables faster response by Croatian CG vessels in the event of accidental marine pollution.

The distribution system is particularly important in situations where a CG vessel, during an incident, is engaged in its regular tasks of monitoring and safeguarding the rights and interests of the Republic of Croatia at sea while located outside its home port in Split. By directing the vessel to the nearest base where the equipment is deployed, depending on the location of the crisis hotspot, valuable time needed for a timely and effective response to the incident is reduced. Ultimately, this can play a decisive role in mitigating the consequences of marine pollution.

EQUIPMENT OF COAST GUARDS WITH VESSELS AND SYSTEMS FOR THE PREVENTION OF MARINE POLLUTION

The technical capabilities of a coast guard operating in a semi-enclosed sea model (such as the Mediterranean Sea) are essential for effective surveillance, border protection, and the response to contemporary security challenges. One of these challenges is unquestionably the prevention and mitigation of marine pollution.

GENERAL CONSIDERATIONS

For the purposes of the comparative analysis, the technical equipment of the dominant comparative coast guard models is presented in relation to the CG of the Republic of Croatia. For example, the U.S. Coast Guard employs a range of vessels and equipment specialized for the prevention of and response to marine pollution, particularly oil spills and hazardous-substance releases [29]. These capabilities encompass categories ranging from national security vessels to VOSS modular systems, which can be rapidly installed on commercial ships to enhance their oil-recovery capacity. However, for the purposes of this research, comparison with smaller but technologically advanced countries is more appropriate. Accordingly, the following section outlines the characteristics of the systems of Norway and Italy.

TECHNICAL EQUIPMENT OF THE ROYAL NORWEGIAN COAST GUARD

The Norwegian Coast Guard (Kystvakten) plays a key role in protecting the marine environment, particularly given the substantial oil deposits and intense maritime traffic in Norwegian waters. Its capabilities for preventing and responding to marine pollution include specialized vessels and advanced equipment [30].

Specialized Vessels

- KV Svalbard (W303): an icebreaker and patrol vessel equipped for operations in Arctic conditions. It has the capability to receive and retain large quantities of spilled petroleum products, as well as equipment for the mechanical removal of oil from the sea surface.
- KV Barentshav-klasa (KV Barentshav, KV Bergen, KV Sortland): this class of vessels uses liquefied natural gas (LNG) as fuel and is designed with specialized equipment for the prevention of and response to oil spills. They are equipped with systems for deploying floating booms and collecting oil.
- KV Harstad (W318): purpose-built for marine pollution prevention operations and search-and-rescue missions. It is equipped with large storage capacity for recovered oil, boom-deployment systems, and equipment for mechanical separation of oil from water.

Pollution Response Equipment

- Floating barriers (booms) – Used for rapid encirclement and containment of an oil slick to prevent its spread.
- Oil collection systems (skimmers) – Mechanical devices for removing oil from the sea surface. There are various types, including drum, disc, and weir skimmers.
- Dispersants – Chemicals used to break oil into smaller droplets, enabling faster biodegradation by microorganisms.
- Floating storage tanks – Mobile tanks used for temporary storage of recovered oil at sea.
- ROV systems (remotely operated vehicles) – Employed for subsea inspection and monitoring of underwater operations in cases of oil leakage from the seabed.

Cooperation And Exercises

The Norwegian Coast Guard regularly conducts exercises in cooperation with other national and international agencies (e.g. the Norwegian Clean Seas Association for Operating Companies, NOFO) to ensure effectiveness in the event of an actual incident. It also works with civilian partners to apply advanced monitoring methods, including satellite-based detection of oil spills through systems such as CleanSeaNet.

TECHNICAL EQUIPMENT OF THE ITALIAN COAST GUARD

In Figure 5, the maritime borders of the countries with access to the Adriatic Sea can be seen. The Italian Coast Guard (Guardia Costiera) maintains a dedicated fleet for surveillance and intervention in cases of marine pollution, known as the environmental protection fleet (Flotta Antinquinamento) [31].

