Unmanned Underwater Vehicles in Crime Detection and Prevention

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The relevance of the research is determined by the need to develop effective methods and strategies for the use of modern technologies to ensure the security of marine and underwater facilities in the face of the growing threat of underwater activity, terrorism, and violations of laws at sea. The research aims to analyse and document specific tactical and organisational approaches to the use of unmanned underwater vehicles aimed at increasing the effectiveness of actions related to the detection, investigation, and prevention of underwater crime. Classification, analytical, functional, statistical, and synthesis methods are among the methods used. The research results highlight the global experience of using drones in forensic practice and may serve as a basis for further improvement of legislation in this area. The application of uninhabited underwater vehicles by law enforcement and state bodies in the investigation of criminal offences is considered in the article, and the norms of criminal procedural legislation of the Republic of Kazakhstan regulating the use of technical means in criminal proceedings are analysed. The study reveals the lack of comprehensive research on the use of unmanned underwater vehicles as scientific and technical means for the investigation of certain types of criminal cases, such as drug-trafficking and poaching, and offers recommendations on their use to identify and search for evidence in the aquatic environment. This research has a practical value by providing new methodologies and strategies for organisations and law-enforcement agencies in the field of underwater security, contributing to more effective detection, investigation, and prevention of crime in the maritime and underwater domains.

KEY WORDS

~ Drones
~ Forensics
~ Underwater security
~ Law enforcement
~ Aquatic crime
~ Marine technology

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1. INTRODUCTION

Unmanned underwater vehicles (UUVs) are a powerful tool for the effective detection, investigation, and prevention of crime, particularly in the areas of underwater activity, drug trafficking, environmental offences, and oil and gas industry. These unmanned devices have significantly streamlined the operations of law enforcement agencies. The efficacy of their use highlights the application of advanced technology in the field of engineering to government and law enforcement bodies. Understanding the organisational and tactical aspects of their use, as well as adapting the global experience to local realities is essential to improving methods and strategies for combating underwater crime and ensuring the safety of marine and aquatic resources. It is necessary to formulate legislative measures to govern the utilisation of drones in the contemporary Kazakhstan. This research can contribute to the development of more effective law-enforcement approaches and promote the development of innovative solutions for maintaining maritime security and combating crime in the aquatic environment.

The problematic issue of this study is the lack of comprehensive scientific research and adequate legal regulation regarding the use of the UUVs in the context of underwater crime. Despite the potential benefits of such technology in combating threats in the marine environment, the lack of clear regulations and methodological guidance may pose legal and practical difficulties for law enforcement, maritime researchers, and security professionals. Consideration of the organisational, legal, and technical aspects of this issue will enable the development of more effective strategies and regulations for the successful deployment of unmanned underwater vehicles in law-enforcement and scientific organisations.

The need for efficient techniques and strategies to guarantee the security of marine and underwater installations stems from the growing threat of underwater criminal activity, terrorism, and maritime law infractions. Although the UUVs may be useful in countering these kinds of threats, there is a dearth of sufficient legislative regulation and thorough scientific research on unmanned underwater vehicles in law enforcement. By taking into account the organisational, legal, and technical issues of using unmanned underwater vehicles for crime detection and investigation, this study seeks to close this research gap. It offers a thorough examination of the experience used worldwide in using drone technology for forensic investigations and investigates how this information may be modified to fit Kazakhstan's unique circumstances and regulatory requirements.

Karsybayev *et al.* (2022) emphasised the role of the UUVs in improving the operational activities of law enforcement agencies and strengthening the fight against smuggling and drug trafficking in maritime zones. However, aspects related to environmental safety and the impact of unmanned underwater vehicles on the marine ecosystem, which is also an important aspect of the study, were not considered. Muratova and Seitova (2022) considered innovative technologies and their application in the field of forensics, especially in the context of evidence collection in underwater conditions. However, environmental sustainability aspects were not considered during the development of this project. Following Ospanova (2021), the task of criminal procedure and forensics is to improve criminal proceedings using modern scientific and technical achievements. Different socio-cultural contexts that may influence the results of the study have not been considered.

