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Maritime Autonomous Surface Ships (MASS) in Gulf of Suez: Safety of Navigation Precautionary Measures

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Abstract

Purpose: *It is widely acknowledged that automation has detrimental effects on both safety of navigation and environmental protection. Improvements to Maritime Autonomous Surface Ships (MASS) may help remove human error and significantly boost overall safety, but they are also likely to cause new threats, especially given the marine industry's increasing interest in MASS. This is certainly relevant in light of the fact that MASS are gaining popularity.*

Design/Methodology/Approach: *Due to the fact that the Gulf of Suez (GOS) is of paramount importance to the global trade and economy, this paper focuses on the threats posed by MASS activities when sailing through the GOS. Therefore, research was conducted on well-selected threats within the area with the objective of finding and prioritizing their potential impacts. In this study, a hybrid approach of research was used, consisting of both observations and a survey using a structured questionnaire.*

Findings: *The results were summarized as follows: The greatest threat to the effective potential completion of MASS operations is "Malfunction of the System" such as inability to locate the ship because of AIS or GPS signal spoofing followed by "Object detection and communication with human-operated ships," "the threat of cyber-attacks," "the human element," and "equipment failure." Based on the reseachers' findings, this study sheds light on the impact of MASS by the most significant threats to the safety of navigation and the protection of marine environment in the GOS and suggests procedures, requirements, and policies for MASS passage in this international shipping area.*

Key-words:
MASS, Threats, Safety of navigation and Gulf of Suez.

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INTRODUCTION

Maritime Autonomous Surface Ships (MASS) is defined as "ships which, to a different degree, can function independently of human involvement" (IMO, 2018). IMO has recognized four autonomous ship categories: (a) automated systems manned to help control the ship systems, (b) a crewed remote-controlled ship, personnel manage the ship systems, (c) a remote-controlled ship with no crew, yet in command, and (d) completely self-driving ships, where Artificial Intelligence (AI) pilots the ship. The development of these automatic control systems and alternative solutions is continuing. In some cases, both positive and negative factors can influence development research (IMO, 2018).

It is hoped that MASS will enhance areas such as safety, environment protection, operational costs, and human resource management. The IMO is examining how to include MASS into existing conventions such as: International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW 78, as amended) and the International Regulations for Preventing Collisions at Sea (COLREG 1972, as amended) (IMO, 2018).

The extensive expenses of establishing new infrastructure, the high cost of repairs, and the technical challenges inherent in the design of ships and their operational systems in addition to the shortage of qualified crew members, the high cost of training, are cons of MASS. Moreover, there are other challenges that need to be solved.

(Chia et al., 2021) argue that there is insufficient evidence to validate the safety deployment of MASS because they consist of several interconnected systems, some of which are based on novel or advanced technologies. So, using MASS can cut down on mishaps caused by humans, but it will not be able to prevent them entirely. They also singled out five primary threats that cannot be avoided in the current ship configuration:

1. Failure of the propulsion mechanism.
2. Errors in identifying and categorizing objects of middle and small sizes.
3. Extremely heavy weather may hinder the ship's ability to maneuver safely.
4. Contact with other ships.
5. Ships collisions can occur if object detection fails.

It is vital to evaluate the severity and unpredictability of MASS due to the great conceptual risk posed by the threat they pose. There is insufficient data to construct conceptual risk models for the analysis of MASS threats.

This research focuses on some the threats that could be posed by MASS in case it navigates in the Gulf of Suez (GOS), the southern entrance to the Suez Canal. The safety of navigation in this region has been a major concern to international shipping stakeholders. This research will investigate these threats and their associated risks that have the potential of jeopardizing the safety of navigation as well as the global economy.

To the best knowledge of the researchers, the impact of MASS on the safety of navigation and the protection of the environment, if any, while transiting the GOS in the future, has neither been investigated nor analyzed; therefore, this research attempts to bridge this gap.

APPLICATIONS OF MASS

Japanese Long-distance Autonomous Ship Operating Demonstration

Japan has recently finished its fifth demonstration and test as part of its Fully Autonomous Ship Program (MEGURI2040). The initiative was launched in February 2022 with participation from approximately 30 companies and 60 organizations. Using containerships and ferries, autonomous ship maneuvering, docking, and departure were demonstrated. In the test, a coastal cargo ship sailed vast distances and busy waterways for four days.

Suzaku, a Japanese cargo ship, was outfitted for an endurance test (IMO number 9853357). The 1800-dwt, 279-foot ship can reach 12 knots. The cargo ship departed Tokyo Bay on February 26 for the Port of Tsu-Matsusaka in Ise Bay, located south of Tokyo on Honshu, a 424-nautical-mile round trip as shown in Figure 1. The vessel was connected by satellite and terrestrial connectivity to a fleet operation centre and

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its autonomous navigation system. During the cruise, remote maneuvering and engine anomaly prediction were evaluated in order to manage a completely autonomous ship from land.

The trial mimicked future ships with complete autonomy by modelling numerous incidents. For offshore, bay, coastal, and berthing maneuvers, a fully autonomous navigation system was deployed. The most difficult aspect of the trail was sailing Tokyo Bay, which averages 500 vessels each day.

The autonomous functioning of the vessel was governed by the trial-specific navigational system. The ship was monitored and supported by an information system and shore-based system, including remote ship handling functions (Insurance Marine News, 2022).

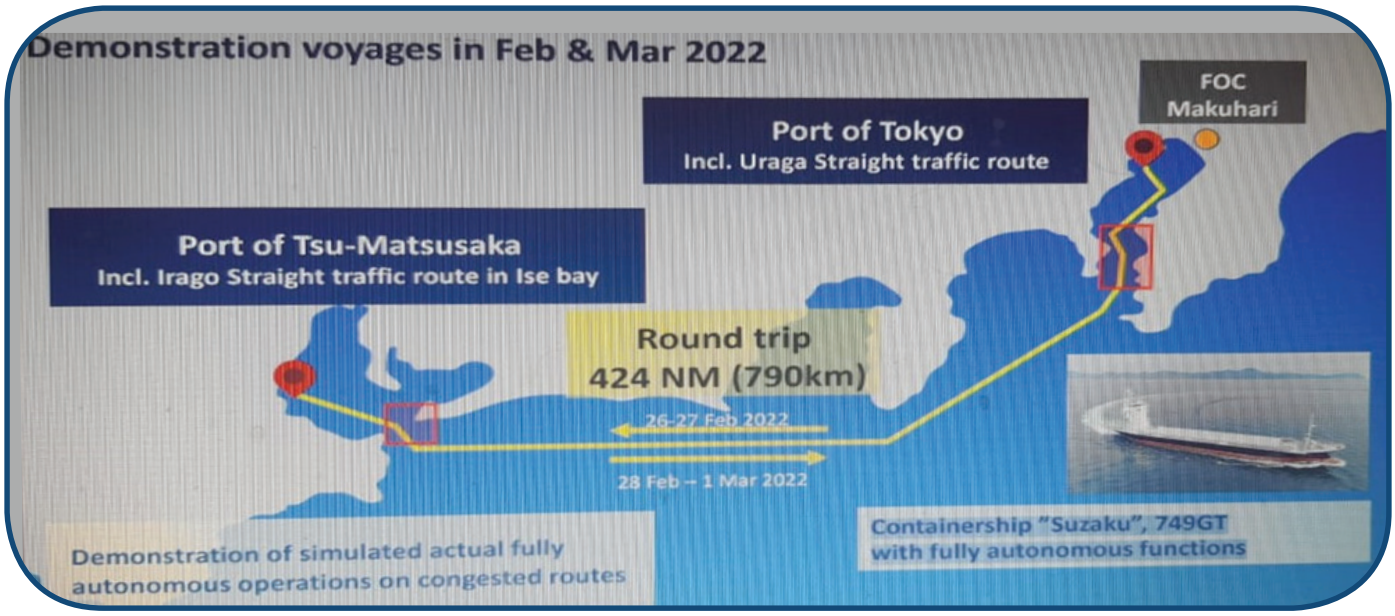

Fig. 1. Japanese long-distance autonomous ship operating demonstration
Source: IMO Seminar on Development of a Regulatory Framework for MASS, 2022

NYK Undertakes the World's First MASS Trial

NYK line has undertaken the world's first experiment in compliance with the IMO's Interim Guidelines for MASS trials, as the company continues testing to attain its objective of manned autonomous ships for safer operations and reduced crew workload.