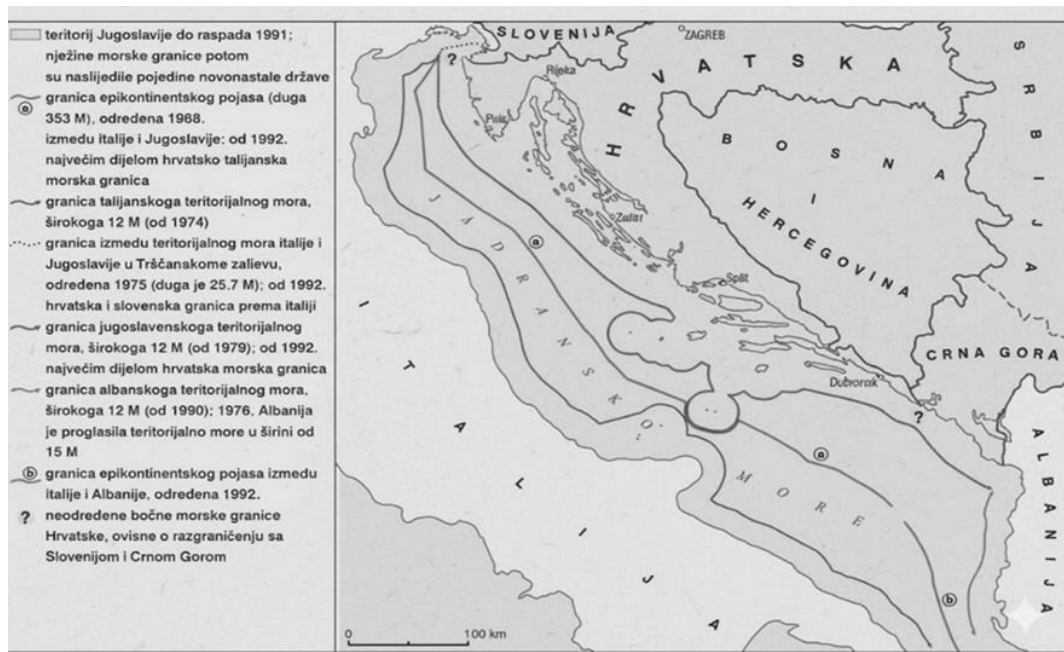


Figure 5. Croatia and Italy as maritime border countries [32].

Specialized Vessels

- Vessels for Pollution Prevention (Unità Antinquinamento): specialized vessels equipped for rapid response to oil spills, chemical discharges, and other incidents.
- Tugboats and multipurpose vessels: used for deploying and manipulating floating barriers, towing damaged vessels, and assisting in the removal of pollutants from the sea surface.
- Oil Recovery Ships: vessels equipped with systems for the mechanical collection of oil spills directly from the surface.

Specialized Pollution Response Equipment

- Floating barriers (Booms): used to control the spread of oil and chemicals from the sea surface.
- Skimmers: mechanical devices that remove floating oil from the sea surface.
- Dispersant Systems: dispersant spraying equipment designed to break up oil slicks into smaller droplets.
- Mobile Waste Treatment Units: portable platforms used for the treatment of water contaminated with oil or chemicals.
- Specialized Double-Hull Ships: reduce the risk of oil-spill accidents.

Organization And Coordination

- Maritime Directorate (Direzione Marittima) [33].
- The central authority responsible for coordinating interventions at sea.
- National Pollution Response Plan (Piano Nazionale di Pronto Intervento Antinquinamento) [34]. It is activated in the event of major incidents in order to rapidly deploy resources from different regions.

Cooperation With Other Authorities

The Italian Coast Guard cooperates with:

- Ministry of Environment and Energy Security (MASE)
- EMSA which provides additional vessels and equipment.
- Private operators specialized for interventions.