Mergembaeva (2020) defines criminalistics technique as a section of criminalistics dealing with the detection, fixation, seizure, and analysis of traces of crimes for their detection, investigation, and prevention, including the development of technical means and methods. However, this field of study does not pay sufficient attention to the social and psychological aspects of the application of forensic technology, which is also an important factor in understanding its effectiveness and impact on society. According to Kornilov (2020), and Yefimenko and Sakovskyi (2022), the use of drones by investigative authorities in the suppression and investigation of criminal offences is increasing each year. It is necessary to continue the research in the field of the effective use of unmanned aerial vehicles by investigative authorities in the suppression and investigation of criminal offences.

The research aims to analyse and document the use of unmanned underwater vehicles for the detection, investigation, and prevention of underwater crime and provide examples of the successful use of such vehicles in other sectors of the economy. The main objectives are to determine the forensic potential of this new technology and investigate the various tactical and organisational strategies for using unmanned underwater vehicles in law enforcement operations.

2. MATERIALS AND METHODS

The analytical method was employed to better understand the potential of digital technologies and scientific and technological innovations, to align them with law enforcement and public safety requirements, and to develop effective implementation strategies and plans, thus contributing to a more successful management of these technological changes in our time. The statistical method was used to assess the effectiveness of digital technology adoption in law enforcement to identify trends, predict potential risks, and identify the most successful strategies for applying these innovations. This approach is based on objective data and contributes to more informed decisions in the field of modern law-enforcement practices.

By applying the functional method, the specific areas and tasks in which digital technologies can be most effectively applied in law enforcement were identified. This method helped to identify the functional capabilities of these technologies and to prioritise and target their implementation, thereby facilitating better use of resources and maximising the benefits of modern scientific and technological developments in law enforcement. The structural-functional method helped in exploring the interrelationships between the various components and subsystems of digital technologies introduced into law enforcement. This method identified important structural elements, their impact on the entire system, and how to effectively coordinate their work to achieve overall law-enforcement and public-safety goals.

The deduction method was used to formulate valid inferences and conclusions based on logical assumptions and patterns related to the introduction of digital technologies in law enforcement. It allowed us to logically establish cause-and-effect relationships between the use of technology and the achievement of certain goals, which contributes to more informed strategic decisions and planning for long-term perspectives in the fields of law enforcement and public safety. Using a synthesis approach, the various aspects and components of digital technologies were combined to create a comprehensive and integrated approach to their implementation in law enforcement. This method contributed to the creation of a set of tools and techniques that provide for more effective data management, crime detection, and enhanced public safety, which is an important factor in today's environment.

To comprehend the current legal framework controlling the use of scientific and technical means in criminal investigations, a detailed analysis of relevant legal documents was carried out. This served as the foundation for the analysis of the laws that are now in place regarding the use of the UUVs as investigation instruments. The study looked at case studies and published research on the use of UUVs and drones for forensics around the world. In order to find best practices, difficulties, and lessons discovered in various national settings, this required evaluating reports, academic papers, and news items. The methodology of this study used methods typical of legal research, including the analysis and interpretation of the following legal documents:

1. Criminal Procedure Code of the Republic of Kazakhstan No. 231-V (2014) (article 7): The use of scientific and technical means to gather evidence is defined.
2. Criminal Procedure Code of the Republic of Kazakhstan No. 231-V (2014) (Article 123, Section 11): methods of approving evidence such as audio recording, videotaping, photographing, making prints, and other means of capturing information are permitted.

3. RESULTS

The use of the UUVs increases the safety of search operations and their efficiency, which is also accompanied by a reduction in the cost of localisation and investigation of objects. The issues of the application of scientific and technical means in the framework of preliminary investigations of criminal cases in law enforcement agencies are an integral part of the duties of operational criminalists. Nowadays, given the rapid development of technology, technical progress in various spheres of society, including social and economic, as well as in the field of crime, is observed. In addition to this, new technical means are finding their application in the world of crime. The objectives of forensic technology are determined by the needs of law enforcement agencies to solve crimes and the ability to meet these needs with the latest advances in science and technology (Zhang and Gong, 2024). The methods of chemistry, physics, and other natural and technical sciences are applied to the detection and analysis of traces and other materials, and specialised forensic techniques are developed for these purposes.

In many cases, the means and methods of technical criminalistics, which are capable of detecting, recording, and seizing convincing traces, instruments of crime, and objects related to the committed criminal offence, are actively used to solve the crime at the scene. Criminal prosecution bodies regularly carry out activities to improve the technical equipment of the investigative apparatus and the effective use of advanced forensic techniques (Moussa *et al.*, 2019). In the arsenal of investigative bodies, there are many tools, including photo and video cameras and specialised equipment designed to detect traces of criminal offences at the scene and to search for and retrieve evidence that is recorded as evidence. The use of the UUVs as a scientific and technical tool will be able to provide easy and effective access to such evidence.