The NYK line-managed 70,826 GT Iris Leader sailed from the port of Xinsha, China, to the port of Nagoya, Japan, from the 14th to the 17th of September, 2019, and from the port of Nagoya to the port of Yokohama, Japan, from the 19th to the 20th of September 2019 as shown in Figure 2. The crew performed their customary duties while circumnavigating Japan's coastline, avoiding entering any of its bays. During the experiment, an enhanced navigation support system's performance was evaluated in real sea conditions. This involved evaluating the risk of collision, automatically identifying the safest and most cost-effective optimal courses and speeds, and then guiding the ship autonomously. NYK was able to confirm the viability of enhanced navigation support system and its contribution to safe and efficient operations by utilizing data and knowledge gathered during this trial that were not accessible via simulators on land (NYK line news releases, 2019).

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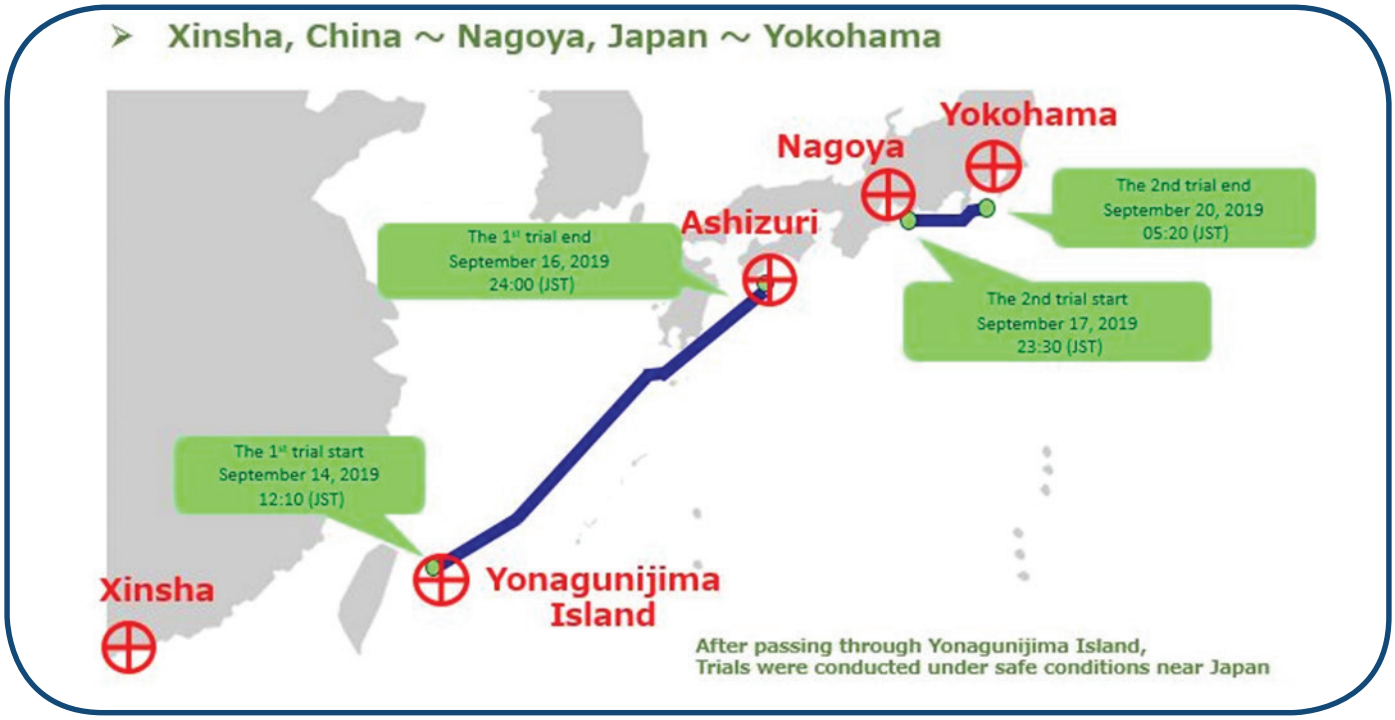

Fig. 2. NYK world's first autonomous ship trial voyage from China to Japan
Source: NYK line news releases (2019)

Advantages of Autonomous Ships

As autonomous technologies grow more prevalent, the prevalence of autonomous ships will increase. Advantages include: First, an improvement in human safety; according to the ILO, approximately 2.2 million people die every year in workplace accidents. Auxiliary ships are unmanned or have a limited crew, hence lowering the likelihood of accidents. In addition, limited system understanding, and fatigue can contribute to human error. Autonomous systems and AI have the potential to significantly minimize human error (Dinç, 2020).

Furthermore, the removal of the accommodation structure results in a 6% decrease in fuel and a 5% reduction in construction costs, i.e., resulting in less light ships weights and has more cargo stowage capacity (Dinç, 2020; Katslvela, 2021).

Finally, ships operation cost would decrease for labor costs, i.e., account for up to 36% of total costs (Bogusławski, Gil, Nasur and Wróbel1, 2021).

Disadvantages of Autonomous Ships

Disadvantages of MASS include: first, cyber-attack threat: Unauthorized access to sensitive data may have financial, commercial, and reputational implications. Avoiding these cyber-attacks also carries operation costs for cyber security plans (Katslvela, 2021). With expanding shipping connections, cyber-attacks became a major problem requiring a complete risk assessment. In January 2021, IMO Resolution MSC.428 (98) requires cyber threats to be handled in safety management systems (IMO, 2017). Second, as automated ships network component's connections grow, the system becomes more complex. Network complexity is costly and ship-borne equipment and communication fees are expensive (Katslvela, 2021). Moreover, many MASS legal and technical aspects need to be issued or amended. Finally, automated ships will most likely change employment requirements; as a result, crew unions are concerned about the safety and cost-effectiveness of autonomous ships (Katslvela, 2021; IMO, 2022).