The United States and Norway have highly developed capabilities for rapid intervention and the prevention of major environmental incidents. Italy has moderate capabilities, oriented more to near-coast operations. The Croatian Coast Guard still relies heavily on conventional resources (floating booms, civilian companies) and does not have its own specialized vessels for large-scale environmental response operations. The fact that the surface area of the Exclusive Economic Zone and the territorial sea, totalling 55 349 km², is approximately equal to the total land area of Croatia, which is 56 594 km², gives rise to the obligation to adopt all legislative and other legal instruments regulating the rights and responsibilities of stakeholders operating in that space; including ministries, agencies, and operational forces. The question is whether these strategic and legal documents were adopted with due consideration for the fact that, on their basis, implementing regulations are enacted that govern the rights and obligations of all stakeholders at the individual/local, regional/inter-regional, and international levels.

MODERNIZATION AND FURTHER DEVELOPMENT OF THE CROATIAN COAST GUARD – SUGGESTIONS FROM THE ChatGPT AI MODEL

Maritime security today no longer encompasses only counter-piracy or search-and-rescue operations; it now includes the protection of submarine communication cables and other critical infrastructure, risks of terrorism, hybrid operations (disinformation, sabotage), and sophisticated smuggling networks. NATO and international expert sources emphasize that the monitoring and protection of the maritime domain have become essential national and allied tasks. Shifts in migration routes and the increasing number of unsafe vessels require faster detection and response, as well as improved coordination between civilian and security services. Croatia's entry into Schengen (2023) further increases the responsibility for surveillance and control of external borders. This requires modern surveillance and rapid response equipment.

PRELIMINARY CONSIDERATIONS CONCERNING THE MODERNIZATION AND FURTHER DEVELOPMENT OF THE COAST GUARD

The modernization process is directed toward the renewal of the fleet, the enhancement of technical capacities, and the strengthening of interoperability with partner countries and international organizations. In this context, the Croatian Coast Guard operational structure includes the coastal patrol boat OOB-31 Omiš, introduced in 2019, and vessel OOB-32 Umag, both equipped with modern navigation, communication, and surveillance systems that enable more effective execution of search and rescue tasks and maritime surveillance. Additionally, the Croatian Ministry of Defence (MoD) has brought the Bayraktar TB2 system into operational service. Bayraktar TB2 is a medium endurance tactical Unmanned Aerial Vehicle (UAV) capable of intelligence, surveillance and strike missions, characterized by long loiter

time over a designated area and high utility for Intelligence, Surveillance and Reconnaissance missions. By employing the Bayraktar system in the execution of its tasks, the Croatian CG would gain the capability to maintain continuous surveillance of sea-ward approaches, identify suspicious vessels (smuggling and trafficking), ensure faster search and rescue operations, and support the protection of critical infrastructure. By integrating data from UAV into the system of the Croatian Coast Guard, the accuracy and speed of decision-making are enhanced.

An analysis of Open Source Intelligence shows that the prevailing trend is the construction of larger patrol vessels capable of a wide range of missions. The requirements placed before designers include modularity, reduced maintenance costs, and maritime capabilities that enable crews to conduct extended operations on the open sea (30 days). Additional specifications include a displacement of 1500 to 2 000 t, a length of 68-85 meters, a speed of 20 to 25 knots; and a range of 6 000 to 8 000 NM at 12 knots. The vessels must also be capable of embarking equipment for the collection and storage of pollution-related materials; feature a flight deck for helicopters of up to 12 t and a hangar for a helicopter of up to 6 t; and support the embarkation and operation of Unmanned Surface Vessels (USVs), Unmanned Underwater Vehicles (UUVs), and UAVs. They must provide accommodation for 30 crew members and 20 personnel from competent authorities (the Coast Guard has no jurisdiction over maritime security); include 20 m² for a laboratory, and offer storage space and the ability to receive up to two TEU containers on deck. Last but not least, the vessels must have the capacity to take on up to 100 shipwrecked persons or irregular mi-grants for up to 24 hours.