Article 7, paragraph 10 of the Criminal Procedure Code of the Republic of Kazakhstan No. 231-V (2014) establishes the definition of scientific and technical means, which encompasses instruments, specialised devices, and materials used within the framework of the law for the detection, registration, seizure, and analysis of evidence. Following Article 123, paragraph 11 of the same Code, the use of such methods as audio and video recording, photographing, making prints, fixing printed marks, drawing up plans, schemes, and other ways of capturing information is allowed for the approval of evidence (Zile *et al.*, 2023). The above norms indicate that the legislation of the Republic of Kazakhstan does not provide specific rules and regulations governing the use and operation of underwater drones. This means that there are no restrictions on their acquisition and use, and no relevant by-laws have been developed that would establish rules for the operation of these drones. In addition, according to the requirements of criminal legislation, scientific and technical means shall comply with the norms and principles of law, be scientifically substantiated, ensure the efficiency of the criminal proceedings, as well as be safe and suitable for use. The concept of "*scientific and technical means*" covers all types of materials and devices that allow one to perform specific tasks facing the person conducting the pre-trial investigation, as well as criminalists in the course of detection, investigation, and prevention of criminal offences.

In the light of the development of digital technologies and to improve the activities of state and law enforcement bodies in the Republic of Kazakhstan, amendments and additions are being made to existing legislation. In the President's Address "Constructive Public Dialogue – the Basis of Stability and Prosperity of Kazakhstan" (Official Information Source of the…, 2019) dated September 2, 2019, the Government of the Republic was instructed to adapt legislation to new technological phenomena such as 5G, Smart Cities, big-data processing, blockchain technology, digital assets, and new digital financial instruments. Following the Order of the Acting Minister of Industry and Infrastructural Development of the Republic of Kazakhstan No. 706 (2020), the Rules for the Use of Unmanned Aerial Systems in the Airspace of the Republic of Kazakhstan were approved. These rules were agreed upon with the Ministry of Defence, State Guard Service, and the National Security Committee of the Republic of Kazakhstan. Thus, the process of introducing and using unmanned aerial vehicles in the work of certain government agencies is developing, although at the legislative level it is progressing relatively slowly (Lee *et al.*, 2022).

The UUVs are becoming effective equipment for oceanographers, botanists, geologists, seismologists, and researchers in other fields related to the study of tectonic changes, water resources, and aquatic research (Alam and Kabir, 2023). In addition to high-quality video recording, such vehicles have the capability of transmitting live video to an appropriate address. Underwater vehicle models can be modified and improved by installing additional equipment (Sagalevich and Sagalevich, 2020). Globally, the UUVs were initially used by professionals from different economic sectors to conduct deep-sea oceanographic research, including oil extraction and the maintenance of underwater infrastructure networks such as pipelines and submarine cables. They have also been used to investigate the wreckage of objects such as the Titanic jet ski and aircraft (including aeroplanes and helicopters) that have crashed over the sea and oceans (Figure 1).

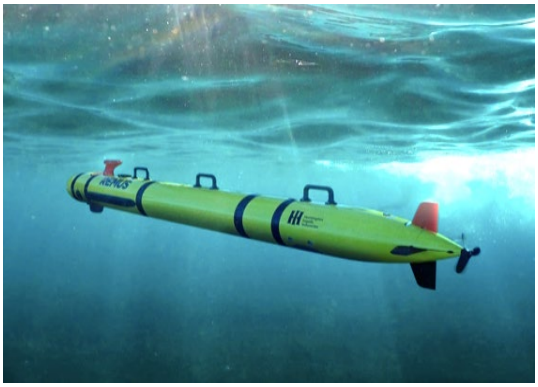

Figure 1. Small class unmanned underwater vehicle REMUS 300 (Source: Naval Technology, 2023)

The use of the UUVs can greatly enhance evidence preservation at underwater crime scenes. The UUVs may access and record the crime scene with little environmental impact, in contrast to human divers. Their sophisticated sensor suites, which include specialised sampling tools and high-resolution cameras, enable thorough documentation and the collection of tangible evidence, including sediments, water samples, and any other items with forensic significance. The thorough documentation of the crime scene contributes to the preservation of the evidence's integrity and guarantees its acceptance in court. Furthermore, the UUVs can visit locations and depths that would be unreachable or dangerous for human researchers. This makes it possible to gather all available evidence from the crime scene, as opposed to depending on incomplete records because of logistical or safety concerns (Ruba Technology, 2020).

