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Evaluation of the operation of lighthouses and beacons in the Gulf of Suez

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EVALUTION OF THE OPERATION OF LIGHTHOUSES AND BEACONS IN THE GULF OF SUEZ

By

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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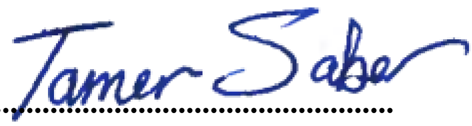

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Abstract

Title of Dissertation: **Evaluation of the operation of lighthouses and beacons in the Gulf of Suez**

Degree: **Master of Science**

Aids to Navigation (AtoN) are crucial for ship safety and effective conduct of navigation. The purpose of this study was to evaluate the operation of lighthouses and beacons in the Gulf of Suez (GOS), which is considered one of the world's most dangerous passages due to the passage of all ships crossing the Suez Canal and the presence of coral reefs along the gulf. The research evaluated three data sources using a quantitative approach. First, twenty-three ships in the GOS or transiting the GOS responded to a questionnaire. Second, a government ship's voyage from 2019 to 2021 data study has been conducted. Finally, the list of AtoN status in GOS was filtered from UK hydrographic office publications in 2016 and 2022.

The analysis indicated that AtoN in GOS perform overall rather poorly. Most of them probably do not function at an acceptable level, with a number of ships not being able even to recognize them; others are simply inadequate for safe navigation. The researcher presented methods for enhancing the efficiency of AtoN while considering the relevant environmental factors. The research revealed that a number of sites require immediate maintenance and repair. The analysis also highlighted the need for an all-encompassing plan to construct and upgrade lighthouses and beacons, including additional devices. Using the AIS network installed in AtoN to construct an exchange system can provide information for the safety of navigation and weather forecast.

KEYWORDS: Aids to Navigation, Lighthouses, Beacons, Suez Canal, Safety of navigation, Coastal states duties.

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List of Abbreviations

AC	Alternating Current
AIS	Automatic Identification System
AtoN	Aids to Navigation
DGNSS	Differential Global Navigation Satellite System
EAMS	Egyptian Authority for maritime Authority
ECDIS	Electronic Chart Display and Information System
ENHD	Egyptian Navy Hydrographic Department
GNSS	Global Navigation Satellite System
GOC	General Operators Certificate
GOS	Gulf of Suez
HF	High Frequency
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IGO	Intergovernmental Organization
IHO	International Hydrographic Organization
III code	IMO Instruments Implementation Code
IMO	International Maritime Organization
INS	Information Services
ITU	International Telecommunication Union
MBS	Maritime Buoyancy Systems
MF	Medium Frequency
MSI	Maritime Safety Information
MTS	Maritime Transport Sector
MTTR	Mean Time For Repair
NA	Not Available
NOAA	National Oceanic and Atmospheric Administration
NTRA	National Telecom Regulatory Authority
PV	Photovoltaic
RCMS	Remote, Control and Monitoring system
SOLAS	The International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watch keeping for Seafarers
TD	Temporarily Discontinued
TE	Temporarily extinguished
TSS	Traffic Separation Schemes

UKHO	UK hydrographic office
UN	United Nation
UNCLOS	the United Nation Convention on the Low Of the Sea
USCG	United States Coast Guard
VHF	Very High Frequency
VTS	Vessel Traffic Service
VTSO	Vessel Traffic Service Operator

1. Introduction

1.1 Background in Aids to Navigation

Aids to Navigation (AtoN) play a crucial role in supporting water transportation, promoting maritime development, and economic activities like fishing, as well as helping to preserve national sovereignty. They are often known as the navigation aid mark, crucial for ship safety and economical navigation. These aids are essential for ensuring the smooth transit of maritime traffic and the flow of ports (Nie et al., 2019). According to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) constitution, they are defined as a device, system, or service outside vessels intended and operated to facilitate safe and efficient navigation of individual vessels and maritime traffic (IALA, 2016). Physical aids or AtoN have been used for thousands of years to guide sailors along their routes and guarantee safe passage by identifying safe waters using recognized features and buildings. Typical forms of AtoN include buoys, lighthouses, light ranges, day markers, and other devices that aid navigators plan a safe path or warn them of risks and impediments (Wright & Baldauf, 2016).

In order to prevent disasters at sea like collisions and groundings, a shore-based guide can be used to provide direction to a ship at sea. Any navigating officer can benefit significantly from the ability to quickly get clear information and an immediate explanation of any pressing difficulties. The Vessel Traffic Service Operator (VTSO) provides Information Services (INS) for all ships in a region with safety-related information as necessary (Siousiouras & Dalaklis, 2009; Dalaklis et al., 2009).

A key component of modernizing marine traffic safety is to improve navigational safety. Approximately 85 percent of all marine accidents are caused by navigational events, such as collisions and groundings. A formal safety evaluation must include emergency resource allocation and risk management to properly analyze the repercussions of such accidents (Lyu & Yin, 2018).

The efficiency of the AtoN is directly proportional to the safety of port water navigation and the preservation of the maritime environment. Therefore, it is essential to conduct efficacy evaluations and guarantee that the AtoN structure is adequate and appropriate (Nie et al., 2019).

1.2 Background of Aids to Navigation in Egypt

Egypt is regarded as one of the earliest nations to erect lighthouses to aid navigation and the day-and-night movement of ships when their activity had previously been confined to daylight hours (EAMS, 2021a). In 280 BC, the “Pharos of Alexandria” lighthouse was built in the north coastal area of Egypt, which is considered as the oldest lighthouse in the world. It was popularly known as one of the Seven Wonders of the Ancient World; more details will be included in the literature review of this research (trethewey, 2016). Egypt is distinguished by its strategic location and its 3000 km-long coastal strips. It is surrounded in the north by the 1000-kilometer-long Mediterranean Sea. It is also surrounded by the 2000-kilometer-long eastern coastlines of the Red Sea, the Gulf of Suez (GOS), and Aqaba (MTS, 2020).
Along this stretch of the Egyptian coast, Egypt built AtoN in order to identify ports and entrances, locate shallow seas, coral reef regions, and submerged islands that might compromise the safety of navigation and make coastal shipping more accessible (EAMS, 2021a). Currently, it covers most of the coastal area in Egypt. It is divided into three groups related to the graphical area, namely AtoN in the Mediterranean Sea, the Red Sea, and isolated lighthouses (EAMS, 2021a).

1.3 Background of Lighting houses in GOS

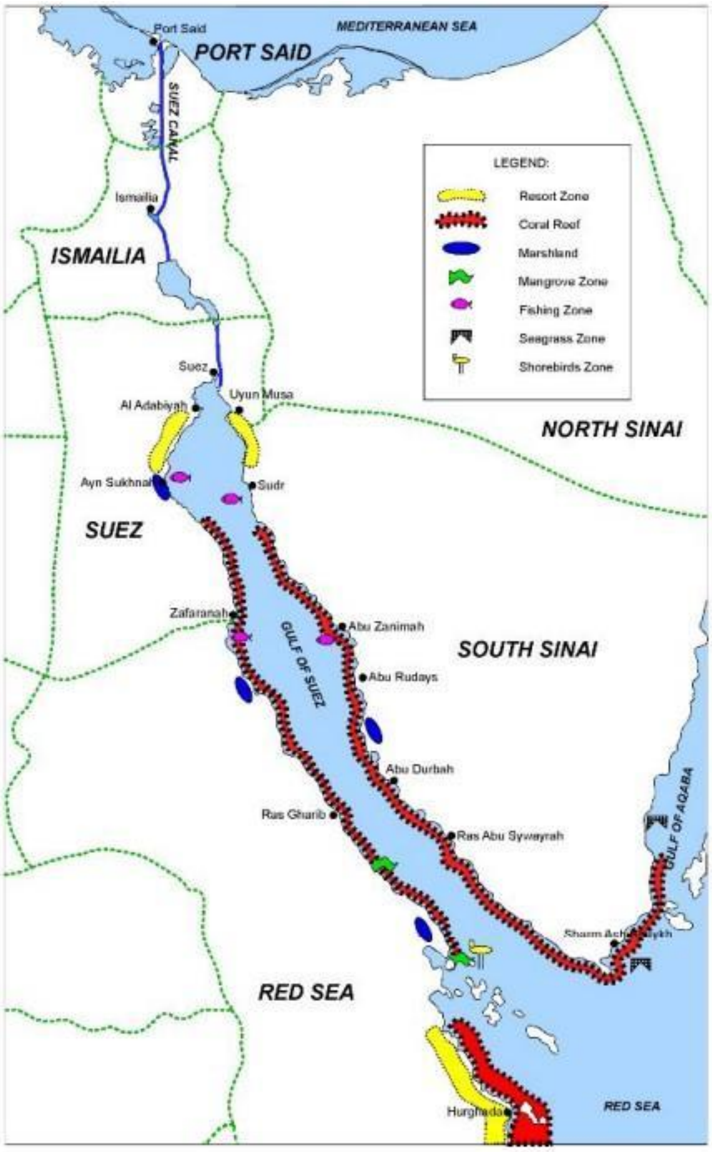
1.3.1 GOS as a major waterway.

On August 18, 1869, the waters of the Mediterranean Sea and the Red Sea physically met, giving birth to what is today known as the Suez Canal, as shown in Figure 1. This canal is sometimes referred to as "the artery of prosperity for Egypt and the world." (Suez Canal, 2019a). In this context, the GOS has become one of the most significant waterways in the world because it links the Red Sea with the Suez Canal. According to the Suez Canal Authority, the total number of vessels that passed through the canal in 2019 was 18,880, with a total gross tonnage of 1,207,080 tons (Suez Canal, 2019a). Figure 1 depicts GOS as a high-traffic area with a short width of 11 to 25 nautical miles and includes environmentally sensitive zones (Jica, 2008).

As a member of international organizations, such as the International Maritime Organization since 1958, Egypt is committed to complying with all international directives by implementing measures to ensure the safety of maritime navigation, the protection of the marine environment, and the protection of its economic interests.

Figure 1

Environmental Sensitivities in Gulf Region (Jica, 2008)



1.3.2 Establishing lighthouses

As a result of the construction of the Suez Canal, it was essential to consider maritime safety and environmental protection in the GOS. As shown in Figure 1, in most areas, the coastlines of the Red Sea are bordered by submerged coral reefs that can be either detached or continuous. These reefs frequently emerge abruptly from extremely deep water, meaning that soundings do not indicate their proximity. Most of the time, the sides of the reefs are completely vertical from a depth beyond the reach of an ordinary ship's sounding line. For this reason, the commanders make every effort to steer a path that is as close to the center of the sea as they possibly can so that they can give these unseen threats plenty of space. Before the lights were installed, the navigational landmarks consisted of several prominent headlands and high islands. These features are virtually always visible at night in the pure atmosphere of that region; hence, they were used as navigational aids prior to the installation of the lights. Therefore, the notion of placing the lights at intermediate places, which were areas where the continuity of the series of landmarks was interrupted, was adopted. This resulted in the transformation of what had previously been perils into factors contributing to safety. In 1860, a survey was carried out to build three lighthouses in the Red Sea (Parkes, 1862). It is concluded that the Egyptian government has begun to consider constructing AtoN in GOS in order to ensure the safety of navigation and the protection of the environment, as will be explored in detail in the literature review.