According to the MoD Implementation Program for the period 2024-2028, dated 28 November 2024 [35], the Ministry of Defence states under budget activity K 545044, Item 11, that during the period from 2024 to 2024 it will equip and progressively introduce into operational service 3 coastal patrol vessels in 2025, reaching a total of 5 vessels by 2028. (pp.11-12). Item 12 (p.11) states that a multi-role vessel/corvette will be equipped and introduced into operational service in the period 2025-2030. It remains unclear whether the vessel is intended for the Croatian Navy Flotilla or for the Croatian Coast Guard?

According to the MoD financial plan for 2025 [36], an allocation of 1193 billion euros is planned. For 2026, an allocation of 1194 billion euros. From the funds listed under Item A 545030, an amount of 3 817 999 will be allocated to the Croatian Coast Guard in 2025, and another 3 897 999 will be allocated for 2026. Numerous tasks of the Croatian CG are listed in accordance with the Law, but it is evident that the funds are allocated for vessel maintenance, propulsion systems, provisions, and related requirements. In the final effort to determine answers regarding modernization requirements and possibilities, the following questions arise:

- How many new coastal patrol vessels should the Coast Guard have in its fleet to meet assigned tasks?
- How many new offshore modular patrol vessels should the Coast Guard have in its fleet for operations in the EEZ?
- What financial resources are required for their construction and outfitting?
- Will the introduction of new material and technical assets increase the need for greater financial resources for their deployment, maintenance, and management, and will this affect the required crew size?
- Should the Coast Guard, in line with its tasks, area of responsibility, and need for rapid response, include unmanned surface and aerial vehicles in its fleet?

The following subsection provides a description of the research conducted using ChatGPT as a large language model. The research was conducted using the free version of the system, and the analysis is grounded in a conversation held on 9 July 2025. In accordance with Research Question **RQ₃**, the underlying assumption is that artificial intelligence can offer usable answers

for planning the development of the Coast Guard. As input material, ChatGPT was provided with the text from a portion of this article, spanning from Section 2 to the introductory section of Section 6.

DISCUSSION WITH THE ChatGPT AI MODEL

QUESTION 1: *Based on the presented overview and the identified uncertainties, as an analyst and strategist, can you propose directions for the modernization and further development of the Croatian Coast Guard?*

ChatGPT responded:

“Based on a comprehensive analysis of the document on the status and challenges of the Croatian Coast Guard (CCG), the following direction for modernization and development of the Croatian Coast Guard can be proposed:

1. STRATEGIC DIRECTION: Strengthening Sovereignty and Resilience through Fleet Modernization

a) Procurement of multipurpose modular patrol vessels

- A total of 5–7 new vessels are required, at least 2 of which should be offshore-capable (OPV class) and able to operate long-term within the Exclusive Economic Zone (EEZ).
- The vessels should feature:
 - Range greater than 6,000 NM,
 - Operational autonomy of up to 30 days,
 - Helicopter platform and hangar,
 - System for deploying and managing USV/UAV/UUV,
 - Modular container system for environmental equipment and accommodation of migrants or shipwreck survivors.

b) Specialization for environmental interventions

- Acquisition or conversion of a vessel (such as Faust Vrančić) into a specialized eco-vessel equipped with:
 - Infrared cameras and radars for oil detection,
 - Floating tanks,
 - Skimmers and oil booms for open-sea operations,
 - Capacity for temporary storage of collected oil.

2. TECHNICAL AND DIGITAL MODERNIZATION

a) Introduction of drones and unmanned systems

- UAVs for surveillance, USV/UUVs for monitoring and environmental mission support,
- Better coverage of the EEZ without increasing the cost of constant human presence.

b) Digitalization and networking

- Implementation of an Integrated Maritime Information System (IMIS),
- Real-time data exchange with EMSA, MRCC Rijeka, JOCs, and civilian actors.