With regard to maintaining a robust chain of custody on the positive side, the UUVs can be programmed to automatically log and timestamp all their activities, including the precise locations and times of evidence collection. This thorough record-keeping, when paired with the images and videos that the UUV's sensors have recorded, can create a thorough audit trail that proves the accuracy of the evidence collection procedure. However, steps need to be taken to guarantee that the data gathered by the UUV is secure and unalterable, and that any recovered physical evidence is handled and stored appropriately. Upholding the admissibility of the evidence in court will depend on the establishment of defined protocols for the deployment of the UUV, data management, and evidence transfer to the appropriate forensic authorities (Sibanda *et al.*, 2021).

In order to construct a thorough case in underwater criminal investigations, data gathered by the UUVs must be integrated with other investigative instruments and procedures. When it comes to forensic investigation, the UUVs' superior video, camera, and sensor data can be a priceless source of evidence for locating contaminants, traces of evidence, and reconstructing the timeline of events. Furthermore, the data gathered by the UUVs can be used to support or refute witness testimony, offering impartial documentation of the actual surroundings and incidents. Law enforcement agencies can gain a more thorough understanding of the crime scene, suspect movements, and connected criminal activities by combining information from the UUVs with the data from other investigative techniques such as aerial drones, maritime patrol vessels, and underwater

surveillance systems. This will strengthen the case overall and improve the likelihood of a successful prosecution (Dubey and Rohatgi, 2023).

The choice of the UUV type would depend on the specific operational requirements, the nature of the crime being investigated, and the environmental conditions. The REMUS 100 UUV by Hydroid Inc. is useful for maritime zone surveillance and ongoing monitoring (Figure 2). This vehicle is lightweight and built for long-duration operations. Its stealthy propulsion system allows it to quietly observe and identify any illegal activity in its surroundings. The REMUS 100 is a useful tool for protecting vital maritime infrastructure and discouraging criminal activity in the aquatic environment because of its capacity to stay under the water continuously and send the operators real-time data.

Figure 2. Small class unmanned underwater vehicle REMUS 100 (Source: Woods Hole Oceanographic Institution (WHOI), 2024a)

The REMUS 600 UUV, also created by Hydroid Inc., has specific capabilities for gathering forensic evidence from seabed crime scenes. The REMUS 600 is equipped with manipulator arms and sample instruments in addition to a variety of superior sensors and imaging systems (Figure 3). This preserves the forensic material's integrity while enabling the vehicle to gather samples of water and sediment, extract tangible evidence, and carefully record the crime scene. Because of its adaptability, the REMUS 600 is an invaluable tool for investigators who perform in-depth underwater examinations.

Figure 3. Medium-class unmanned underwater vehicle REMUS 600 (Source: Woods Hole Oceanographic Institution (WHOI), 2024b).

The General Dynamics Mission Systems Bluefin-12 UUV (Figure 4) is a good choice for search-and-rescue operations in watery settings. With its sophisticated sonar equipment and high-resolution cameras, this small but mighty vehicle can search underwater regions in great detail, find people who have gone missing, and look into cases like drownings. The Bluefin-12 is an invaluable tool for these urgent search and rescue missions because of its agility and capacity to reach otherwise difficult-to-reach areas.

Figure 4. Medium-class unmanned underwater vehicle Bluefin-12 (Source: General Dynamics, 2024)

In modern Kazakhstan, as well as in other countries, research and development in the field of unmanned vehicles such as drones is being actively carried out. They find application in space, air, land, and water environments. These vehicles are created both for military purposes, including defence and security, and for use in civilian industries (Saputra *et al.*, 2023; Ruslan *et al.*, 2023). The literature presents a variety of definitions of unmanned vehicles, ranging from simple definitions to more detailed ones covering the key characteristics of this concept.