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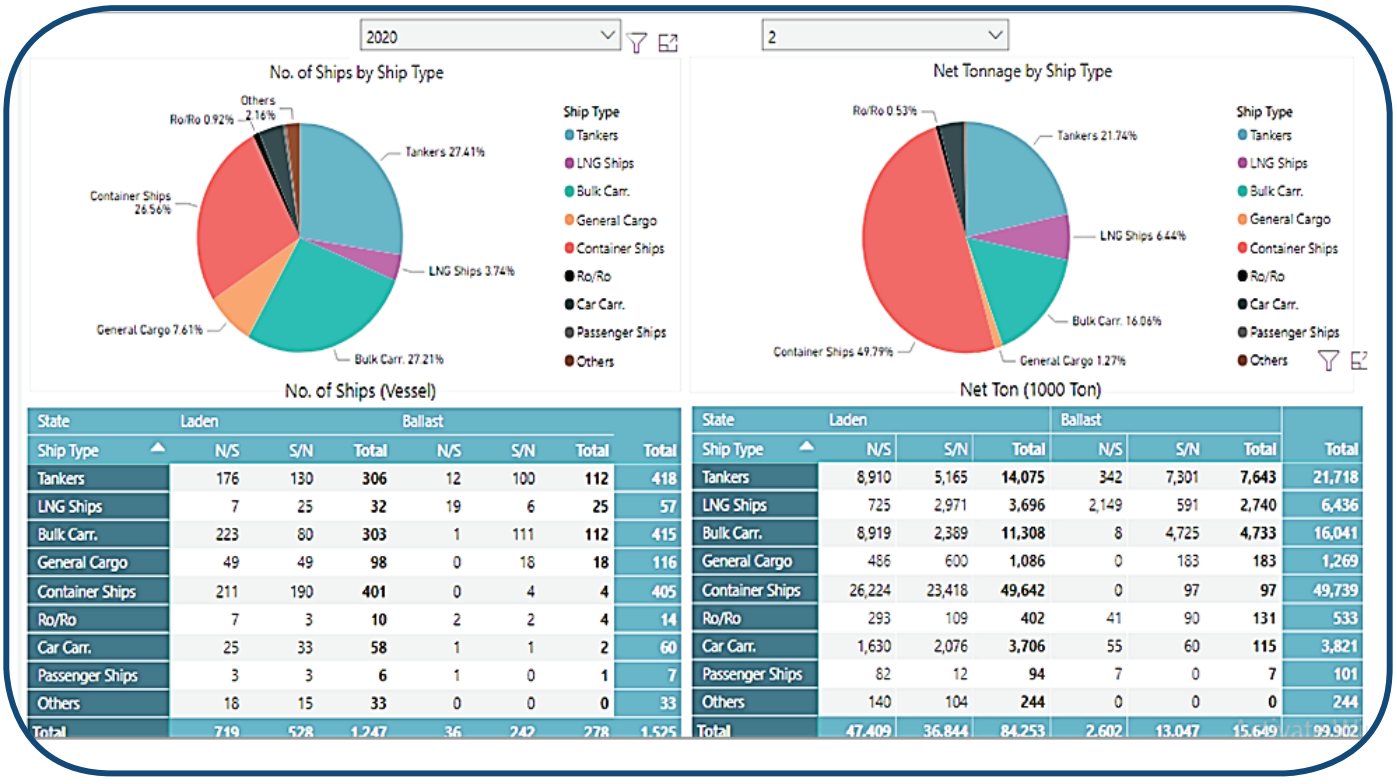
NAVIGATIONAL HAZARDS AFFECTING THE SAFETY OF NAVIGATION IN THE GULF OF SUEZ (GOS)

The GOS is one of the most important global shipping routes since it provides a passageway for vast numbers of ships bound to and from the Suez Canal and the Red Sea. This includes ships of the northern and southern convoys of the Suez Canal as well as service vessels for oil platforms and rigs, and tankers that discharge oil in Ain Sukhna, Ras Shuqair, Zaafarana, and Jabal al-Zeit. The safety of navigation and protection of the marine environment may be compromised in the event of an accident in this vital area, resulting in significant economic damages.

The number of ships that passed through the Suez Canal in February 2019 reached 1,525 with a total net tonnage of 99,902 tons, according to a report issued by the Suez Canal Authority in 2020 and depicted in Figure 3. As illustrated in Figure 4, the marine traffic website for 2019 also reveals that more than 229,000 ships navigated the northern Red Sea and GOS, which confirms the high ship density in the GOS. Accordingly, there is an urgent need to identify the most hazardous areas in the GOS in order to determine the extent of their impact on navigational safety and the marine environment, particularly during the potential navigation of MASS ships in these areas (Suez Canal Authority, 2020; Marine Traffic, 2019).



No. of Ships (Vessel)

State	Laden			Ballast			
Ship Type	N/S	S/N	Total	N/S	S/N	Total	Total
Tankers	176	130	306	12	100	112	418
LNG Ships	7	25	32	19	6	25	57
Bulk Carr.	223	80	303	1	111	112	415
General Cargo	49	49	98	0	18	18	116
Container Ships	211	190	401	0	4	4	405
Ro/Ro	7	3	10	2	2	4	14
Car Carr.	25	33	58	1	1	2	60
Passenger Ships	3	3	6	1	0	1	7
Others	18	15	33	0	0	0	33
Total	719	528	1,247	36	242	278	1,525

Net Ton (1000 Ton)

State	Laden			Ballast			
Ship Type	N/S	S/N	Total	N/S	S/N	Total	Total
Tankers	8,910	5,165	14,075	342	7,301	7,643	21,718
LNG Ships	725	2,971	3,696	2,149	591	2,740	6,436
Bulk Carr.	8,919	2,389	11,308	8	4,725	4,733	16,041
General Cargo	486	600	1,086	0	183	183	1,269
Container Ships	26,224	23,418	49,642	0	97	97	49,739
Ro/Ro	293	109	402	41	90	131	533
Car Carr.	1,630	2,076	3,706	55	60	115	3,821
Passenger Ships	82	12	94	7	0	7	101
Others	140	104	244	0	0	0	244
Total	47,409	36,844	84,253	2,602	13,047	15,649	99,902

Fig. 3. Suez Canal report in February 2020
Source: Suez Canal Authority (2020)

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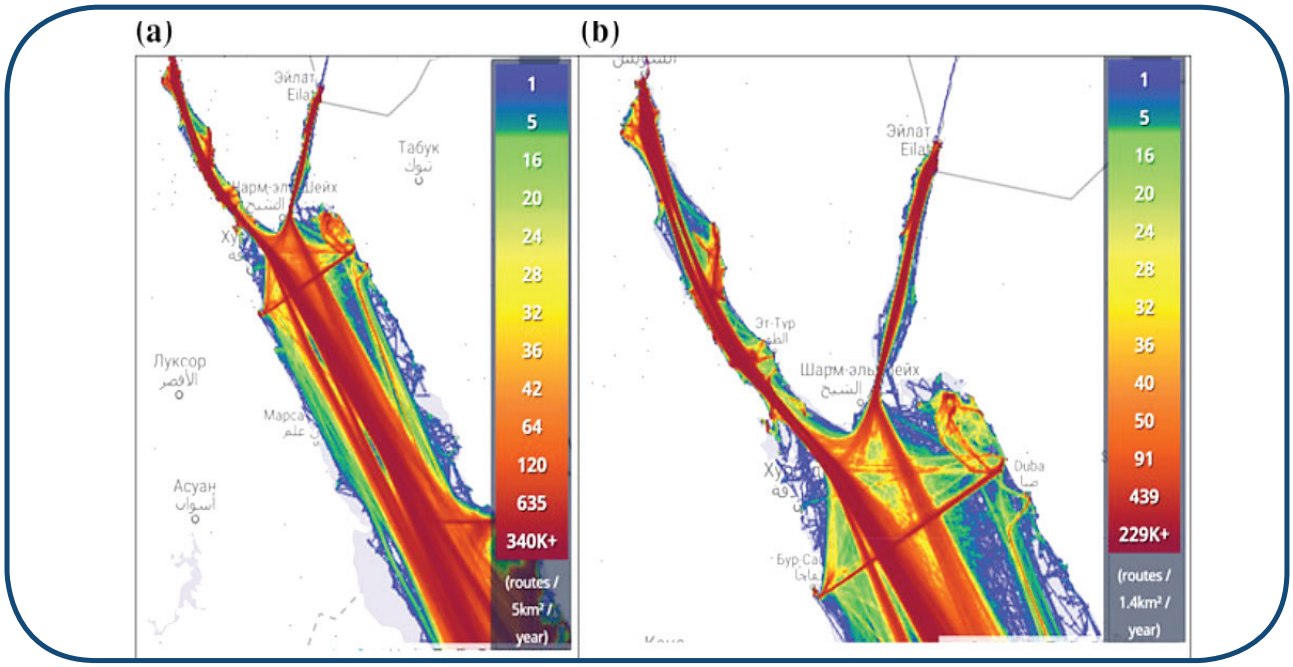