3. STRUCTURAL AND OPERATIONAL UPGRADE

a) Reorganization of the command chain and operational readiness

- Clearer division of responsibilities between the CCG and the Croatian Navy (HRM) – transformation of the CCG into an independent service, following the Norwegian model, could be considered.

- Establishment of permanent bases with equipment in Pula, Split, and Dubrovnik (partially already underway).

b) Training and interoperability

- Systematic interagency and international exercises, such as Jadran 20 and COASTEX 22.
- Training in the use of modern EMSA equipment, drones, and satellite systems.

4. FINANCIAL PLANNING AND LEGISLATION

a) Clear allocation of funds within the defense budget

- Current allocations for the CCG (~€3.8 million annually) are insufficient. A multiple increase is needed to maintain new vessels, equipment, and personnel.

b) Updating the legislative framework

- The Coast Guard Act must reflect actual tasks and equipment needs (e.g., defining the status of drones and assigned aircraft).
- A national maritime security and resilience strategy must be developed.

5. REGIONAL AND INTERNATIONAL COOPERATION

- More active involvement in the Subregional Contingency Plan for marine pollution (Croatia–Italy–Slovenia),
Development of joint capabilities with the coast guards of Italy, Montenegro, and Albania through exercises and equipment sharing.

CONCLUSION (Question 1): The Croatian Coast Guard must evolve from a defense auxiliary of the Navy into an independent, technically equipped, and modularly organized maritime service, with a primary focus on environmental security, continuous presence in the EEZ, interoperability, and digitally networked capabilities for surveillance, protection, and intervention.”

The AI tool independently structured the development challenges into five categories – strategic direction, technical and digital modernization, structural and operational enhancement, financial planning and legislation, and regional and international cooperation. In addition, the tool offered the possibility of developing an action plan for the next five-year period. Therefore, a second question was also posed.

QUESTION 2: *Can you create an action plan according to two scenarios — first with lower overall costs, and then with higher modernization costs?*

ChatGPT responded:

“ACTION PLAN FOR THE MODERNIZATION OF THE CROATIAN COAST GUARD (2025–2030)

SCENARIO A: Limited Budget (Realistic, Low-Intensity Development)

Focus: Efficiency through modification of existing assets, increased training, and digitalization.

2025–2026

Modernization of the vessel OB SB-73 “Faust Vrančić”:

Installation of IR cameras and radars for oil-spill detection,

Modular container-based equipment (skimmer, oil booms).

Deployment of existing EMSA equipment sets in Pula, Split, and Dubrovnik.

Introduction of unmanned aerial vehicles (UAVs) for EEZ surveillance (one team per base).

2027–2028

Crew and technical personnel training (national and international exercises).

Digital networking with MRCC Rijeka, Joint Operations Centers (JOCs), and EMSA.

Conservative acquisition of one new coastal patrol vessel, up to 65 m in length (partially modular design).

2029–2030

Increased use of unmanned systems (night surveillance, EEZ monitoring).

Development of a national concept for maritime and EEZ protection (legislative component).
Sustainability analysis and preparation for transition to Scenario B (if feasible).

Estimated total cost (6 years):

€40–50 million

(1 new vessel, modernization, equipment, UAVs, training)

SCENARIO B: Expanded Budget (Ambitious, High-Capability Development)

Focus: Establishing an independent, modern, and modular Croatian Coast Guard with full operational capability in the EEZ.

2025–2026

Launch of a project to build two offshore modular patrol vessels (OPVs):

Displacement 1,500–2,000 tons, range 6,000–8,000 NM,

Helicopter platform and hangar, UAV/USV capability,

Capacity for 100 migrants or shipwreck survivors.

Acquisition of two additional smaller patrol vessels for coastal operations (up to 500 tons).

Formation of an independent Croatian Coast Guard Directorate within the Ministry of Defence (or a hybrid MoD–MoI structure).