In the summer of 2022, an annual operational and preventive event called “Karasora-2022” was conducted in the Zhambyl region, particularly in the Shu district, together with the intelligence unit of the Regional Command “South” of the Taraz Garrison of the Ministry of Defence of the Republic of Kazakhstan. The event was aimed at detecting and suppressing various criminal offences, including trafficking in narcotic drugs. To support the operation, law enforcement used unmanned aerial vehicles, also known as drones. Thanks to these drones, police officers were able to apprehend illegal cannabis harvesters (Yefimenko, 2022a; Yefimenko, 2022b). The use of such drones in criminal prevention has demonstrated its effectiveness and led to successful results. The press service of the Taraz garrison also reported the successful and efficient use of military drones with video-recording capability to search for and identify illegal cannabis pickers in the Shu district of the Zhambyl region (“Kazinform” International News Agency, 2022). In addition, on August 7, 2022, the body of a five-year-old girl named Madina, who had been reported missing, was found drowned in an artificial reservoir near the village of Zhambyl in the Kostanai region. To search for this child, police officers, together with a volunteer, D. Bekturganov, used an unmanned aerial vehicle, which made it possible to conduct aerial reconnaissance of the area and locate her body during an aerial inspection (Liter, 2022).

Between 2011 and 2022, drug traffickers in Spain actively used the UUVs for illicit drug trafficking. Spain, due to its location close to Morocco, where most of the world’s cannabis and cocaine are produced, has become an important area for drug trafficking into Europe (Nurgaliyev *et al.*, 2014). One of these drones is capable of carrying up to 200 kg of drugs. Police in Spain have successfully seized three underwater drones designed to smuggle drugs across the sea from Morocco. In addition, 14kg of hashish, 8kg of marijuana, and more than 157 thousand euros in cash were seized as part of the operation, along with six large drones. These drones are equipped with the GPS navigation and can be controlled by drug traffickers from anywhere in the world using tablet devices. The construction and use of underwater drones were carried out by criminal groups (Pavliuk, 2021). In December 2019, the Peruvian Navy seized a submarine designed to smuggle narcotic drugs. These drug submarines are special types of self-propelled underwater vessels custom-built by drug traffickers to conduct drug smuggling. In recent years, the number of such boats has increased rapidly, and their performance has improved significantly, to the point of being able to cross the Atlantic Ocean. They are used

by members of Colombian drug cartels to transport cocaine from Colombia to Mexico. There have also been concerns in the US that such submarines could be used in terrorist attacks. New generations of drug submarines are fully submersible and can bypass radar and other detectors (Wikibrief, 2024).

In the end, the employment of unmanned underwater vehicles might significantly augment the competencies of law enforcement authorities in the marine and underwater settings, permitting them to gain entry to hazardous or challenging-to-reach regions, gather superior-quality evidence, and carry out exhaustive crime-scene reporting. The results show that the UUVs have been effectively used in many different situations, such as drug trafficking, poaching, and other marine offences. Nonetheless, it was also mentioned that in the Kazakhstani environment, there is a dearth of thorough legislative regulations and methodological guidelines concerning the use of the UUVs in criminal investigations. Unlocking the full forensic potential of these technologies and guaranteeing their responsible and efficient use by law enforcement authorities will depend on closing this gap through the creation of suitable policies, procedures, and training initiatives.

4. DISCUSSION

The use of unmanned underwater vehicles in the practice of crime detection, investigation, and prevention represents an important step in the development of modern criminology and law enforcement. The organisational and tactical aspects of this technology have several features that deserve attention and discussion. The UUVs enable operational services to respond quickly to underwater incidents and conduct real-time surveillance. The use of unmanned underwater vehicles avoids the risk to the lives of personnel who might go to dangerous objects underwater. This is particularly relevant in cases involving the search for drowned people or the survey of underwater objects. The UUVs can be used for a variety of tasks, such as searching for and recovering evidence, surveying submerged objects, monitoring environmental parameters of water resources, and even detecting underwater criminal operations such as drug smuggling. To successfully incorporate unmanned underwater vehicles into law enforcement operations, appropriate legislation must be developed to regulate their use, address data privacy issues, and ensure safe and effective use. The full use of the UUVs requires the training of officers and specialists to work with this technology. It is also important to develop cooperation between law-enforcement agencies and academic institutions to share knowledge and experience. The information collected from the unmanned underwater vehicles may contain sensitive data, so it is important to protect it from unauthorised access and use.