Fig. 4. The marine traffic density in the northern part of the Red Sea and GOS
Source: Marine Traffic (2019)

The most hazardous zones in the GOS have been identified as (the Strait of Jubal in the south of the GOS and the Ras Shuqair area in the middle of the GOS and the north of the GOS. As MASS ships will pass through certain regions in the future, the level of hazard in these regions could increase.

Strait of Jubal

Strait of Jubal zone was chosen due to (i) the presence of a rocky mountain on the eastern edge of the ship transit area in the traffic separation scheme (TSS) region, (ii) the absence of a navigational aid to direct ships away from this area, and (iii) the narrow safe navigational route for navigation in this area, which is less than 1 nautical mile, as depicted in Figure 5.

These considerations pose a direct impact on the safety of navigation and the marine environment in this crucial region, which encompasses the most popular touristic diving spots in Egypt and where numerous oil platforms are installed. The passage of MASS ships through this hazardous zone will raise the likelihood of accidents, which could result in major economic and environmental consequences.

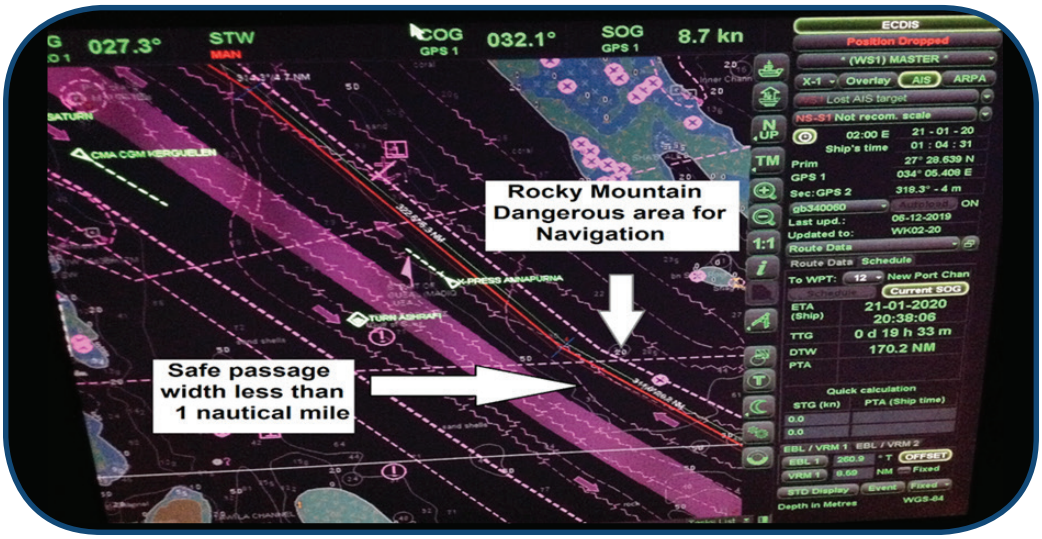

Fig. 5. Dangerous area for navigation in (Strait of Jubal)
Source: Photo by Transas ECDIS of Aida IV (01/2020)

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Ras Shuqair Area

Ras Shuqair is one of the most hazardous areas in the GOS due to the existence of a high number of oil platforms and rigs, as well as isolated danger areas in the north-east and south-west that are not provided with any navigational aids, as shown in Figure 6.

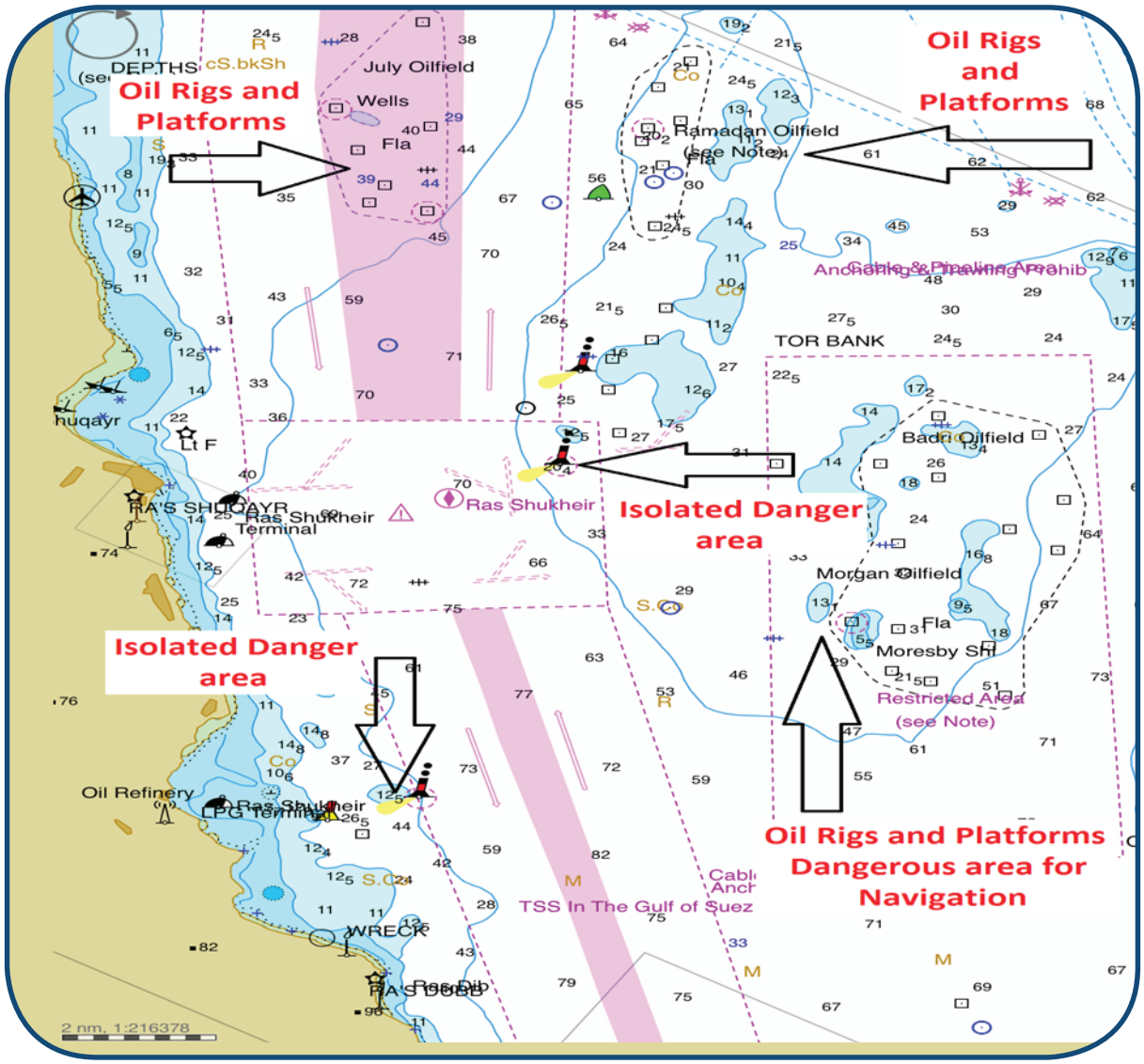

Fig. 6. Dangerous area for navigation in Ras Shukheir
Source: Photo by Transas ECDIS of Aida IV (09/2020)

Furthermore the presence of large numbers of fishing vessels in this area, with no commitment to conduct fishing activities far from the shipping lanes in the Traffic Separation scheme (TSS), will lead to a negative impact on the safety of sailing of ships, especially MASS vessels, thus leading to a diverse impact on the safety of navigation and the marine environment, as well as the safety of oil platforms in this important navigational and economic area.