1.4 Problem statement

After the inauguration of the Suez Canal in 1869, with the expansion of the amount of international trade and the passage of roughly ten percent of worldwide trade through the Suez Canal, the GOS has assumed considerable importance of the international and local levels in the contemporary period (Hafez & Mandey, 2020).

The traffic of ships in the GOS has grown, necessitating a greater emphasis on Egypt's duties as a GOS coastal state in terms of marine safety and environmental protection. According to the IMO Instruments Implementation (III) code, one of the responsibility of the coastal state is to establish AtoN service in its coastal area (IMO, 2013). The heavy traffic of ships in the GOS necessitates the provision of AtoN service to the coastal state, whose role is crucial and distinct from that of the other AtoN in Egypt. This study evaluates the effectiveness of navigational aids in the GOS area and emphasizes the necessity for routine maintenance. In addition, it evaluates the development proposal and enhances the system's efficacy to guarantee that all ships in transit get their signals with clarity and precision.

1.5 Aims and objective

This research aims to enhance maritime safety and environmental protection in the GOS by utilizing AtoN operating inside the coastal state. To achieve this, it evaluated the efficiency of the AtoN in the GOS and examined that AtoN operate with the most up-to-date technology utilized by ships to ease signal transmission and timely routing. Finally, specific suggestions to improve the efficiency of AtoN in GOS were provided.

1.6 Research questions

Regarding the aims of this work, the accompanying research questions have been formulated to provide significant guidance for contributing to the improvement of the quality of the AtoN service in GOS: -

- Are the lighthouses in GOS currently fulfilling the essential purpose for which they are designed? Or are there any weaknesses identified?
- How can lighthouses in GOS enhance their performance in coastal state duties?

1.7 Ethical issues

Quality and integrity of the research were ensured by adhering to the university's stringent guidelines, including taking the utmost care to protect the identity and confidentiality (as appropriate) of the ship's crew and ship names engaged in the study. The researcher highlighted that the individuals' involvement was voluntary and based on informed permission, with no risk of damage associated with voicing their opinions. All the ship's crews were made to feel at ease while participating. A permission form was sent to respondents. On the permission form, the following details are included:

1- All information obtained will be used solely for research purposes.

2- All data and information gathered from respondents will be held in the utmost secrecy. Participants have the choice to decline participation and may withdraw at any time throughout the survey.

3- All incidentally gathered data will be saved on a cloud-based disk and will be destroyed after the degree has been earned.

1.8 Expected results

The study revealed the level of AtoN performance and provided ways for improvement.

1.9 Scope of study

The research focused on lighthouses and beacons that serve ships in the GOS. The study excluded the buoys in the GOS and the other AtoN that function within the ports in the GOS region. It focused on 8 lighthouses and 16 beacons covering all GOS regions. This research also focused solely on the GOS, which is regarded as one of the most hazardous places in the world for navigation because of the high number of ships intending to transit the Suez Canal or depart the canal from the Mediterranean.

1.10 Methodology

This study evaluated lighthouses and beacons in GOS in Egypt by measuring their performance on a designated scale. The research primarily used a quantitative methodological approach. The study used three distinct data sources to obtain precise results. The data gathering instruments for this study are the survey questionnaire, data from one of the government survey ships, and the UK Hydrographic Office (UKHO) publication in 2016 and 2022.

A survey questionnaire was used as the primary data source for the study. Quantitative research measured and analyzed variables to arrive at findings, as demonstrated by the study. Using particular statistical approaches to answer the research questions was utilized to analyze numerical data. It also covered the techniques used to explain an issue or occurrence by collecting numerical data (Apuke, 2017). A total of 23 ships responded to this questionnaire. A total of 23 ships responded to this questionnaire. Some work in GOS, while others pass through the Suez Canal. As part of the data analysis, the results were compared with the evaluation of one of the government ships for the lighthouses and beacons in GOS and the primary data from the UKHO publication in 2016 and 2022.

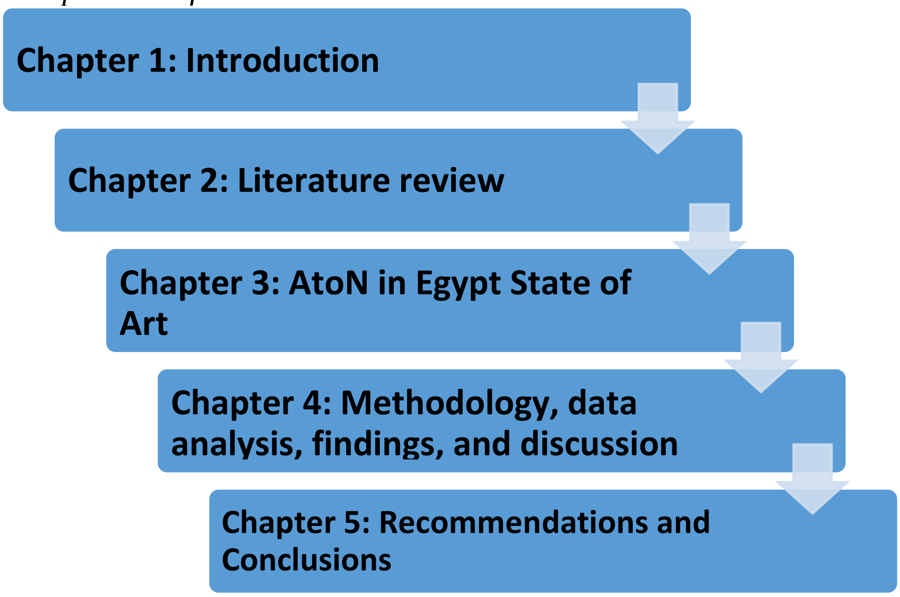
1.11 Composition of the Dissertation

The dissertation consists of five chapters, as described in Figure 2:

- Chapter one is the introduction, which contains the background, the problem statement, the aim and objectives, research questions, and the scope of the study.
- Chapter two is the literature review. It consists of a historical overview, AtoN globally and the implementation of AtoN under the international and national framework of AtoN in Egypt.
- Chapter three is a state of art that describes AtoN in Egypt. The chapter clarifies the role of AtoN in Egypt, its operation; the AtoN fault recognizing; AtoN income; the challenge of safe navigation and risks in GOS; and the lighthouses and beacons in GOS.
- Chapter four is the methodology, data analysis, findings, and discussion.
- Finally, chapter five discusses the recommendations with a suggestion for future research and conclusions.

Figure 2

Composition of the Dissertation



2. Literature review

2.1 Historical overview

A few thousand years ago, humans pondered the ocean. It is easy to envision that the summits of tall mountains, the heads of capes, enormous trees, and spectacular natural locations functioned as landmarks on the way to the goal. With the growth in size, however, ships began to go out at night and further away from the shore (Tokokai, n.d.). Thus, it became imperative to replace existing landmarks with structures that could be identified at night and from a distance. Fires were lit on capes, islands, and high structures so that the flames and smoke might serve as navigational aids for ships. This method marked the beginning of contemporary lighthouse construction (Tokokai, n.d.).

In 280 B.C., during the height of Alexandria's wealth, a vast lighthouse made of marble stone was built on the eastern end of the island of Pharos near the port's entrance. According to historical records, several lighthouses with a chapel and living quarters for the holy staff were constructed in the 17th century. Light signals were provided by burning torches and grass on the roofs of these structures. The Corinna Lighthouse, constructed in 1595 on the east side of the Strait of Gibraltar, was the first lighthouse to be constructed for the exclusive purpose of functioning as a lighthouse. A modest 9-foot-tall building was constructed, a glass lantern was placed, and oil was burnt within the lantern (Tokokai, n.d.). In the early days, lighthouses were simple constructions that burned wood and coal as a source of illumination, and later oil and candles. The advent of the lens increased the light output, and the availability of electricity as a power source in lighthouses facilitated the production of several million candelas of light (Tokokai, n.d.).

The Lighthouse of Alexandria, located on the little island of Pharos in the port of Alexandria, Egypt, was one of the Seven Wonders of the Ancient World and the prototype for all later lighthouses. In 1480, the Sultan of Egypt converted it into a medieval fort, making it one of the last of the original Seven Wonders to be destroyed. Multiple earthquakes reduced the majority of the original edifice to rubble, and the Sultan of Egypt converted it into a medieval fort (The Rosicrucian Egyptian, 2022).

Shortly after declaring himself king in 305 BCE, the first Ptolemy, the Greek officer who remained in Egypt following Alexander the Great's conquest, commissioned the construction of the lighthouse. Construction began around 280 BCE during his son's reign, lasted an estimated 33 years, and cost approximately twice as much as the Parthenon (The Rosicrucian Egyptian, 2022).

Figure 3

A contemporary artistic rendering of the Pharos of Alexandria (Trethewey, 2016)

As shown in Figure 3, the tower was constructed in three diminishing-sized sections and was over 300 feet in height. It was one of the highest artificial structures in the world for millennia, second only to the Great Pyramid of Giza. Every night, a fire burning near the top supplied illumination, augmented by a polished bronze mirror. Many historical depictions of the tower describe a statue at the tower's summit. While many historians believe it was initially a statue of Zeus, it may have been altered throughout the years to portray a variety of gods or kings. After being lost for decades, the remains were unearthed on the harbour bottom of Alexandria in 1994, and divers may now explore them (The Rosicrucian Egyptian, 2022).

In light of the geographical nature of GOS and the extent of coral reefs in its coastal area, the government realized the need for navigation aids. Before this date, the government had begun the construction of the Suez Canal, which began in 1859. At that time, it was expected that more ships would sail in this area once the Suez Canal had been completed, which was inaugurated and on August 18, 1869. Parkes (1864), received the opinions of several commanders in the Peninsular and Oriental services. In February 1860, Parkes visited most of the areas recommended by these officers. Due to Parkes' research, it was suggested that lighting be installed in three areas. The first location is Zafarana Point, about 50 miles south of Suez on the Egyptian shore. Ushruffee Reef is located on the western side of the Straits of Jubal's navigable channel, 150 miles from Suez. Dzdalus Reef is located in the heart of the Red Sea, 350 miles from Suez and 180 miles from the entrance to the GOS (Parkes,1864).

2.2 Aids to Navigation globally

2.2.1 The importance of AtoN worldwide for safety Navigation

AtoN serve a crucial role in safeguarding the environment by averting maritime disasters that might have a cataclysmic ecological impact on fragile marine and terrestrial ecosystems and, by extension, the entire environment (IALA, 2017a). Consequently, the absence of navigational aids or their failure as a consequence of any external cause in a heavy navigation area can lead to marine accidents or disasters, resulting in the loss of life and property. For example, according to the United States Coast Guard (USCG), Hurricane Katrina destroyed around 63 percent and 87 percent of all AtoN in New Orleans, Louisiana, and Mobile, Alabama, respectively (USCG, 2005). It led to the closure of eleven Gulf Coast ports, which reopened four days later amid shipping problems. Four weeks after the storm, however, 500 AtoN remained unrepaired (Caldwell, 2006).