According to the results of recent studies by Tymoshenko *et al.* (2022), the introduction of the latest technologies in criminal investigation is an important stage of modern criminalistics, which is actively tested in Ukraine, following world experience. One of the key directions of this process is the use of modern means of technical diagnostics and forensic examination. Such technologies as forensic laboratories with high-precision analysers, 3D-scanning of accident scenes, and automated systems of face and evidence recognition significantly improve the quality of evidence collection and analysis. Notwithstanding the results obtained, the appraisal of global experience includes research in the field of digital forensics (Dudchenko *et al.*, 2023). Given the growth of cybercrime and the use of the Internet in crime, the Ukrainian law-enforcement agencies are actively developing methods to detect and suppress such offences (Semenenko *et al.*, 2023). This includes network monitoring, digital-footprint analysis, and cooperation with international organisations in the field of cyber security. To counter the Russian aggression in the maritime domain, Ukraine has been actively deploying underwater drones as part of its defence efforts. These UUVs have proven valuable for a variety of tasks, including gathering intelligence, detecting underwater mines or other submerged threats, and monitoring enemy movements. By combining the data collected by the underwater drones with other surveillance tools and investigative techniques, the Ukrainian military and security forces have been able to strengthen their tactical response and build a more comprehensive understanding of the Russian activities.

In their work, Zhantureyev *et al*. (2024) provided a thorough analysis of the application of underwater drones in forensic examinations involving drowned victims. The researchers investigated the useful uses of the UUVs for identifying, logging, and examining submerged bodies, offering insights into the advantages and disadvantages of these tools in these kinds of situations. Underwater drones' capabilities and technical details were explored, with an emphasis on how they can improve evidence gathering and documentation at underwater crime scenes. The researchers also looked at case studies or practical data that supported the use of the UUVs in forensic investigations, which helped to clarify how they could expedite and enhance the precision of forensic processes pertaining to drowned victims.

Paba *et al*. (2023) highlight that among other things, water visibility, which can vary from clear to drastically reduced, often poses particular difficulties for underwater crime scenes. Forensic evidence needs to be preserved and documented in these kinds of situations, and the UUVs with sophisticated imaging and sensing capabilities can be of great assistance. Without the dangers and restrictions of human divers, they may obtain excellent video, photos, and other data from the crime scene – even in poor visibility situations. The study emphasises the significance of improving the visual records acquired via the UUVs to guarantee their superior quality and their potential for efficient use in the investigative procedure. This can entail using methods like changing the settings on the cameras, adding more lighting, and using image processing algorithms to improve the sharpness and detail of the gathered photos. This is consistent with the results of the current study, which highlighted the necessity of combining data gathered by the UUVs with other investigation instruments and forensic analysis methods in order to construct a thorough case. Furthermore, both studies highlight how important UUVs are to overcoming the particular difficulties presented by underwater crime scenes and to facilitating more efficient crime detection, investigation, and conviction.

Referring to the definition provided by Coito (2021), maritime autonomous surface ships represent an important development for shipping and the maritime industry, opening up new opportunities and raising several challenges in maritime law and policy at the same time. Autonomous ships can significantly increase the efficiency of maritime transport by reducing the risks of human intervention and ensuring continuity of operations. They can be used for automated cargo transport, offshore patrols, search and rescue, and marine science research. This could lead to lower labour costs and reduce the risk of human error. The advent of autonomous ships raises several maritime law and policy issues. One of the main issues is the question of liability in the event of accidents and incidents at sea when there is no human crew on board the ship and the establishment of culpability alongside damages to be compensated in such cases. Another important aspect is the security and cyber defence of such ships as they may be susceptible to cyber and hacking attacks. These findings are consistent with the theses in the previous section. Thus, maritime autonomous surface ships represent a promising direction for the maritime industry but require serious attention from maritime law and policy to address emerging issues and ensure the safety and sustainability of maritime activities.

Liu *et al.* (2022) determined that the study of human-machine interaction in the context of maritime autonomous surface ships plays a key role in the development of this technology. Efficient navigation and control of a ship without human intervention requires the development of sophisticated artificial intelligence and automation systems that can adapt to different maritime conditions and scenarios (Mazakova *et al.*, 2022). One of the important research objectives is to develop robust algorithms and sensor systems that could provide surface ships with the ability to detect other ships, obstacles, changes in weather conditions, and other factors affecting the safety and efficiency of navigation. This also includes the development of technologies to enable communication and remote control of the ship. Analysing the results obtained as well as the conclusions, an important aspect is also the education and training of the personnel to work with autonomous ships, including maintenance, monitoring, and management in case of emergencies.