Northern Gulf of Suez

The northern GOS region is one of the most important navigational and economic areas in the GOS due to the presence of coastal touristic places, oil-discharging tankers of the Sumed Company in the Ain Sukhna area, the southern entrance to the Suez Canal, and the port of Ain Sukhna, as well as the large density of ships in the eastern and western anchorage areas waiting to cross

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the Suez Canal and entering the port of Adabiya, as shown Figure 7.

With the anticipation of future passage of MASS ships through the GOS, now it is time for the Egyptian Maritime Authority to begin implementing the necessary precautionary measures and procedures to preserve the safety of navigation for MASS ships along this vital route.

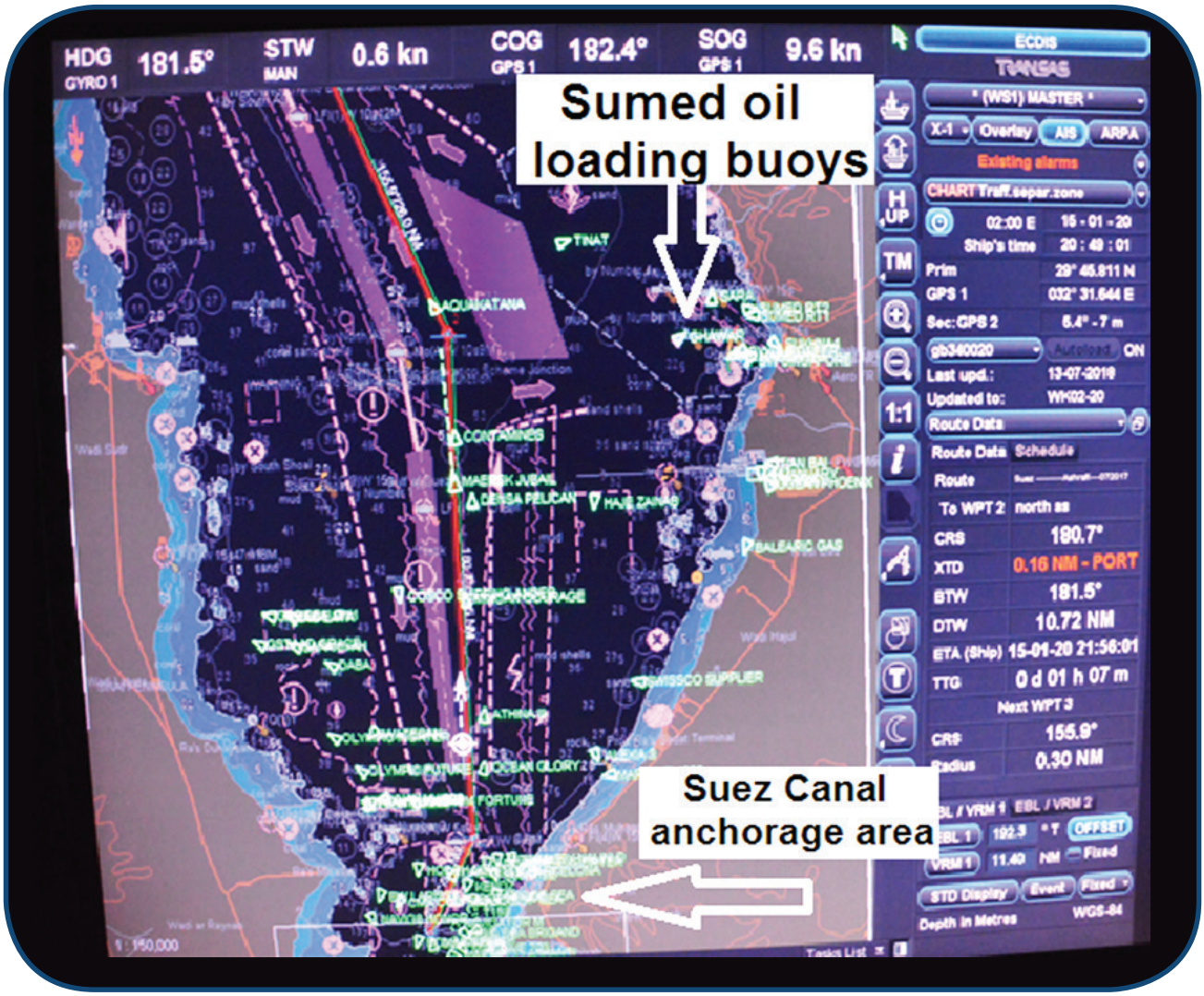

Fig. 7. North Gulf of Suez and southern entrance of Suez Canal
Source: Photo by Transas ECDIS of Aida IV (01/2020)

THREATS IN MASS OPERATIONS WHILE SAILING IN THE GULF OF SUEZ

The primary threat categories associated with MASS operations have been identified and are outlined in Table 1 as a result of an exhaustive analysis of the relevant literature. The researchers are aware that there is a serious shortage of published research in this field; however, there is a growing body of work devoted to MASS, which includes a few survey-based papers. Munim (2019) examines the development projects for autonomous ships and discusses the economic, environmental, and social benefits that have resulted from these projects. Dreyer and Oltedal (2019) review the difficulties associated with the operation of autonomous ships. Kim et al. (2020) examine the impact of MASS on various regulations, technologies, and industries. Wróbel et al. (2020) conduct a thorough literature review of the operational characteristics of remotely controlled vessels with the third-highest level of autonomy. This review is based on System-Theoretic Process Analysis (STPA) principles and identifies current and potential future research directions in the field of autonomous vessels. (Chia, Christos, Qing and Zaili, 2021).

Because of the difficulty of navigation in the GOS due to a number of the previously mentioned factors, including the presence of a rocky mountain in Gubal Strait at the southern entrance of the navigational route in the GOS, isolated navigational dangers, the large number of rigs and oil platforms in the Ras Shuqair area, and oil loading and unloading areas in Ain Sokhna, Zaafarana, Ras Shuqair, and Jabal Al-Zit, which will have a negative impact on the safety of navigation and the marine environment along one of the world's most crucial shipping routes.

As a result of the researchers' review of the pertinent literature, they have determined the threats categories listed in Table 1, which have been evaluated after carrying out a Questionnaire by a group of professionals to determine threats impact of MASS on the safety of navigation and the marine environment in the GOS.