2027–2028

Operational commissioning of 2 OPVs and 2 smaller patrol vessels.

Procurement and activation of systems:

UAVs (4 units),

USVs (2 units),

1 ROV for underwater surveillance.

Establishment of a permanent technical base in Ploče for EEZ interventions.

2029–2030

Development and testing of a domestic AI-based early-warning system for oil spills (AI + drones).

Gradual replacement of the aging fleet (including reconstruction of Faust Vrančić).

Establishment of a NATO/EU-compatible command system, positioning Croatia as a regional leader in marine pollution response.

Estimated total cost (6 years):

€220–280 million

(Includes: 2 OPVs, 2 smaller patrol vessels, unmanned systems, infrastructure, equipment, digitalization, and training.)

ADDITIONAL RECOMMENDATIONS (for both scenarios):

Legislative updates – clearly define Coast Guard authority independently from the Navy (HRM).

Increase the budget for operational expenses and personnel capacity.

Ensure constant participation in international exercises with Italy, Slovenia, and NATO member states.

Cooperate with the private sector for faster procurement and maintenance (dual-use models).

Following the development of the action plan, the AI model was asked to elaborate and provide cost estimates for the more modest scenario of future development and modernization of the Croatian Coast Guard.”

QUESTION 3: *Can you, for the two previously defined scenarios, specify the expected annual costs for each item in Scenario A?*

ChatGPT responded:

“COST BREAKDOWN – SCENARIO A: LIMITED BUDGET (2025–2030)

Below is the action plan for the modernization of the Croatian Coast Guard (2025–2030), with annual costs per key item for Scenario A (limited budget). All costs are approximate and expressed in millions of euros. The estimates are conservative and based on available open sources, comparable international experiences, and the Ministry of Defence’s procurement data.

Year	Item	Estimated Cost (€ million)
2025	Modernization of vessel OB SB-73 “Faust Vrančić” (sensors, modular containers)	4.0
	Procurement of 2 unmanned aerial vehicles (UAVs) + training	1.5
	Deployment of EMSA equipment and initial simulation exercises	0.5
	TOTAL 2025	6.0
2026	Acquisition of 1 additional equipment set (booms, floating tanks)	2.0
	Digital integration with JOCs and MRCC Rijeka	0.7
	Annual maintenance of UAV systems and equipment	0.4
	TOTAL 2026	3.1
2027	Procurement of 1 small modular patrol vessel (up to 65 m)	12.0
	Crew training and international exercise	0.8
	TOTAL 2027	12.8
2028	Modernization of communication systems on 2 vessels	1.0
	Servicing of existing equipment (EMSA + UAV)	0.5
	TOTAL 2028	1.5
2029	Installation of additional equipment on OB SB-73 (e.g. storage tank)	1.5
	Upgrade of software tools (AI analysis, drone data integration)	0.5
	TOTAL 2029	2.0
2030	Development plan for 2030+ and system maintenance (no capital investments)	1.0
	TOTAL 2030	1.0
TOTAL COST OF SCENARIO A (2025–2030):		≈ €26.4 million”

REFLECTIONS ON ChatGPT RESPONSES

An expert review of ChatGPT’s answers offers a clear look at how well the AI handles topics related to the development and functioning of the Croatian Coast Guard.

When it comes to modernization, ChatGPT performed surprisingly well. Its overview lines up with current discussions on maritime security and the long-term direction of the Coast Guard. While some technical specifics were missing – such as vessel dimensions, crew size, or speed capabilities – the model correctly identified the major trends shaping future operations. It emphasized the growing need for digital upgrades, along with the introduction of drones and other unmanned systems that are rapidly changing maritime surveillance worldwide.