Issa *et al.* (2022) identified that maritime autonomous surface ships are a new generation of ships that pose several complex problems and challenges to the regulatory process. One of the main problems is the lack

of maritime legislation considering the characteristics of autonomous ships. Traditional maritime laws and regulations are designed for ships with the crew on board, and the issues of liability, safety, and international standards for autonomous ships require more detailed consideration. Overall, the regulation of maritime autonomous surface ships is a complex task that will require cooperation between maritime authorities, industry, and international organisations. Modern and adaptive regulations need to be developed to facilitate the safe and efficient development of this promising area of marine technology.

Males *et al.* (2022) demonstrated that the application of multi-agent systems on unmanned surface ships represents an important and innovative area of research and development in the maritime autonomous technology. Multi-agent systems are a network of autonomous agents that can interact with each other, make decisions, and perform tasks independently. Such systems can improve coordination, navigation, and mission execution, making them more efficient and adaptive to variable conditions at sea (Averin and Borovytskyi, 2023). One example of the application of multi-agent systems is the management of a fleet of autonomous ships in the task of exploring the marine environment or securing sea lanes. The agents can exchange data on weather conditions, ship movements, and other factors to optimise routes and predict potential conflicts. Both this paper and the authors' research on the application of multi-agent systems open new horizons for autonomous maritime technologies but require comprehensive research and engineering solutions for effective integration and use in real-world maritime environments.

As noted by Smirnov (2022), the development of a prototype autonomous robot for underwater crime scene investigation and emergency response represents a significant step in modern forensic and criminal investigation techniques. These autonomous robots provide law-enforcement agencies with a powerful tool to collect evidence and respond to various incidents, especially in the marine and aquatic environments, quickly and safely. The main functions of these robots are to explore the underwater space with sensors and cameras, collect water and material samples, and be able to respond quickly to emergencies such as vessel accidents, wrecks, or search operations (Mazakov *et al.*, 2020; Khodyko, 2023). They can carry out missions at great depths and in conditions that are dangerous for humans. This study confirms the results of this paper. However, the development and operation of such robots also involve challenges such as reliability and safety, as well as control, programming, and data processing. In addition, the legal and ethical aspects of using autonomous robots in criminal proceedings need to be considered.

5. CONCLUSIONS

Unmanned underwater vehicles have the potential to greatly improve law enforcement organisations' capacity to detect, investigate, and prevent crime. They are an invaluable tool for forensic investigations and maritime security because of their capacity to enter hazardous or difficult-to-reach locations, collect tangible evidence, and obtain high-quality video and sensor data. Underwater crime scenes can benefit from the deployment of the UUVs to reinforce the chain of custody, expedite procedures, and better preserve evidence. The admissibility of evidence in court hearings can be ensured with the use of the UUVs, which offer comprehensive documentation and an auditable record of actions.

However, the findings point out that Kazakhstan lacks thorough legal and regulatory frameworks that would control the use of the UUVs for law enforcement. To fully realise the forensic potential of these technologies and guarantee their appropriate and efficient implementation, it is imperative to establish well-defined policies, protocols, and training initiatives. The study gives examples of how the UUVs have been successfully used in other nations to combat maritime crimes like drug-trafficking and poaching. By tailoring these best practices to Kazakhstan's unique operational and legal environment, more effective underwater security and crime prevention initiatives may result. In order to enable the Kazakhstani law-enforcement authorities to take advantage of these new technologies, it will be imperative to address the organisational, legal, and technical issues associated with UUV implementation. Important actions in this direction include creating

relevant laws, educating staff, and encouraging cooperation with scientific and technical specialists. By taking proactive steps in this regard, crime in the nation's maritime and aquatic domains can be detected, investigated, and prevented more successfully.

The absence of thorough empirical data on the actual application of the UUVs for law enforcement in Kazakhstan is one of the study's limitations. Although the research offers instances of effective UUV deployments in other nations, it does not thoroughly examine the unique difficulties, recommended procedures, and lessons discovered from applying these technologies in the Kazakhstani setting. Furthermore, the study skimps on discussing the social, ethical, and privacy ramifications of using the UUVs in criminal investigations – a topic that end users and governments should take seriously. In order to fill in these gaps and create a stronger body of data, future research could carry out comparative analyses, stakeholder discussions, and field trials.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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