Breakdown of Equipment

Failure of equipment during voyages is a key category of threat. In the event of a problem, since there is no crew onboard an autonomous ship, it must be immobilized and wait for the repairing company to arrive. Sensor failure, temporary loss of electricity (e.g., owing to black-out), failure of the ship's IT system (e.g., due to a fire in the server room), total loss of propulsion, and entire loss of rudder are examples of equipment failure. Moreover, Wróbel et al. (2017) list all potential scenarios for preventing or responding to fires on a MASS and assert that a fire accident is an exceptionally difficult obstacle in MASS operations.

Engagement with the Physical Reality

This type of threats may include extreme weather, reduced visibility, icing, ice pathways, and strong tidal waves. Winter passage in ice areas for a MASS would likely demand the help of an ice breaker, which poses a threat because of the closeness of the ships. To prevent the structural damage to the ship, heavy weather may necessitate slower maneuvering. Traditionally, all of these maneuvers are executed using manual steering (Banda et al., 2015).

Human Element

Despite the fact that MASS will aid in decreasing human error, the researchers can argue that human error or incompatibility between person and task cannot be totally avoided because the design and remote control still contain human elements. Due to the wide scope of coding and programming, human error may transfer from the incident time to the pre-voyage time. The associated systems cannot be exhaustively studied or tested before the commencement of actual ship operations. Due to the huge number of software package programming and the complexity of the coding, there is a possibility that software engineers will make wrong decisions during the design or programming process and, as a result, introduce vulnerabilities into the system. Inadequate design and interaction will also lead to an increase in operational human element concerns (Ahvenjarvi, 2016). Since operators in the Shore Control Centre (SCC) may be uninformed of the actual scene conditions, they bear the same or even new human error threats. Additionally, autonomous ships require periodic remote or in-person maintenance. In either scenario, human error will play a role, and this must be viewed as a threat to MASS operations.

In the future era of autonomous shipping, non-technical skill requirements are also vitally crucial and will differ greatly from those of conventional ships. Future ships will eliminate some human jobs and replace them with remote controllers (MUNIN, 2015).

Malfunction of the System

Since autonomous ships mainly rely on information technology (IT), it is possible to debate whether or not these systems are as competent as humans. Autonomous systems rely on machine learning, which requires considerable training to cover the vast majority of conceivable real-world scenarios. Due to the unpredictability of the system's behavior, however, it cannot account for all circumstances, and extraordinary circumstances are associated with the most difficult and dangerous system faults. In addition, systems and software should be designed to tolerate unanticipated failures. It is not easy to quantify the tolerance required

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to make the system work smoothly while assuring the safety of the voyage. It is believed that communication link failures are the new threats posed by the operation of MASS (Ahvenjarvi, 2016).

Object Detection and Communication with Human-operated Ships

Although Komianos (2018) asserts that MASS can substantially reduce the risk of collision and is compliant with COLREGs, they also argue that MASS does not comply with Rule 5 of COLREG, which requires a proper look-out by sight and sound on every ship to assess the situation and the risk of collision. A substantial amount of research also focuses on collision avoidance and guidance systems; for instance, Perera et al. (2018) who propose a ship collision situation avoidance algorithm based on fuzzy logic to support decision-making systems in autonomous ships, and Xu et al. (2019) who use AIS data to propose a path generation system.

The Threat of Jamming and Cyber Attacks

The CEO of CyberKeel, Lar Jensen, asserts that "autonomous ships will not become a mainstream reality in the next few years due to unresolved cyber-security issues on the technology". This quote is supported by recent examples of attacks including the events at COSCO US in 2018, Maersk in 2017, and the Port of Antwerp in 2011 and 2012. Hence, proof that cyber-attacks and jamming, which is usually caused by interference to the signals at Global Navigation Satellite Systems (GNSS) frequencies, are seen as one of the most serious threats in MASS operations because of the reliance of autonomous ships on information and communication technologies (Chia, Christos, Qing and Zaili, 2021).

Jammers represent a threat to GNSS since they intentionally interfere with signals and cause damage. Hence, the autonomous ship will rely heavily on the GNSS receiver for its positioning requirements. Even though it provides precise location data, the system's upkeep is in jeopardy. Multiple instances of significant GPS interference have been reported by ships operating in the Eastern and Central Mediterranean Sea (U.S. MARAD Alert 013, 2019).

The United States Maritime Administration (MARAD) has released Advisory 2019-013, which provides the following information: Ships operating in the Eastern and Central Mediterranean Seas have reported multiple instances of serious GPS interference. In the Eastern Mediterranean, most of these reports have been centered around Port Said, Egypt, the Suez Canal, and the Republic of Cyprus. There were additional reports of interference between Hadera, Israel and Beirut, Lebanon. This interference is causing GPS signals to be lost, impacting bridge navigation, GPS-based timing, and communications equipment. Additionally, satellite communications equipment may be affected (U.S. MARAD Alert 013, 2019), (Felski and Zwolak, 2020).

CONDUCTING A QUESTIONNAIRE TO EVALUATE THE MASS THREATS

A questionnaire was carried out to evaluate the MASS threats when passing through the GOS by 15 professionals in the field of maritime transport which are 11 lecturers from AASTMT (Sea Training Institute) and four officers onboard M/V Aida 4. The respondent assessment questionnaire consists of six groups for a total of 25 MASS threats that were asked to fill out a questionnaire as a source of information as shown in table 1. By using Likert scale questions which provides more granular information on respondent's attitudes towards a subject than a simple yes/no question type. Each respondent ranks each threat on a scale from one to five, with one being the lowest and five the highest. Figure 8 explains the overall score of MASS threats based on the questionnaires. According to the data shown in table 1, group no. (4) had the greatest score of (76) out of (100) as shown in Figure 8. This value indicates a negative impact on the safety of navigation and the marine environment in the GOS due to the malfunction of the System such as (inability to locate the ship because of AIS or GPS signal jamming or spoofing or an error caused by a disrupted communication link). Group no. (2): Engagement with the physical reality such as (Failure occurs due to a significant tidal effect, collision due to Low-visibility) had the lowest score of (64) out of a possible (100).

THREATS POSED BY MASS

Table 1: MASS Threats Evaluation Questionnaire

	Threats posed by MASS	Score
Group (1) Breakdown of equipment		
1	Complete lack of thrust.	3.2
2	Blackout or other temporary disruption of power supply - a lack of ability to manage a situation.	3.7
3	Inadequate sensing causes loss of control.	3.7
4	Absence of all rudder functionality.	3.1
5	IT system failure (e.g., server room fire) results in loss of control.	3.5
6	Loss of ship or systems due to fire.	4.1
Group (2) Engagement with the physical reality		
1	Failure occurs due to a significant tidal effect.	3.3
2	Low-visibility collision.	2.6
3	Failure because of ice navigation.	3.2
4	Heavy weather-caused failure.	3.7
Group (3) Human element		
1	Ineffectiveness because of a faulty remote control centre software.	3.4
2	The complexity of the system's coding and programming leaves room for human error throughout the design phase.	3.6
3	Problems made by humans not knowing how MASS will respond to an unusual situation.	3.1
4	Ineffectiveness caused by faulty on-board software design.	3.3
5	Inaccuracy in repair work caused by humans using remote controls.	2.8
Group (4) Malfunction of the System		
1	Inability to locate the ship because of AIS or GPS signal spoofing.	3.7
2	An error caused by a disrupted communication link.	3.9
Group (5) Object detection and communication with human-operated ships		
1	Failure to notice an object or ship can cause a collision.	4.0
2	Unable to locate objects drifting partially submerged	3.3
3	Inability to detect low-visibility targets, such as abandoned or broken objects	3.2
4	Failing to properly interact with a human-operated ship(s) in a dense traffic situation can lead to a collision.	4.3
5	Not knowing what to do around ships that are towing, have limited manoeuvrability, or are trawling.	3.5
Group (6) The Threat of Jamming and Cyber Attacks		
1	The operating system crashes because of harmful hacking attempts.	3.2
2	Cybercriminals disrupt ship-to-shore communications.	3.5
3	Jammers represent a threat to global navigation satellite systems (GNSS) and cause damage.	3.8