When AtoN fail due to vessel collisions or inclement weather, they constitute a navigational danger to a variety of users, including ship operators. For example, Busan Port, the largest cargo port in Korea, has seen over 400 navigational mishaps with AtoN in the past twelve years (2006-2017) (Kim & Moon, 2018). Therefore, constructing AtoN necessitates considerable deliberation to maximize their effectiveness and utility. According to research conducted by Dimailig et al. (2017), insufficient AtoN and a lack of maintenance of Maritime Buoyancy Systems (MBS) at light stations are the leading causes of marine accidents in the Philippines. In addition, the location of light station AtoN was riddled with inconsistencies and problems. It was because the navigator's visible recognition level should be utilized to establish the optimal placement of AtoN (Fang et al., 2015).

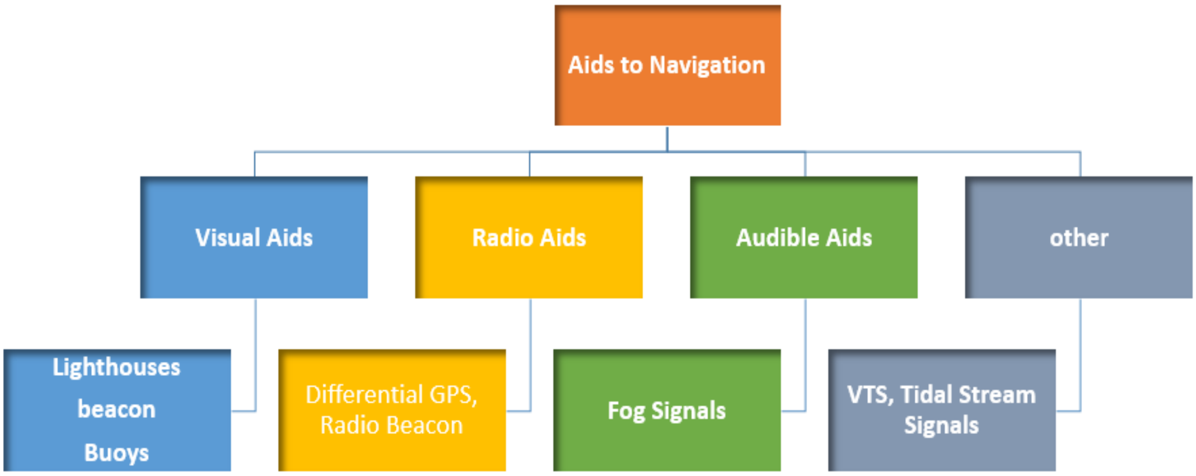
Another illustration demonstrates the relevance of AtoN's absence in the Red Sea, where coral reefs jeopardize marine safety close to the coast. The "Salem Express" was a roll-on, roll-off ferry for automobiles and passengers in the Mediterranean that debuted in 1966 under the name "Fred Scamaroni" in France. It measured 100 meters in length and 18 meters in width. In 1988, it was sold to the Samatour Shipping Company, which began operating it as the Salem Express between Safaga and Jeddah. On December 17, 1991, the vessel returned to Jeddah with hundreds of pilgrims who had recently visited Mecca. People on the outside decks were wet due to the gale-force winds, so the skipper chose to stay close to the shore in order to save time rather than take the lengthier trip via the outer reefs. Sadly, the skipper underestimated their location, and just after midnight, the ship collided with an outlying pinnacle of Hyndman Reef. The consequences were devastating. In addition to water entering via a breach on the port side, the impact also forced the bow loading door to open, allowing thousands of gallons of water to enter. The crew could not launch any lifeboats because the ferry began listing to the port side almost immediately, making it challenging to do so. The Salem Express sank 20 minutes after striking the reef (maritimecyprus, 2018).

2.2.2 Type of AtoN and related function

It is crucial for vessels' safe and effective navigation to recognize their precise position and keep a constant course. AtoN are designed to aid vessels in navigating where land markings are not visible and in locations with dense vessel traffic, small channels, and hazardous impediments. Lights, shapes of things, colors, sounds, and radio waves help vessels determine their whereabouts (Tokokai, n.d.). As a result, the AtoN vary depending on their role in safe navigation and the location they are situated in.

Figure 4

Types AtoN and some examples for each type (created by the author)



As it is shown in Figure 4, the types of AtoN are visual aids, radio aids, audible aids, and other different systems.

1- **Visual Aids**

First, the visual aids may be identified by the color and rhythm of the light at night, as well as by the construction, shape, and color of the tower during the day. The visual aids are lighthouses, beacons, and lighting buoys.

a. Lighthouses

Lighthouses are towers with flashing lights and fog horns positioned in critical or hazardous areas. They inhabit stony cliffs or sandy shoals on land, wave-swept reefs in the ocean, and port and bay entrances. They serve to alert seafarers of dangerous shallows and treacherous rocky coastlines and to direct vessels into and out of harbors safely (NOAA, n.d.).

Figure 5

Example for lighthouses in the red sea Abū el-Kizân (Daedalus Reef) and akhawieen lighthouses (EAMS, 2021b)

For example, as shown in Figure 5, the lighthouse Abū el-Kizân (Daedalus Reef) was constructed in the Red Sea more than a century ago and is still operational with a focal plane of 30 m (98 ft); three white flashes, in a 1+2 pattern, every 12 s. The tower is coated with horizontal stripes of black and white paint, a Fresnel lens in use. It is located on a reef that barely breaks the surface of the water, approximately 100 kilometers (60 miles) east of Marsa Alam, and is only accessible by ship (ibiblio, 2021).

b. Beacons

Beacons are structures permanently affixed to the seafloor or land. These include buildings like lighthouses and single-pile poles. Most beacons are equipped with a lateral or non-lateral assist. Lighted beacons are referred to as "LIGHTS" whereas unlit beacons are referred to as "DAYBEACONS" (BoatUS Foundation, 2022).

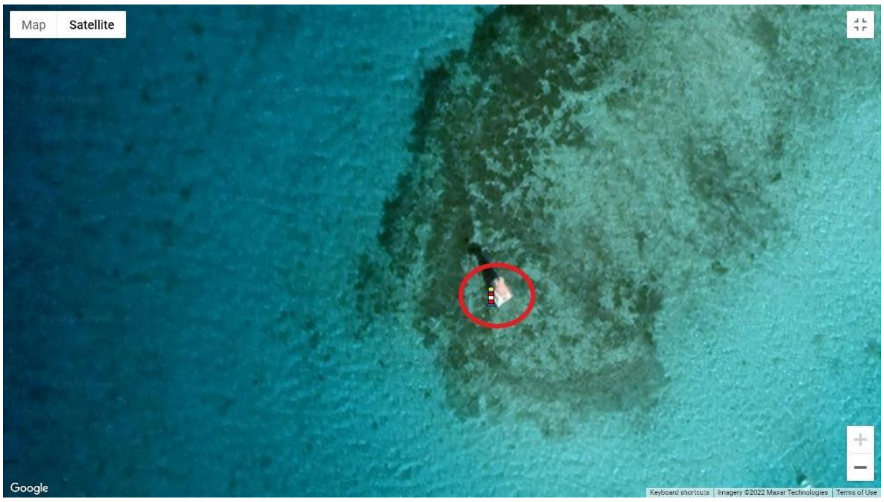
Figures 6 and 7 show an example of an offshore beacon placed on shoals and reefs to alert navigational routes of the presence of hazardous obstructions.

Figure 6

Beacon Abū Minqār Light, Ghardaqah (ibiblio, 2021)

Figure 7

Elevation of a vertical perspective of Bacon Abū Minqār Light, Ghardaqah



Note: created by author using google maps

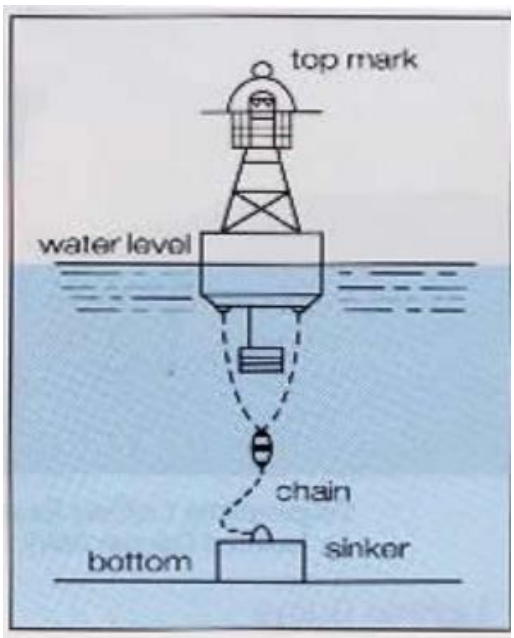
The Beacon Abū Minqār Light, shown in Figure 6, is located in Hurghada City in Egypt. It is a 9 m (30 ft) spherical hourglass-shaped fiberglass tower set on a stone pier. The entire beacon is crimson. It is located near the southeast end of a reef opposite the Hurghada shoreline. It is apparent in Figure 7 that the importance of this beacon is related to the spread of coral reefs in this area. The beacon warns the ships to avoid this area to avoid being grounded by coral reefs.

c. Buoys

A buoy is a form of an item that floats in water and is employed amid the seas as a locator or warning point for ships. Buoys are often in bright (fluorescent) colors (Trinity House, 2016). Lighted buoys float in the water at the entrance of a fixed channel, the channel's center, the channel's left and right boundaries, and the turning points. In addition, the buoys identify reefs, shoals, and other impediments in the vicinity of the channel. As shown in Figure 8, a chain connects the buoy body on the top of the water to a sinker at the bottom of the water. As with permanent lights, the color and light characteristics of lit buoys are selected in line with the IALA Maritime Buoyage System based on the intended use of the buoys. The buoy denoting the channel's middle is known as the "Safe Water mark." The body is painted with horizontal red and white stripes; the light is white, and the top mark is a single red cylinder. The safe water mark is established in regions with no obstructions in the adjacent waterways (Tokokai, n.d.).

Figure 8

Details of the light buoy (Tokokai, n.d.)



d. Leading Lights

According to the IALA (2017b), the leading lights are a collection of two or more markers or lights in the same vertical plane, allowing the navigator to follow the leading line while maintaining the same heading. Its structures may be any color or shape that provides a distinctive feature that cannot be mistaken for an adjacent structure.

a- Others

Many other visual aids like sector lines and projectors are also available. However, the design of AtoN depends on the decision of the established country related to the needs of AtoN in a specific location.

1- Radio Aids

Radio AtoN are tools that help find the way by using radio waves. The radio navigation assistant system is called the radio tool that helps find the way. Ships can see their positions even when it is raining or foggy, and visibility is low (Tokokai, n.d.). For example, racon is considered as one of significant radio aids. It consists of three primary components, namely a receiver, a transmitter, and an antenna shared by the receiver and transmitter. Each time the radar antenna points towards the racons, a radar within range of the racons queries the racons. The racons receiver detects the signal-interrogating radar and activates the racons transmitter. The transmitter may respond with a single pulse for each trigger, but the typical response for racons identification is a series of coded pulses like the Morse code (Government of Canada, 2011). In addition, the Differential Global Navigation Satellite System (DGNSS) considers a radio aids, which sends the correction of the error in the Global Navigation Satellite System (GNSS) for ships.