Considering the analytical context evaluated by ChatGPT and the recommendations formulated within the presented scenarios, it is important to emphasize that the practical CG exercises conducted during the period 2017-2025 at both national and international levels, together with participation in international workshops organized by the EMSA, significantly contributed to the identification and systematic application of “lessons learned” by members of the Croatian Coast Guard. These lessons primarily include the need to increase the frequency and scope of exercises; to harmonize equipment procurement with regional partners in order to prevent duplication of capacities and capabilities; to acquire two to three larger offshore patrol vessels for the purposes of integrated border management; to procure one to two larger auxiliary vessels capable of conversion for oily water treatment operations; and to ensure sufficient human resources as well as inter-ministerial budgetary allocations to support the implementation of these measures. Furthermore, it should be noted that the planned outfitting and

reconstruction of patrol vessel OB SB 73 Faust Vrančić represents only the minimum threshold of operational capability required for effective mission execution. *Consequently, the recommendations generated by the AI model can be assessed as both relevant and methodologically well-founded.*

The response provided by ChatGPT, in the form of assessment of unmanned systems, including the integration of UAVs, can be considered satisfactory. However, it is not feasible to accurately define the required types and operational capabilities of USVs, UUVs and UAVs, without a clearly articulated strategic vision regarding the future fleet structure for Integrated Border Management, including both the projected number of platforms and their tactical and technical characteristics. Such a vision represents a fundamental prerequisite for adopting a modular capability development approach, enabling the design of multiple mission-configurable variants for larger vessels, as well as for structuring procurement planning and increasing Coast Guard personnel strength – particularly highly specialized operators and maintainers capable of effectively employing advanced unmanned systems.

Furthermore, on corvette-class platforms, the proportion of “general duty” (unskilled) sailors is marginal compared to the overall crew complement, which is predominantly composed of specialists, non-commissioned officers, and officers. A longitudinal analysis of operational challenges demonstrates that, in the absence of a substantial increase in financial contributions from all relevant ministries that rely on Coast Guard data to support Maritime Domain Awareness, the generation of a Common Operational Picture, and interagency decision-making processes, the currently approved funding levels remain limited to sustaining basic maintenance and partial capability upgrades.

Consequently, currently available resources are insufficient to achieve the required level of operational readiness and capability maturity at national and regional levels, in accordance with NATO standards and EMSA best practices.

Within the conceptual framework of organizational structure, the AI model identified a perennial discourse that periodically re-emerges within academic and professional circles: should the Coast Guard remain under the Croatian Navy, or would it function more effectively as an independent service, possibly within the Ministry of Defence or the Ministry of Maritime Affairs? The fact that the AI detected this long-standing question reflects a solid understanding of the broader institutional landscape.

The financial picture, however, paints a more difficult reality. Both experts and the AI model reached the same conclusion – the Coast Guard operates with limited resources. The Ministry of Defence’s financial plan makes this evident: the projected defence budget for 2025 is €1193 billion, and €1194 billion for 2026. Within this framework, the Coast Guard receives only a small fraction – €3 817 999 for 2025 and €3 897 999 for 2026 – primarily covering essentials such as vessel maintenance, fuel, and basic operational costs.

The Long-Term Development Plan of the Croatian Armed Forces 2025-2036 [37] also openly acknowledges a persistent gap between strategic ambitions and the funds needed to achieve them. Despite that, the Plan still envisions capability improvements once the remaining domestic coastal patrol vessels are fully procured and integrated into service, enabling the Coast Guard to strengthen maritime monitoring and the protection of Croatia’s sovereign interests at sea.

In the end, although the available cost estimates are detailed, they remain indicative rather than definitive. Under current legislation, the Government and relevant ministries still have room to explore procurement options – whether through cooperation with NATO partners, the use of EU funding mechanisms, or relying on domestic shipbuilding capacities.

CONCLUSION

The Adriatic Sea plays an exceptionally important role due to the many ways in which its maritime space is used, including cargo and passenger transport, oil and gas exploration, energy production, communication routes, fisheries, tourism, and the protection of natural areas. Its multifunctional character makes it a strategic resource not only for the Republic of Croatia but for the wider Adriatic-Mediterranean region. As maritime traffic continues to grow, economic benefits increase, but so does the risk of marine pollution, especially oil spills that can have severe environmental and economic consequences.