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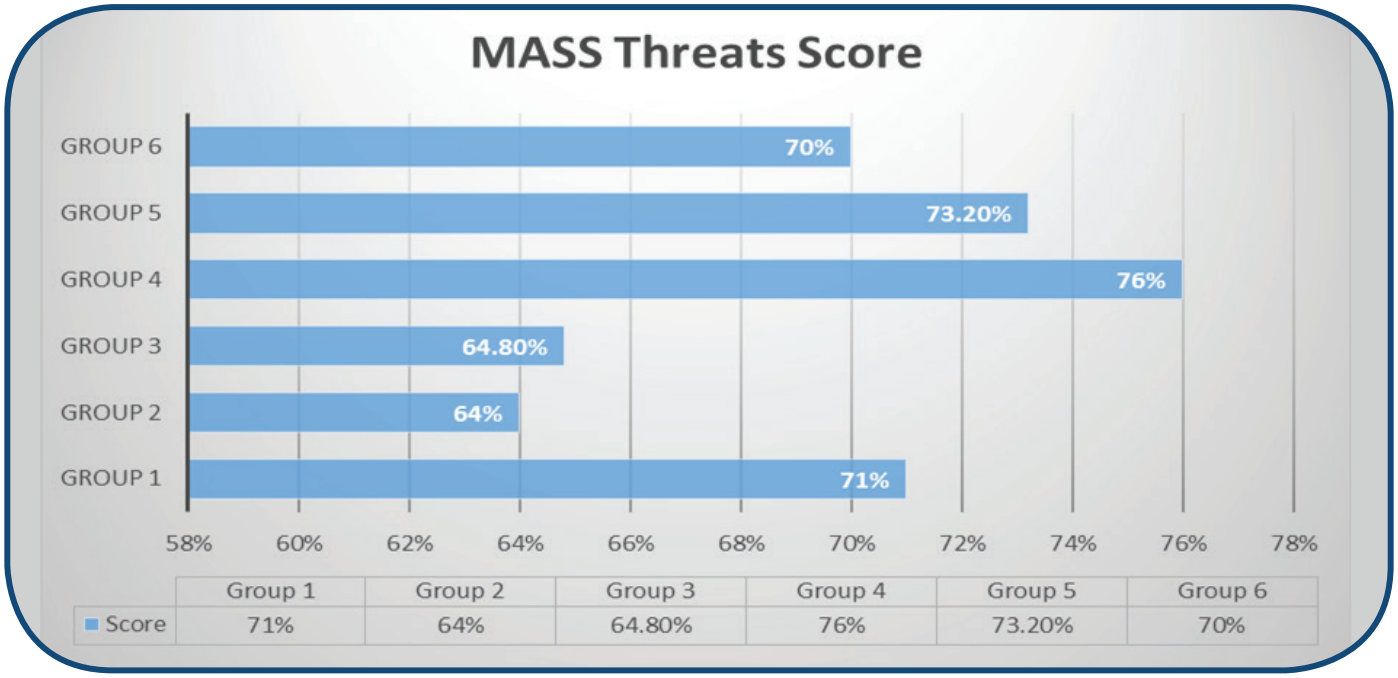

Fig. 8.. MASS threats score

The total score of respondents' assessment questionnaire is (1287) out of a possible (1875), which represents maximum value for a (68.50%) average and which indicates a high threat to the safety of navigation and the marine environment in the GOS.

There are values that need to be determined before the total questionnaire findings can be evaluated. Here are some examples of such values:

1. The maximum value=1875
2. The minimum value =375
3. The median (Q2) = 1125
4. The first quartile (Q1) = 750
5. The third quartile (Q3) = 1312.5

By using a box plot which is a method to summarize a set of data that is measured and used in explanatory data analysis. The threats of MASS based on the minimum value, the first quartile, the median, the third quartile, and the maximum value. Score between the third quartile and the maximum value will be extremely high threats (1312.5.-1875), score between the median and the third quartile will be high threats (1125.-1312.5), score between the first quartile and the median will be medium threats (750-1125.), and score between minimum value and the first quartile will be low threats (375.-750). The total score for the questionnaire, which included fifteen experts who judge a total of twenty-five potential MASS threats that were broken down into six groups, was 1287 which is high threats between the median and the third quartile (1125-1312.5) as shown in Figure 9. Based on the results of the questionnaire, it has become clear that MASS pose a threat to the safety of navigation and the marine environment in the GOS, which requires most appropriate measures to be taken to allow these MASS ships to sail in the GOS.

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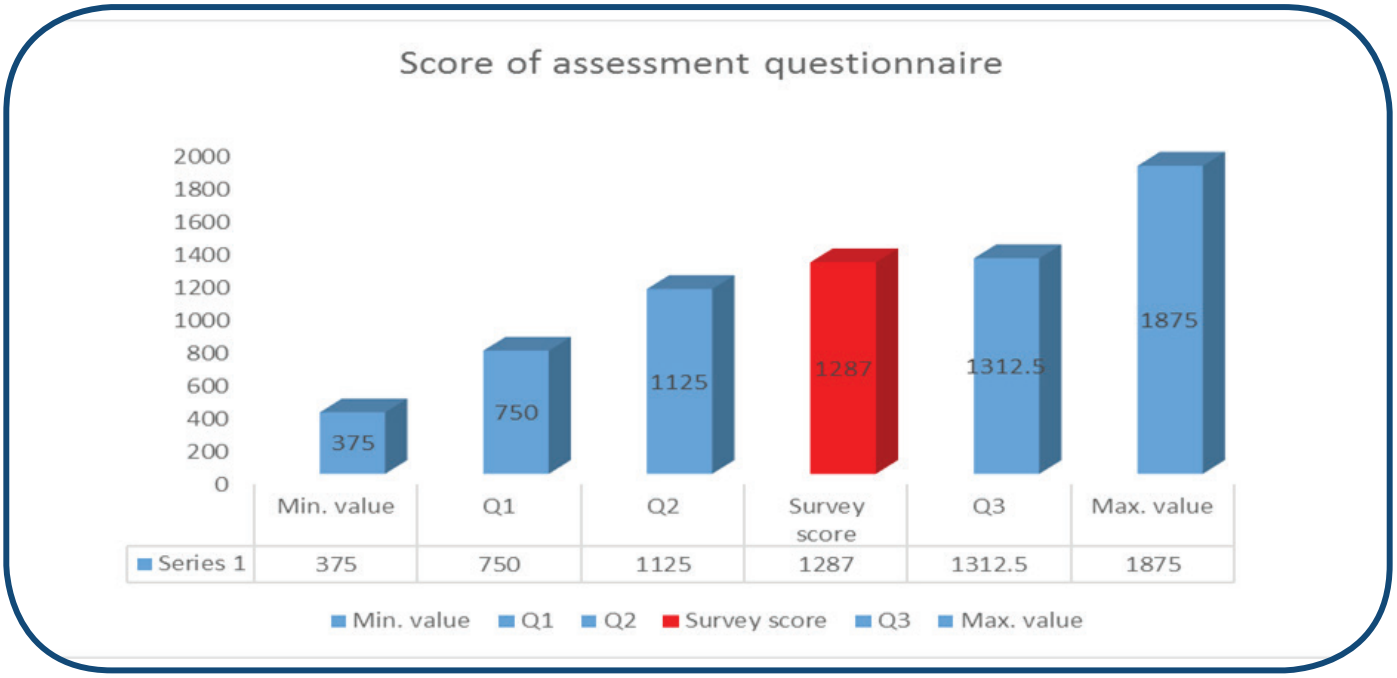

Fig. 9. Score of assessment questionnaire

Proposed Control Actions for MASS Transit in GOS

1. Establishment of three land stations for command, control, and guidance in the areas of (Al-Zafarana - Ras Ghareb - Ras Mohammed) after dividing the GOS into three sectors as depicted in Figure 10, to be able to utilize the MASS guidance system by connecting to terrestrial networks and satellites.