2- Audible aids

Audible navigational aids use the navigators' sense of hearing. When fog or snow makes it hard to see, sound signals are sent to ships to tell them where the sound is coming from. Fog signal stations are what people call these places. Each station plays different sounds at set times. The main way fog signals which are sent is with a system called a diaphragm. The distance to be travelled is short, and the direction of the wind, its speed, noise on the ship, and other obstacles make it harder to get there. Reflection is not a good way to figure out which way to go, and since the distance to be travelled is not fixed, the number of audible aids is going down. Most fog signal stations are part of lighthouses on the coast (Tokokai, n.d.).

3- Other AtoN

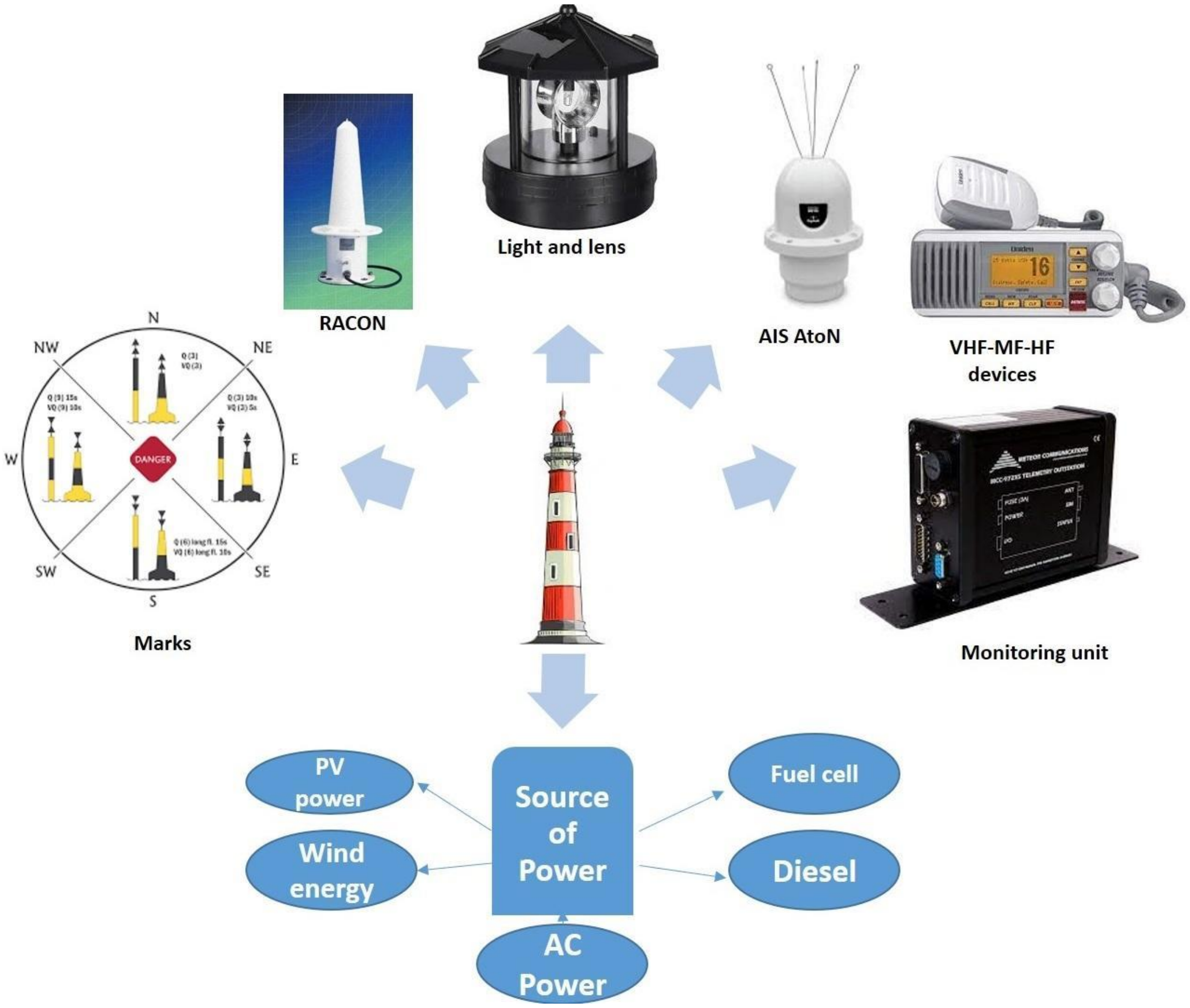
Many other AtoN were not classified above. For example, VTS Stations gather data on the movement of vessels within ports, certain waterways, adjacent waters, and regions with considerable traffic and notify the position of the vessel and the movement of other vessels through wireless telephones (Tokokai, n.d.). Further, Tidal Stream Signal stations are facilities that inform mariners of the direction and velocity of tidal currents in straits with tidal solid currents using light signal boards, unique features, lights, and radio telephones (Tokokai, n.d.).

2.2.3 The technical equipment of AtoN

Not all of the components requested below could be included in a single AtoN. Depending on the nature of its geographical position and the role of AtoN, the site typically has a set of different signals, such as a radio, lighting system, or warning sign. Some governments or groups responsible for navigational aids in their respective nations have realized that navigational aids must contain many signals to ensure that any of these signals reach the passing vessel. However, as stated in the above paragraph, some AtoN only transmit a single signal. As shown in Figure 9, the AtoN may send one or different signals. The signals may be visual, such as light and marks. Other signals may be radio signals like racons, AIS AtoN, and VHF-MF-HF devices. In addition, the monitoring unit is responsible for sending the technical status to the control center, which monitors the technical status for all AtoN and takes action if necessary.

Figure 9

Sample for Comprehensive AtoN for most of the signals broadcast utilizing several power sources (created by the author)



1- Lighting

Before the beginning of the industrial revolution and the lighting industry in the early 20th century, all artificial lights were created by fire. Wooden pyres, used until the 18th century, gave way to oil wick lights, vaporized oil and gas burners, electric arcs, and tungsten filament lamps. Optical equipment accompanied these advancements, initially with reflector systems and afterward with lenses. It is noteworthy that attempts to understand human perception of light and to increase the efficiency and efficacy of AtoN illuminating and optical equipment have been at the forefront of scientific endeavors for several decades. The lens design pioneered by Fresnel in 1820 continues to be an essential component of current AtoN lighting. However, Modern lenses, are frequently composed of plastic rather than glass. While a minority of nations still employ gas lights that burn acetylene or propane, most AtoN lights use various types of electric light sources (IALA, 2011).

These light sources are increasingly fuelled by renewable energy sources, including the sun, wind, and waves. Optical equipment for lighthouses and beacons is typically a patented product; however, lighthouse administrations have occasionally built their own optical equipment. Some electric bulbs have been built specifically for AtoN applications, especially for tiny beacons used in large quantities. However, bulbs chosen from the vast selection of commercially available items have also been utilized or adapted for AtoN equipment. Light-emitting diode (LED) technology is advancing quickly as a standalone or arrayed alternative light source. The development of robust and efficient white LED components has surpassed the development of color LED components due to lighting application requirements for mass markets (IALA, 2011).

2- Racons

As mentioned above, racons are radio devices. IALA set some guidelines for racons to ensure the effectiveness of their work. racons working on the 9 GHz and 3 GHz bands should typically be provided for ship Radar compliance (IALA, 2004). The codification of racons should adhere to IMO resolution A.615(15) (IMO, 1987).

3- AIS AtoN

An Automatic Identification System (AIS) is a VHF marine mobile band-operating autonomous broadcast system. Ships have AIS devices onboard. AIS facilitates sharing vessel identity, location, course, and speed information between mobile and base stations. The main goal of using the AIS at AtoN is to improve and increase the safety and efficiency of navigation by the dissemination of Application Specific Messages, such as the marking or delineation of tracks, routes, locations, and boundaries (such as areas to be avoided and Traffic Separation Schemes (TSS)). In addition, it identifies offshore structures (such as wind turbines, wave and tidal energy devices, and oil and gas platforms) and giving weather, tide, and sea status information (IALA, 2021). Many other essential functions will be described later in this research.

4- Marks

A mark is a signal available to a mariner to provide navigational advice. The MBS and other AtoN offer the following sorts of markers that can be combined (IALA, 2017b). There are six beacons and buoys under IALA-A or IALA B: lateral marks, cardinal marks, isolated danger marks, new wreck marks, safe watermarks, and other unique marks (IALA, 2017b). For example, isolated danger marks in black-and-red stripes cover the building with white light. The top marks are two black balls. The light signifies an impediment nearby.

Further, cardinal marks are used in combination with the compass to show the direction of the deepest navigable water from a mark, to identify a bend, junction, or fork in a channel, or to mark the end of a shoal (Trinity House, 2016). Furthermore, lateral marks, utilized in conjunction with a "traditional direction of buoyage," are generally applied to clearly defined waterways. These symbols show the port and starboard sides of the path to be followed. Where a channel divides, a modified lateral mark may be used to indicate the preferred course (IALA, 2017b).

5- Very High Frequency (VHF), Medium and high frequency (MF & HF)

Some lighthouses are equipped with VHF, MF, and HF stations to broadcast navigational warnings or update information. For example, China's Maritime Safety Administration announced that all five lighthouses are between 50 and 55 meters tall and equipped with AIS and VHF radios, allowing vessels to receive navigational information and alerts from the lighthouses (safety4sea, 2016).

6- Remote, Control, and Monitoring System (RCMS)

A remote monitoring system can monitor many locations or systems remotely. Existing remote monitoring systems can connect to various communication networks, including cellular, terrestrial, satellite radio, microwave links, landline telephones, and the Internet (IALA, 2009a). The aims of RCMS differ based on the administration's policies, the type and significance of the AtoN being monitored, and the local conditions. RCMS may connect one or several hundred Remote Terminal Units

(RTUs) to a central monitoring station. The RTU offers a mechanism for transmitting and receiving data between the central monitoring site, AtoN equipment, and auxiliary devices. According to the administration's design for RCMS, it provides the operator with information and control proportional to his degree of skill (IALA, 2009a). The system could identify the failure of AtoN, assume the availability of AtoN, assist in the maintenance of AtoN, and reduce the cost of maintenance. Typically, for each piece of equipment at an AtoN, a typical set of standard signals is often provided, like navigation lights, racons, AtoN AIS, DGPS, power supplies, ancillary systems, and sensors (IALA, 2009a).

7- Sources of power

Many power sources are used to supply and operate the equipment inside the AtoN. First of all, the main power or the Alternating Current(AC) could be available as the primary concern at the site or nearby. Wherever dependable AC power is accessible, it should be the chosen energy source. In order to prevent AtoN failure in the event of a power loss and avoid a negative impact on the availability, backup solutions may be implemented (IALA, 2017c). In addition, the AtoN Photovoltaic (PV) power system consists of a PV module, solar cells, a charge regulator, and a secondary battery. PV power systems are a well-established technology, and equipment is readily accessible from various vendors. When correctly constructed with protection from the maritime environment in mind, PV power systems are very dependable and the most popular renewable energy source for charging secondary batteries (IALA, 2017c).