Regarding **RQ₁**, it is evident that pollution prevention mechanisms in the Adriatic rely heavily on subregional cooperation between Croatia, Italy, and Slovenia, established through the Barcelona Convention and its Protocol on Preparedness and Response to Emergencies. The Joint Subregional Contingency Plan ensures coordinated action among national authorities in the event of a major pollution incident. Key resources include national response systems, MRCC Rijeka, the Croatian Coast Guard, County Operational Centres, a network of private companies, and technical support from EMSA, which provides equipment, satellite monitoring, and standby vessels for oil spill response.

Responding to **RQ₂**, the analysis shows that the Croatian Coast Guard holds a central role in preventing and responding to sudden marine pollution events. However, additional investment is needed, particularly in specialized vessels, early-detection sensor systems, and equipment suited for operations in the Exclusive Economic Zone. Exercises conducted to date, combined with international cooperation, confirm a high level of training and coordination, but also highlight the need to strengthen offshore capabilities and improve digital connectivity with national and EU systems.

The answer to **RQ₃** was developed through the use of an artificial intelligence model (ChatGPT) applied to a hypothetical modernization planning scenario. Drawing on the descriptive content of this study up to Section 6, the AI extracted two potential development paths:

- Scenario A focuses on the rational upgrading of existing assets and introduction of unmanned systems, with an estimated cost of around €26 million.
- Scenario B is a more demanding option that includes the acquisition of two modular offshore patrol vessels, digital modernization, and the establishment of a permanent intervention base within the EEZ, with an estimated cost between €220 million and €280 million.

The results demonstrate that artificial intelligence can serve as a highly effective support tool in strategic planning, scenario modelling and preliminary cost estimations, provided there is adequate expert oversight and validation. Notably, the outputs generated by an open-access AI model, when supplied with appropriate documentation, were produced in a fraction of the time normally required by a team of specialists. These findings align with insights from [38], which emphasize how AI accelerates data collection and analysis across large information sets, significantly enhancing strategic processes. As noted in [38], AI integration has the potential to fundamentally reshape strategic decision-making and the way strategies are generated and evaluated, leading to improved quality, efficiency and accessibility. Observations from [38, 39] also illustrate the progress made in the field compared with earlier studies, such as those examining AI in marketing strategy in 2020 [40], before large language models were developed and widely accessible through online tools.

In conclusion, the further development of the Croatian Coast Guard should prioritize building stronger offshore capabilities, expanding digital maritime surveillance, enhancing interoperability with European partners, and exploring the thoughtful use of AI technologies as tools for more effective maritime security management and environmental protection.

Our future research will focus specifically on examining the practical application of AI models in strategic planning for the Croatian Coast Guard. In this study, the AI-based analysis relies on a single publicly available large language model, which represents a certain methodological limitation. Therefore, future research may focus on strengthening the robustness and validity of the results through a comparative assessment of multiple available AI systems, enabling cross-model triangulation of findings. Given the dynamic development of generative artificial intelligence, it can be expected that new model versions, becoming available on a timescale measured in months, will be increasingly advanced. In parallel, the research design will be expanded to include structured expert validation. This process will incorporate Delphi-method panels, semi-structured interviews, and potential workshops with subject matter experts from naval, coast guard, EMSA, and NATO maritime communities.

REMARKS

¹Protocol to the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution, concerning cooperation in preventing pollution from ships and, in cases of emergency, combating pollution of the Mediterranean Sea.

²EMSA provides technical expertise and operational assistance to strengthen maritime safety, pollution preparedness and response, and environmental protection measures.

³The EAS consists of stockpiles of stand-alone oil spill response resources positioned in selected locations across Europe.

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