2. Establishment of a group of Tug Stations (TS) for tugboats that will escort on request MASS in areas that pose a threat to the safety of navigation and the marine environment, namely: the southern entrance to the Suez Canal, Ain Sukhna, Ras Ghareb, Ras Shukair, the Strait of Jubal, and south of the GOS, to be equipped with Moor Master System due to the significance of the system in escorting MASS without the need for the human element or the mooring lines.

3. Forming a committee affiliated with the Egyptian Authority for Maritime Safety (EAMS) to develop training requirements for the officers and crew operating the ground stations for commanding, controlling, and monitoring MASS, and submitting a proposal to the IMO.

4. Forming a committee affiliated with the Egyptian maritime transport sector to discuss proposals and special requirements to expedite the Egyptian House of Representatives' consideration and issuance of legislations regarding the passage and entry of MASS into territorial waters, Egyptian ports, and the Suez Canal, following consultation with the IMO.

5. Establishing a committee from the Egyptian maritime transport sector to meet with the classification societies, companies owning MASS and insurance companies to study the most appropriate procedures for issuing a special international certificate for MASS that transit the GOS after ensuring the implementation of all requirements and safety procedures that will be agreed upon and presented to the IMO to be binding on all MASS, while setting periodical dates to discuss any developments and/or improvements that may arise in the field of MASS.

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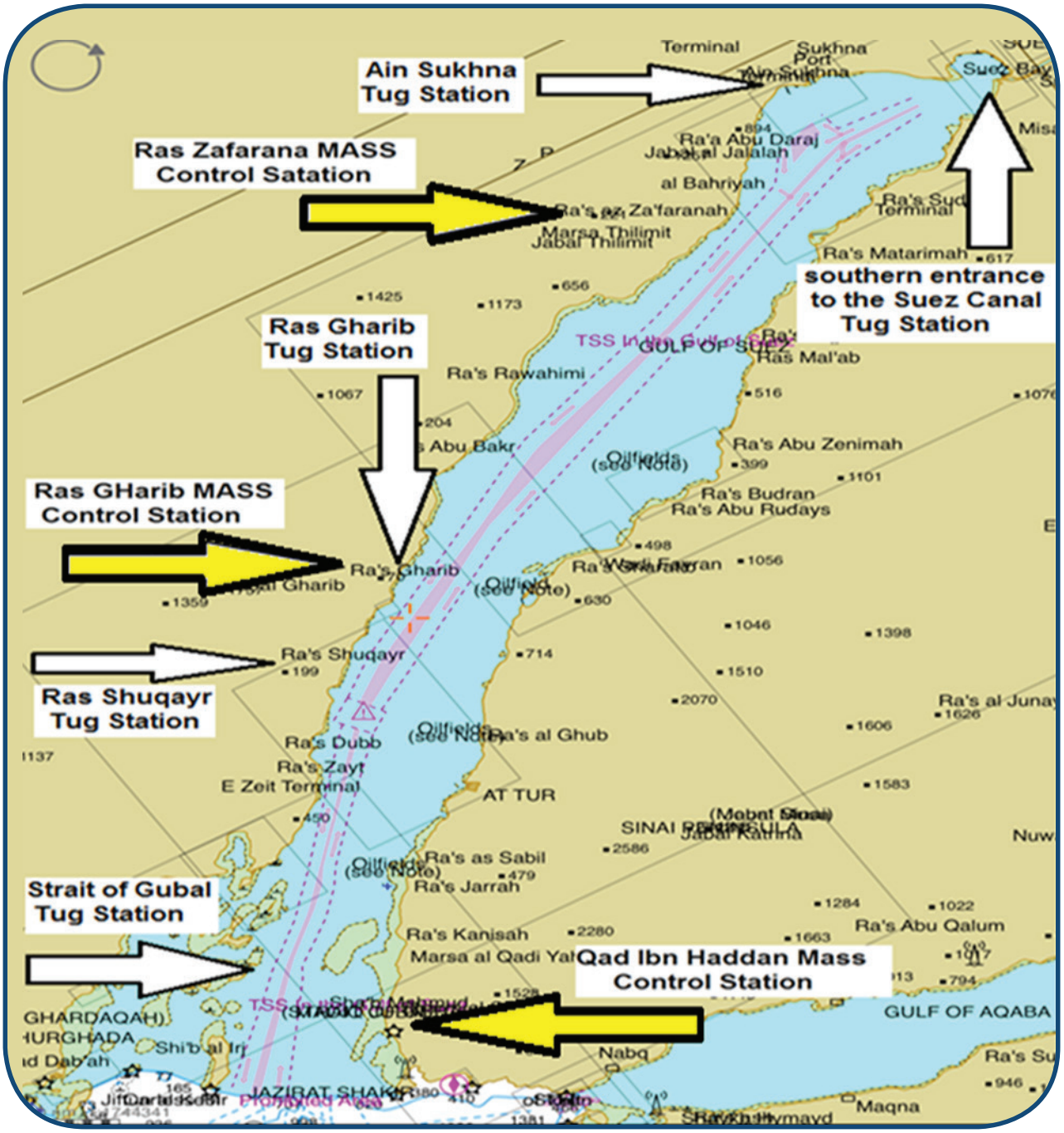

Fig. 10. Proposed MASS control stations and tugboat mooring stations in the GOS
Source: Photo by Transas ECDIS of Aida IV (08/2022)

CONCLUSION

The primary objective of this research paper is to demonstrate the impact that the sailing of MASS in the GOS could have on the safety of navigation, maritime security, and environmental protection. The most significant advantages and disadvantages of MASS highlighted in this study are based on the most recent literature available at the time this paper was written.

Due to the significance of the GOS to world trade and economy, ensuring that ships can navigate through it safely should be a top priority, and any potential threats to this safety should be in continuous and thorough investigation.

The purpose of this paper was to protect both the

safety of navigation and the marine environment by conducting a comprehensive investigation of the six primary threats and their effects on the GOS. According to the results of a questionnaire completed by fifteen maritime transport experts, MASS operations in the GOS will have a negative impact on the quality of the marine environment protection, the safety and security of navigation.

When comparing the findings of this study with those of other studies that have been published in the past, we can conclude that the current findings confirm the presence and effects that have been established in the past. Even so, there are divergent views regarding its order of priority. This is evidence that the GOS region is distinct from other regions and has its own distinctive features. This emphasizes the significance of taking measures to ensure the safety of navigation in this vital region and putting those measures into effect. Therefore, before allowing MASS to navigate through the GOS, regulations, precautionary measures, and policies must be developed and evaluated, as suggested by the researchers.

Ultimately, Developers and operators could use the findings of this paper to concentrate their efforts on the areas of autonomous shipping safety where they are most needed to make the shipping industry safer.

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