Further, wind energy is a renewable energy source that might be explored for powering AtoN. As part of a hybrid system, the wind generator can be employed as a supplementary source of power generation. There are wind turbines with both vertical and horizontal axis configurations. Furthermore, fuel cell technology is very new and continues to evolve. Regarding AtoN in remote locations, the fuel cell can be utilized as a primary energy source or in conjunction with a PV or wind generator (a hybrid system). Finally, diesel generators are utilized to meet high power demands on fixed AtoN in isolated locations or as a backup for grid electricity. When feasible, diesel generators should be replaced with renewable energy systems. Diesel production may function as the reserve portion of a hybrid system or as an emergency power source. When domestic electricity is required, installing a diesel generator system could be deemed appropriate (IALA, 2017c).

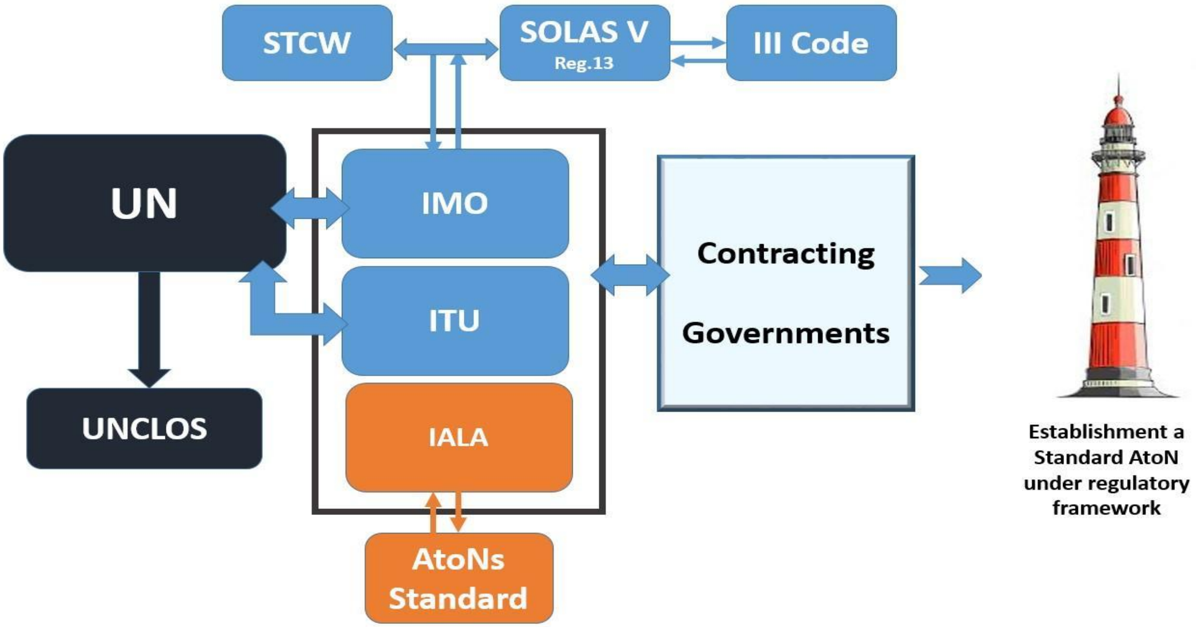
2.3 AtoN under regulatory framework

The creation and development of AtoN are governed by a set of regulations and guidelines established by international organizations such as the United Nations (UN), the IMO, the International Telecommunication Union (ITU), and IALA. However, the IALA is still non-Intergovernmental organization (IGO), but it is on the way, as it will be described later. Figure 10 shows the international organizations that collaborate and integrate to establish and enhance AtoN by formulating regulations. In 1982, the United Nations Convention on the Law of the Sea (UNCLOS) was ratified. It establishes a comprehensive system of law and order in the world's oceans and seas, regulating all uses of the oceans and their resources. In addition, the IMO is considered a competent agency of the United Nations (UN). It promotes safe, secure, ecologically efficient, and sustainable shipping via cooperation. In addition, the IMO has enacted several conventions and codes and is continually revising them to maintain the safety and security of efficient navigation and to avoid and battle marine pollution (IMO, 2019).

Further, the ITU is a specialized body of the United Nations for information and communication technologies (ICTs). Furthermore, IALA is an international, non-profit technical association. It was founded in 1957 and allowed Marine AtoN authorities, producers, consultants, and scientific and training institutes from all around the world the chance to discuss and contrast their experiences and accomplishments.

Figure 10

The regulatory framework under international organizations (created by the author)



2.3.1 Sovereignty under UNCLOS

The Convention is commonly recognized as a constitutive instrument that offers a fundamental legal framework that was supposed to be reinforced by other international agreements, most of which are developed through the IMO (Allen, 2009). The UNCLOS, which was finalized in 1982 and has been in effect since 1994, provides the flag state with primary responsibility for maritime navigation safety. Coastal and port states have the authority and, in certain instances, the responsibility to implement maritime safety and pollution prevention measures. Article 21 of the UNCLOS permits a coastal state to adopt laws and regulations pertaining to foreign vessels in innocent passage through the territorial sea, so long as these laws respect the safety of navigation and the regulation of maritime traffic, among other things. In addition, under Article 22, Sea lanes and traffic separation in the territorial sea, when it is essential for the safety of navigation, the coastal state may force foreign ships exercising the right of innocent passage in its territorial sea to employ the sea lanes and traffic separation schemes it has designated or prescribed for the passage of ships.

In designating sea lanes and prescribing traffic separation schemes pursuant to this article, the coastal state should consider the recommendations of the competent international organization, the distinctive features of individual ships and channels, and the traffic density. The coastal state must clearly mark such sea lanes and traffic separation systems on maps and due publicity should be given. Furthermore, Article 262, as regards installations or equipment mentioned in this article, must be marked with the name of the country where they are registered or the name of the international organization to which they belong. They must also have warning signals agreed upon internationally to ensure safety at sea and in the air, considering the rules and standards set by competent international organizations (UN, 1982).

Thus, UNCLOS offers the basic framework for navigation safety measures within or outside the territorial waters of a coastal state. At the same time, other treaties or conventions, most notably the SOLAS Convention, give further specificity (Allen, 2009).

2.3.2 Costal state duties as member state in IMO

The International Convention for the Safety of Life at Sea (SOLAS), as one of the significant conventions adopted by IMO, in Chapter V regulation 13, establishment and operation of AtoN, mentioned the significance of the establishment of AtoN. It states that each Contracting Government agrees to provide, as it considers possible and required, AtoN as traffic volume and risk necessitate. Contracting Governments should follow international guidelines and regulations when creating aids to navigation. It should make information on navigational aids accessible to all parties involved. Changes in the transmissions of position-fixing systems that might have a negative impact on the performance of receivers installed on ships should be avoided as much as feasible and implemented only after timely and proper notification has been sent (IMO, 2022).

In addition, the III codes addressed the rights and obligations of the coastal state. Various international instruments confer certain rights and duties on coastal states. When coastal states use their rights under these accords, they incur extra liabilities. A coastal state should ensure that its legislation, guidelines, and processes are in place for the continuous execution and verification of its rights, obligations, and responsibilities outlined in the relevant international agreements to which it is a party. These rights, responsibilities, and duties could include, but are not limited to, radio communication services, meteorological services, maritime warnings, search and rescue services, hydrographic services, ship routing, ship reporting systems, vessel traffic services and AtoN (IMO, 2013).

On the other hand, in the context of the International Convention on Standards of Training, Certification, and Watch keeping for Seafarers (STCW), officers in charge aboard ships with a gross tonnage of 500 tons or greater must meet the minimum criteria for navigational watch knowledge, awareness, and competency. Officers must be able to identify the ship's location using landmarks, AtoN such as lighthouses, beacons, and buoys, and dead reckoning, while taking into consideration winds, tides, currents, and expected speed (IMO, 2017a).

2.4 IALA and AtoN.

IALA allows all AtoN authorities and the relevant parties to discuss and share their expertise. Several international technical committees have been created to consider the demands of seafarers, technological advancements, and the requirements and limits of AtoN authorities. Through the publication of IALA standards, recommendations, guidelines, and model courses, the work of the committees aims to create standardized best practices. This effort assures that Marine AtoN will continue to satisfy the demands of seafarers in the future. Consequently, IALA helps with the prevention of maritime accidents, the protection of life and property at sea, and the preservation of the marine environment. IALA also supports nation-to-nation collaboration to help developing nations create AtoN networks according to the risk level of the waterway in question (IALA, 2022). It is concluded that IALA aims to promote the safe, economic, and efficient movement of boats via the global enhancement and harmonization of marine AtoN and other suitable measures for the benefit of the maritime community and the preservation of the environment. IALA is apolitical and secular. IALA unites services and organizations involved with supplying or maintaining maritime AtoN and linked operations at sea and inland waterways (IALA, 2022).

2.4.1 IALA instruments

IALA sets an IALA standard, which is a component of a framework whose application by all coastal governments would result in global harmonization of marine AtoN. Non-mandatory IALA standards involve technology and services. Further, an IALA recommendation describes the procedures that must be implemented to comply with the recommendation and may be cited in whole or in part in an IALA standard. Furthermore, IALA adopted guidelines to clarify the implementation practices in the recommendations. Moreover, catalogues provide a comprehensive overview of a specific subject. Currently, this consists of the NAVGUIDE, the VTS Manual, and the CLU Manual. The NAVGUIDE covers all areas of AtoN and is updated at each IALA conference every four years. The VTS Manual includes all areas of Vessel Traffic Services and is updated at each symposium every four years (IALA, 2022).

Generally, IALA requirements should be adhered to by all maritime AtoN. In order to establish an AtoN, it is necessary to adhere to several specific regulations and processes. It guarantees that AtoN are globally standardized and uniform while recognizing that their needs vary based on their function and purpose. Regarding inland navigation, where there is now no unified legal framework, the situation is drastically different. Internal waters, also known as interior waters, are subject to the country's total sovereignty as if they were a part of its land mass (FARLEX, 2019).

2.5 Implementation AtoN in Egypt under the regulatory framework

2.5.1 International Conventions

Egypt was among the 51 founding nations of the United Nations, whose membership started with the organization's establishment on October 24, 1945. As a result, Egyptian policy has been positioned to be in the vanguard of the world's founding countries of the United Nations (SIS, n.d.). Egypt has been involved in UNCLOS since it was signed on December 10, 1982. UNCLOS entered into force on November 16, 1994, when the ratification instruments of sixty nations were placed.

In addition, in 1958, Egypt became a member of IMO. It approved SOLAS 74 and many other related conventions adopted by IMO (MTS, 2022). Further, Egypt is considered one of the 27 states that signed the Convention on IALA on January 26, 2022. IALA is a competent organization for AtoN, and it has an essential role in the safety of navigation, as mentioned in the previous part of this chapter. Furthermore, Egypt signed and ratified the Constitution and Convention of the ITU on May 15, 1996 (ITU, 2022). Egypt is evidently one of the earliest nations to engage in international organizations and to observe its rights and responsibilities under international conventions.

2.5.2 National legislations

Egypt issued much national legislation related to the international conventions ratified. It issued decisions to ensure compliance with UNCLOS and other conventions. For example, President Decision No. 145 in 1983 agreed to ratify the UNCLOS. Further, the governmental decision in 1951 addressed the Egyptian national coastal area. Moreover, President Decision No. 27 in 1990 addressed the baseline for territorial waters (Official Bulletin, 1990). The marine zones of Egypt, comprising its internal waterways and a twelve-nautical-mile territorial sea, were outlined in two annexes appended to decree No. 27 of 1990 by the President of the Arab Republic of Egypt. The passage of nuclear-powered and comparable ships in Egypt's territorial waters was also noted in Declaration No. 27 of 1990. Considering the Egyptian proclamation, it is evident that Egypt would not adhere to any agreement that is not part of it addressing the precautions that nuclear ships must take. Moreover, the prior notification ensures the passage of warships in the territorial waters without incident (Official Bulletin, 1990).

Therefore, Egypt uses various government instruments to ensure the safety of navigation in its territorial waters. According to the Egyptian president decision no.399 article 3 issued in 2004, the Egyptian Authority for Maritime Safety (EAMS) is responsible for planning, developing, installing, monitoring, upgrading, and maintaining AtoN throughout all national coastlines, territorial waterways, and EEZ, as well as granting relevant licenses and certification (Official Bulletin, 2004).

Although EAMS is the leading player in AtoN and all related issues, it is not the only organization with the same approach. There are many other stakeholders in the work system with EAMS as follows:

1- The Egyptian Navy Hydrographic Department (ENHD) is Egypt's national hydrographic office. ENHD reports directly to the Egyptian Naval Headquarters. The department's responsibilities include but are not limited to hydrographic security for Egyptian fleets, coastal zone management, nautical/electronic charts and goods for Egyptian territorial waters, maritime safety information and navigation, and coastal zone management. ENHD is the Egyptian government's official representative to the International Hydrographic Organization (IHO) and the hydrographic commissions of the Mediterranean Sea and the Red Sea (ENHD, n.d.).

2- The National Telecom Regulatory Authority (NTRA) was established under the legal foundation for implementing and enforcing the Telecommunications Law of 10/2003. A Marine Communications Services Directive governs the processes that NTRA is responsible for being the National Data Provider by registering the data of all types of radio and wireless communications devices, particularly distress devices of Egyptian ships using the COSPAS SARSAT System, issuing radio licenses for Egyptian vessels, registering Egyptian ship's data at ITU (List of Ship Stations), and issuing General Operators Certificates (GOC) to radio operators under STCW 78 (NTRA, n.d.). The ENHD and NTRA are considered the most important stakeholders for EAMS in all issues relevant to AtoN in Egypt. However, there are many other stakeholders like the Maritime Transport Sector (MTS), port authorities, Suez Canal Authority, Ministry of Environment, and Ministry of Affairs.

2.6 Chapter Summary

To sum up, this chapter provided a literature review in relation to AtoN. A brief overview of their history revealed that they have been in use for several thousand years. Egypt had the first AtoN in the world. In 260 BC, Greece constructed the Pharos Lighthouse in Alexandria. In the modern era, during the construction of the Suez Canal, which began in 1859, the Egyptian government devoted careful attention to the importance of constructing AtoN in the GOS. It is due to the growth in the number of ships transmitting the GOS and the GOS's geographical characteristics. Numerous coral reefs are haphazardly positioned within the bay.

AtoN preserve the environment on a global scale by preventing maritime disasters that can impact fragile marine areas. There are numerous sorts of AtoN, including visual, audio, radio, and unidentified types. Common varieties such as beacons and beacons send many signals to passing vessels. For instance, AtoN transmit lighting signals, racon signals, AIS AtoN signals, and specific devices like VHF, MF, and HF to ships sailing within the operating range of AtoN. Some AtoN have a remote monitoring device for AtoN administrators to assess the AtoN technical conditions.

The power supply of AtoN differs. The designer makes a decision based on the location and neighboring hydrographic region. For example, the power sources include alternating current, photovoltaic systems, wind energy, fuel cell technologies, and diesel generators. AtoN are managed following international regulations. Beginning with the UNCLOS, the IMO, ITU, and IALA participated in its establishment. However, IALA is a specialist organization in AtoN that gives suggestions and guidelines for establishing, installing, designing, and maintaining AtoN. AtoN in Egypt are governed by national law no.399, article 3, issued in 2004. The EAMS is responsible for planning, implementing, monitoring, updating, and maintaining AtoN in all national regions, considering the aforementioned international instruments.

3. AtoN in Egypt: Current State of Affairs

3.1 Egyptian AtoN in brief

The EAMS, as mentioned before, is the leading player in planning, designing, installing, monitoring, modifying, and maintaining AtoN throughout all national coasts, territorial waterways, and EEZ. EAMS (formerly Ports and Lighthouses Authority (PLA)) is one of the oldest governmental authorities in Egypt, as its establishment dates back to 1830. In 2004, according to the president's decision 399, the EMAS had additional missions shown in the decision. The EAMS is the maritime administration for coastal states, flag states, and Port State Control. EAMS provides AtoN in Egyptian coastal and territorial waters, publishes publications and navigational alerts, and investigates marine accidents (EAMS, 2021c). The EAMS constantly interacts with international organizations such as IMO, IALA, and the European Maritime Safety Agency (EMSA).

3.2 Egyptian AtoN operation overview

Each AtoN has a distinguishing mark, and the navigator recognizes it as soon as he sees it by the shape and color of the AtoN during the day. However, at night, the navigator recognizes it by the range of the light, the way it flashes, its color, the time intervals between each flash, and the estimated visibility of the AtoN in nautical miles. The AtoN is illuminated minutes before dusk and extinguished minutes after dawn. As for locations experiencing dense fog, they remain illuminated throughout their duration (EAMS, 2021a). Some AtoN are guarded by a whole crew who take turns serving in them, and at dusk, they illuminate them with electricity. Other AtoN are not guarded and run automatically on solar power. In the El-Max area of Alexandria, a monitoring center is equipped with computers and wireless devices for identifying technical issues in AtoN all over Egypt so they may be repaired (EAMS, 2021a).

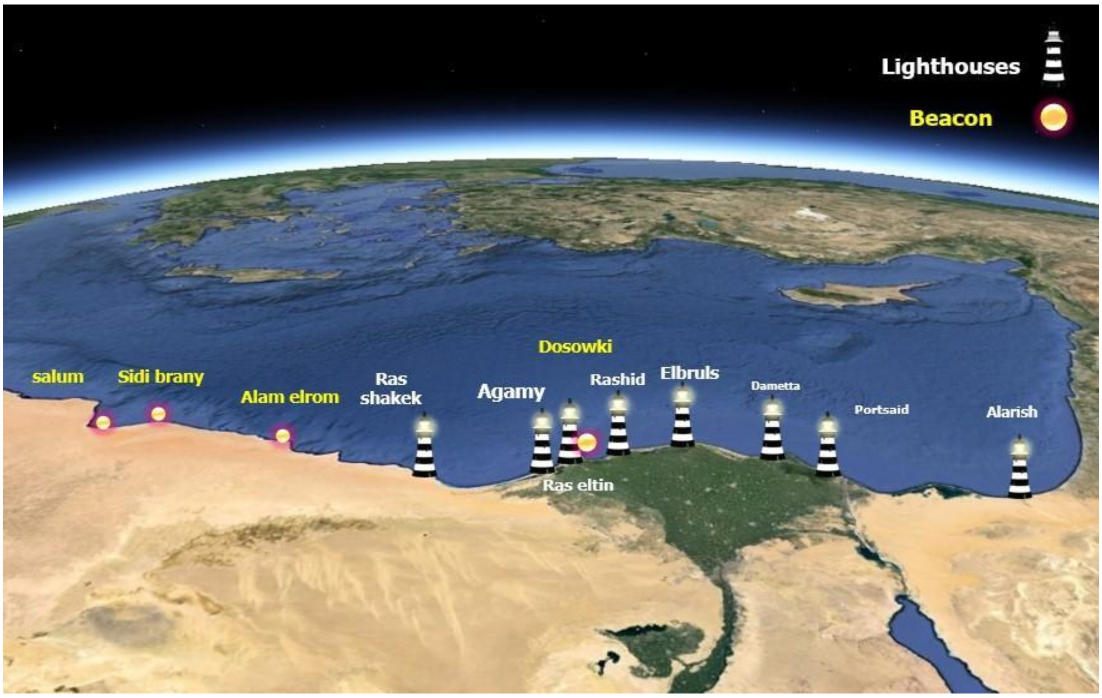
The EAMS divided the AtoN according to their geographical location into AtoN at the Red Sea, AtoN at the coastal area of the Mediterranean Sea, and the isolated lighthouses at the Red Sea as follows: -

a. AtoN at the coast of the Mediterranean Sea

According to EAMS (2021d), the AtoN in the Egyptian coastal area of the Mediterranean Sea are eight lighthouses, four beacons, and around eight entry marks and leading lights. As shown in Figure 11, the lighthouses and beacons are dispersed throughout the northern shore of Egypt in accordance with the hazards posed by ships navigating neighboring waters from the perspective of the AtoN designer (EAMS, 2021d).

Figure 11

The Lighthouses and beacon at the coast area of The Mediterranean Sea (created by the author)



b- the Isolated lighthouses at the Red Sea

As shown in Figure 12, only four isolated lighthouses are situated in the middle of the Red Sea. These lighthouses are all manned by operators, and every 40 days, the Aida IV, the governmental ship, visits them to replace the staff and provide fuel for the diesel engines. Over the past century, they have been built over the largest reef islands in the Red Sea. Due to the vast coral reefs in these areas, these lighthouses are vital to international navigation as they alert ships to avoid getting grounded (EAMS, 2021b).

c- the AtoN at the Red Sea

Most AtoN are located in the Red Sea region, including the Gulf of Aqaba and GOS. Various AtoN, such as lighthouses, beacons, buoys, leading lights, and entrance beacons, can be found in these areas. AtoN are distributed in danger zones in coastal and mid-gulf regions, entrance ports, and TSS (EAMS, 2021e; UKHO, 2022).

Figure 12

The locations of Isolated Lighthouses at the Red Sea using Hydrographic Office Maps (created by the author).

3.3 AtoN Fault recognizing

As previously explained, the AtoN contain several devices and equipment that may be susceptible to malfunction owing to external factors such as the end of the device service life, operator mistake, an increase in weather temperature, battery issues, and numerous other associated technical concerns. For EAMS to fulfill its duties as the authority responsible for AtoN, it receives defects from various sources.

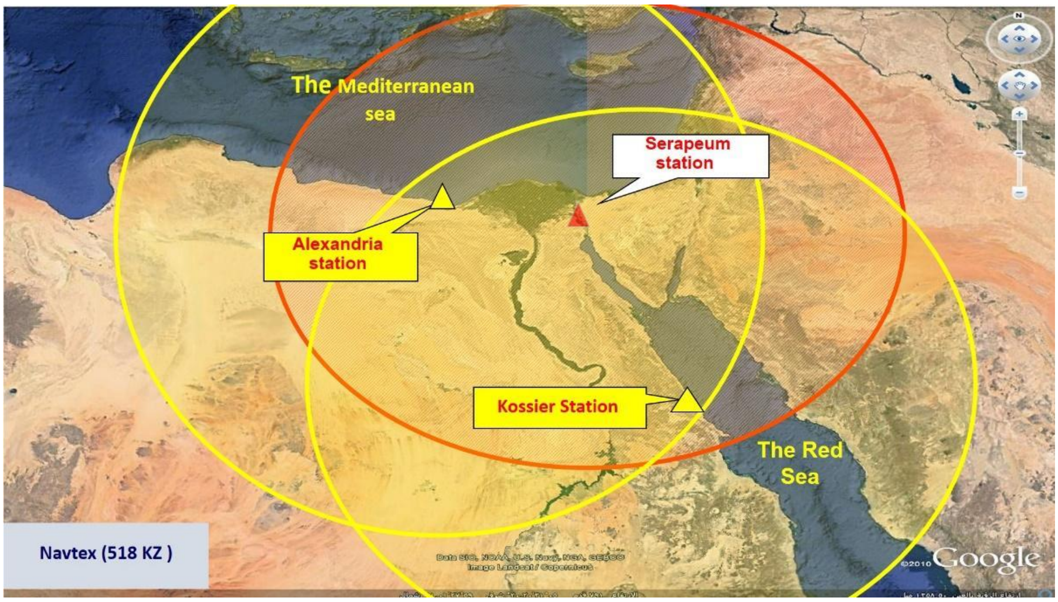
First, most AtoN are equipped with a monitoring device that relays technical incidents to the EAMS monitoring center. In addition, petroleum companies are operating in certain offshore regions where the existence of idle AtoN provides significant navigational difficulties for their ships. Further, shipping companies with vessels frequently use Egyptian shores.

Additionally, the ENHD by Navy ships investigated the failure in AtoN. Moreover, the port authorities ask EAMS to fix any errors in entry marks. Finally, the government ship Aida IV, on its regular voyages, provides a full report about the technical statutes (EAMS, 2021f). After receiving the errors, the EAMS performs two actions. First, it dispatches its technical team or asks the firm responsible for installing the AtoN to resolve the issue. Second, if the problem is expected to last for a long time, EAMS sends a nautical alert through NAVTEX stations to all ships in the area that are traveling near the failed AtoN (EAMS, 2021g).

The NAVTEX stations broadcast the Maritime Safety Information (MSI) and other specific navigational warnings pertinent to the region. Some of these unique navigational alerts are transitory within a specific period. Examples include artillery fire zones, the failure of any AtoN in light or racon, and petroleum extraction in a particular concession region (EAMS, 2021g). Additionally, it transmits persistent navigational notifications. For instance, restoring offshore oil rigs, marine communication lines, an unrecovered or stranded undersea float, or any maritime installation jeopardizes navigational safety (EAMS, 2021g). As shown in Figure 13, there are three NAVTEX stations in Egypt. Egypt's coastal regions are covered by Alexandria station, Serapeum station, and Kossier station. All stations transmit on 518 kHz (the mandated broadcasting frequency) except for the Serapeum station, which possesses both 518 kHz and 4209.5 kHz (IMO, 2017b).

Figure 13

The NAVTEX Station in Egypt



Note: created by author using google map

3.4 The challenges of safety navigation and risk of pollution at GOS

GOS is considered one of the riskiest maritime areas in Egypt because of many factors. Many maritime accidents have occurred, leaving many people injured or dead. In 1990, there were seven incidents/casualties in the GOS; by 1997, this number had climbed to sixteen. Between 1990 and 1997, the total number of occurrences reached 88, with oil pollution, collisions, and grounding serving as incidents (Abelhafez, 1998). In 2014, a collision between a fishing vessel and a cargo ship flying the flag of Kuwait caused 25 deaths in the GOS (Ahram 205 Online, 2014). In addition, GOS is the location with the highest danger of pollution in the Red Sea, namely oil pollution (Ghalwash & Elkawam, 2004). Egyptian officials said in June 2021 that the inspecta 7 ship captain had died and that eleven other crew members had been saved when it sank in the GOS (Marefa, 2021). In general, several elements impact the safety of navigation in the GOS, hence increasing the likelihood of maritime accidents in that region relating to some factors as follows:

3.4.1 Nature geography of GOS

GOS is an area of water located north of the Red Sea. The area of interest (AOI) that spans the whole Gulf is around 175 nm in diameter. In most regions, the GOS is barely 10-15 nm broad, and at its widest, it is around 25 nm (Jica, 2008). Coral reefs are scattered randomly throughout the GOS. The Pleistocene coral reef terraces at Gebel Zeit and Ras Gemsha (western edge of the GOS) have varying heights above the current sea level (El-Sorogy, 2002).

3.4.2 Human activity

The GOS is rich in various natural resources, which encourages humanity to invest in diverse sectors. For example, the GOS is the most productive fishing area in the Egyptian Red Sea, accounting for approximately 64% of total Egyptian Red Sea fish output (Mehanna & El-Gammal, 2007). Further, the region of El-Ain El-Sokhna, located in the northwest portion of the GOS, is distinguished by the existence of human and natural resources, ecosystems, a broad coastal plain, huge tidal flats, and an aquatic environment that supports a significant coral reef. In recent decades, this region has experienced significant and rising changes in land use patterns, notably due to the expansion of tourism, the development of El-Ain El-Sokhna Port and resorts, and the resulting population rise. As a result of the fast development initiatives, the region is currently experiencing environmental contamination and the depletion of natural resources (Abdallah, 2007). On both sides of the GOS, numerous oil rigs and platforms, some of which are designated by lights, provide the most significant navigational risks. Sailors are also warned that some of these buildings are temporary and that they should not rely on written locations. They should be careful when sailing near these buildings and are not allowed to enter certain areas, such as oil fields (UKHO, 2022).

3.4.3 Influence of Suez Canal to navigation in GOS

The Suez Canal is an artificial sea-level canal that connects the Mediterranean Sea to the Red Sea via the Isthmus of Suez in Egypt. The Canal divides the continents of Africa and Asia and provides the shortest marine route between Europe and the regions bordering the Indian and western Pacific seas. It is one of the world's most extensively used maritime waterways (Suez Canal, 2019b). The Egyptian government created a new canal parallel to the current one to maximize the value of the existing Canal and its by-passes and double the longest possible waterway segments to improve traffic in both directions and reduce ship waiting time. It will minimize the time needed to go from one end of the Canal to the other and boost its capacity in anticipation of global commerce expansion. Parallel to the Suez Canal Area Development Project, the two projects will boost the Suez Canal's prominence, making it the preferred route for ship owners globally (Suez Canal, 2019c). As shown in Table 1, the number of ships passing through the Suez Canal increased between 2011 and 2020. Because of this, there will be more ships in GOS, which will make accidents more likely in this area.

In conclusion, the challenge of safe navigation and the threat of pollution in the GOS is extraordinarily significant. The safety of the GOS and pertinent environmental issues are impacted by the inhospitable terrain, high human activity, and heavy traffic of ships passing through the Suez Canal. Therefore, the existence of AtoN in GOS are vital for mitigating accident risk, enhancing marine safety, and preventing pollution.

Table 1

The total number of ships with the net Ton and Cargo Ton for which passed through the Suez Canal from 2011- 2020 (Suez Canal, 2019d)

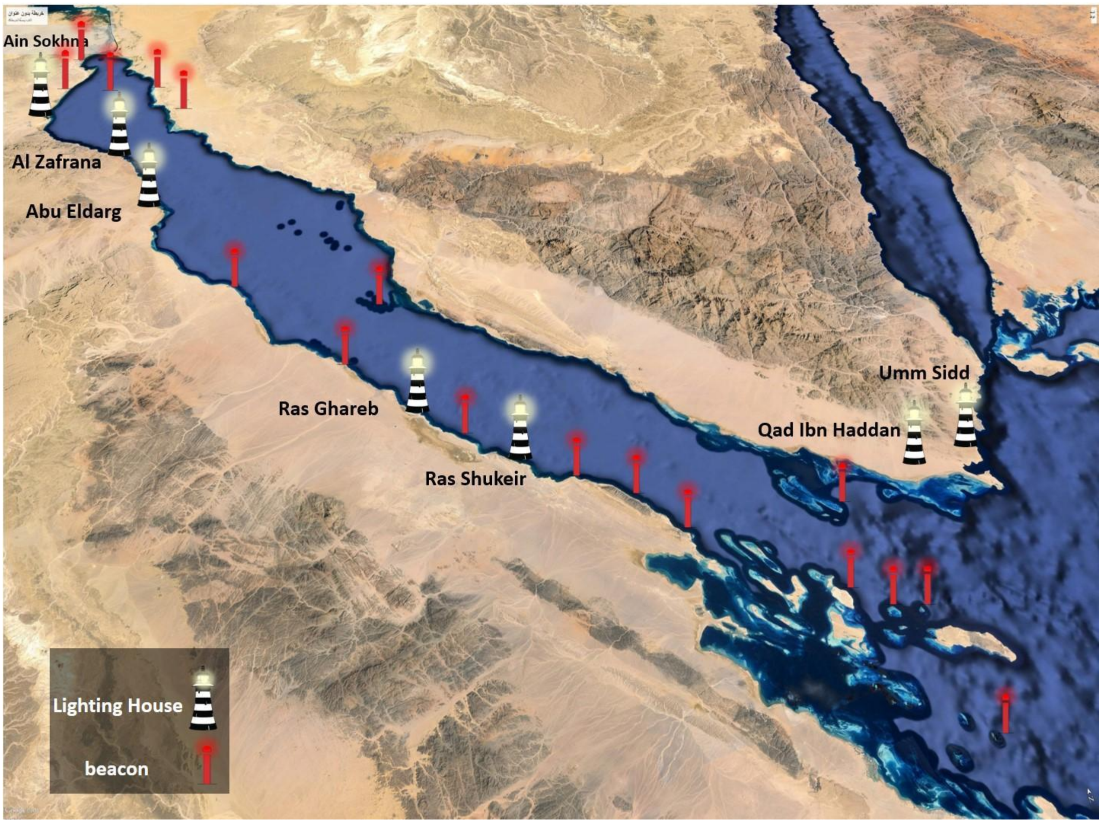
Fiscal Year	No (Vessel)	Net Ton (Ton)	Cargo Ton (Ton)
2011/2012	17,665	938.6M	727.6M
2012/2013	16,663	911.9M	733.4M
2013/2014	16,744	931.2M	784.2M
2014/2015	17,544	992.0M	835.1M
2015/2016	17,252	987.1M	814.8M
2016/2017	17,004	995.1M	860.4M
2017/2018	17,860	1,092.8M	942.4M
2018/2019	18,482	1,174.7M	1,013.9M
2019/2020	19,311	1,210.7M	1,038.9M

3.5 The Lighthouses and beacons in GOS

According to EAMS (2021e), there are seven lighthouses and seventeen beacons in GOS with other types of AtoN such as buoys and DGPS stations. A detailed description of all lighthouses and beacons in GOS with pictures and specifications will be shown in the Appendix A. As shown in Figure 14, the lighthouses and beacons mentioned above cover the whole area of GOS, especially the area of heavy traffic with ships at the last point of the Suez Canal and the area of exit from the GOS, and the vast underwater islands of coral reefs inside the GOS.

Figure 14

The Lighthouses and beacons in GOS (created by the author)



The lighthouses mentioned in Appendix A are situated inside the AOI. Each of them is staffed. The power sources for the lighthouses include leading electricity (city current), diesel, and PV. The signals that lighthouses send out are light and radio by racon and VHF, MF-HF (EAMS, 2021e; UKHO, 2022)

In addition, there are 17 beacons in the GOC listed in Appendix A. Each of them is not staffed. The power source for the lighthouses is PV. The signals that beacons send out are lighting, and some of them have radio signals by racon device (EAMS, 2021c; UKHO, 2022).

3.5.1 Role of EAMS in development the AtoN in GOS

According to EAMS, it is responsible for planning, designing, installing, monitoring, modernization, and maintaining all National AtoN (Official Bulletin, 2004). EAMS has created the majority of lighthouses and beacons with limited technology. For instance, the previous monitoring system has been replaced by a new system that utilizes GSM and satellite technologies. Additionally, some outdated light bulbs were replaced with new LEDs (EAMS, 2021f). However, these advancements are limited and insufficient to ensure ships receive quality. "Admirals List of lights and log signals: eastern Atlantic, western Indian Ocean, Arabian Sea. NP 77 volume D" as one of admiralty publications has cautioned mariners that AtoN in the GOS are unreliable and urged them to report any faulty or misplaced AtoN they encounter while traversing the waterway (UKHO, 2016; UKHO, 2022). After updating the scenario from 2016 to 2022, it is observed that the two editions of the publication are almost identical.

3.6 Chapter Summary

This chapter heightens the AtoN in Egypt. The purpose of the presence of AtoN in Egypt includes guiding ships from a great distance to the port. Additionally, it improves coastal navigation. Further, it indicates the dangerously shallow waterways and islands, such as the islands of the Red Sea, which threaten the safety of maritime navigation. The EAMS classified the AtoN based on their geographical position as AtoN in the Red Sea coastline area, AtoN in the Mediterranean Sea coastal area, and isolated Red Sea lighthouses. It employs monitoring devices put on AtoN to assess and verify AtoN failure. EAMS announces the status of AtoN by using NAVTEX stations and UKHO publications to notify ships in the event of a major fault in AtoN that requires a significant amount of time to repair. The significant ship traffic caused by the presence of the Suez Canal, the random distribution of coral reef islands in the

GOS, and human activity are examples of obstacles to safe navigation and pollution prevention in the GOS.

Consequently, the significance of AtoN in GOS rises in order to ensure the safety of navigation and prevent marine accidents, particularly those involving ships that may run aground on coral reefs. The research scope focuses on seven lighthouses and seventeen beacons in GOS. All lighthouses are staffed and transmit radio and lighting signals to ships. However, the beacons are not armed and only transmit a lighting signal, with some also transmitting a radio signal. EAMS should fulfill its responsibilities to develop and ensure the efficiency of AtoN. However, the UKHO warned seafarers that AtoN in the GOS are unreliable. In this context, the research assessed the function of AtoN in GOS and proposed potential ways to improve their efficacy.

4. Research Methodology, Data Analysis, Findings, and Discussion

4.1 Research Methodology

4.1.1 Introduction

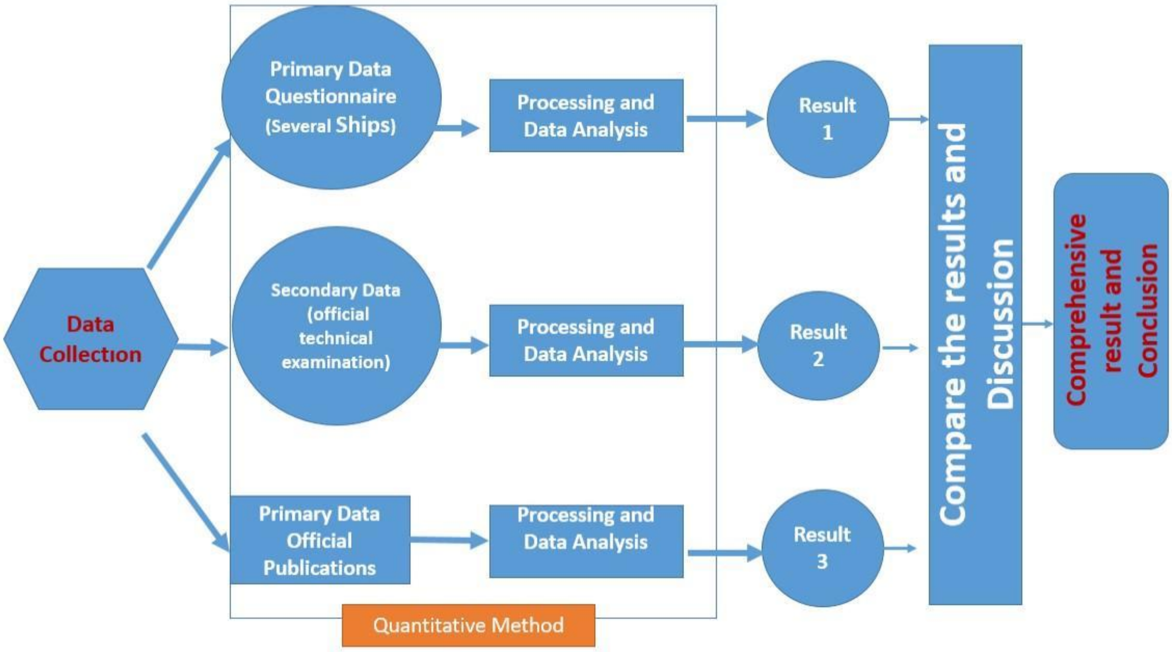
Research methodology is a strategy to tackle the research challenge methodically. It may be seen as a branch of science that investigates how scientific research is accomplished. It enables an examination of the various methods commonly used by a researcher in examining research issues and their logic (Kothari, 2004). While research methods may be seen as any approach or technique used to undertake research, Thus, the words "research methods" or "research techniques" reflect the procedures that researchers follow when completing their studies (Kothari, 2004).

4.1.2 Methodology Approach and strategy

Before picking an acceptable research approach, it is essential to thoroughly comprehend the philosophical tension between quantitative and qualitative methodologies (Bearman & Dawson, 2013). Concerning this research, which intends to analyze the operations of seven lighthouses and seventeen beacons in the GOS, the quantitative approach is preferable for gathering accurate and truthful information about the present service status. Comprehensive quantitative research is regarded as objective; hence, dissemination of research methodology is essential. However, its methodical nature is also a limitation since it may overlook other topics the qualitative technique addresses. It does not consider all knowledge quantified (Suri & Clarke, 2009). In this context, the research is based on many different data sources to ensure the accuracy of the result. As shown in Figure 15, the methodological strategy is depicted by a route map. An analysis of three different data sources will be performed, and the results will be compared and discussed. After the research findings are evaluated, appropriate recommendations will be made, followed by conclusions.

Figure 15

Methodology Approach



4.1.3 Data collection instruments

1- Questionnaire

The questionnaire was designed to conduct a study to assess the effectiveness of 24 AtoN in the GOC (7 lighthouses and 17 beacons). At each site, there are two types of signals, a light signal (which can be observed visually) and a radio signal (which is received by X-band radar). The questionnaire aims to determine the functionality and quality of service (signal strength) of AtoN at each location using Likert scales. Likert Scales offer the benefit of not requiring a simple yes/no response from the respondent but instead allowing for varying degrees of opinion or no opinion at all. Hence, quantitative data is generated, which can be analyzed easily (McLeod, 2008). The collection of data through a questionnaire commenced on June 9, 2022. The researcher finalized data gathering on August 15, 2022. As indicated in Table 2, there was 23 participants from various flag states who filled out the questionnaire. Participants are the ships themselves, represented by the captain or his representative. The target ships operate in GOS or pass via the Suez Canal; therefore, they will transit GOS.

The questionnaire is included in the Appendix B. The questionnaire was sent to the participants via the researcher's network in the Egyptian flag state, port state control, and Suez Canal Authority. In addition, the researcher utilized a maritime traffic website to identify the ships sailing in GOS, followed by a search for the ship management company; the researcher then emailed the ship management company with this questionnaire.

Table 2

The Flag state of participants

Flag states	No. of participants
Liberia	2
Egypt	5
Portugal	1
Germany	3
Saudi	1
Palau	1
Jordan	1
Cyprus	2
Sierra Leone	2
Panama	3
Comoros	1
Niue	1
Total	23

2- Governmental data

One of the most critical missions for the governmental ships is to examine the technical conditions of all AtoN on Egypt's Mediterranean and Red Sea coastlines, which serve primarily to and from the Suez Canal and the principal Egyptian ports, to maintain the safety of navigation in Egyptian waters. The researcher gathered all accessible data from 2019 to 2021, which addressed the technical conditions of AtoN and specified the lighthouses and beacons in GOS. During the specified period, the researcher collected data from the ship's five voyages.

3- Official Publications

The publication of the UKHO contains data on all light and fog signals worldwide. The researcher analyzed the data and obtained all the information about lighthouses and beacons in GOS, and the sustainable technical status of each AtoN mentioned in AOI for two different years.

4.1.4 Data analysis tools

The researcher used Microsoft Excel. This software has a great measurement toolset that lets the researcher find methods and medians. It has a programming feature called Visual Basic for Applications. It lets users use various numerical methods to solve different scientific and material science problems and then shows the results in a spreadsheet and graphs. It also has several useful features that let the user interface cover the whole spreadsheet from the client's point of view (De Levie, 2004).

4.1.5 Reliability and Validity

The quantitative method used in this research provided deep insights and information regarding the research's aim and objectives. The questionnaire was prepared carefully concerning content and structure to cover all AOI. Twenty-three ships participated from different flag states. The variety of the ship's flag states gave reliability and validity to the data. In addition, the governmental data was gathered by a certified governmental ship over three years (2019–2021).

Further, the data was collected by the UKHO in 2016 and 2022. It concludes that the data collected from various sources was not dependent on each other. On the other hand, all data collection is mixed between old and new data, which means that the methodology approach in this research gives deep insight and information regarding the research's aim and objectives.

4.1.6 Data analysis process

a- The data collected by questionnaire.

The data consisted of Likert scale data split into five cases. Each scenario described the performance of the signal received from AtoN from the perspective of each participant ship. Very weak signal, weak signal, moderate signal, strong signal, and very strong signal were the possible outcomes. On the other hand, participants may not be selected if they do not get a signal or do not identify the AtoN. Some participants indicated that they did not get any in this instance, while others replaced it with an x mark or a deleted line. The researcher considered the unknown data from participants were Not Available (NA) data. The collected data of the questionnaire was put into an Excel spreadsheet. According to the questionnaire, the researcher determined the quality of service provided to ships and assessed the technical conditions of all AtoN in the AOI using Excel data analysis tools. Separate analyses were conducted for lighting signals and racon signals.

b- Data collected from governmental examination

The data acquired by governmental ships evaluates the technical status of radio and lighting signals for AtoN in GOS. The data clarified if each AtoN was working or not. However, it did not explain the quality of the received signals. The study showed how many AtoN are working compared to how many are not working between 2019 and 2021.

c- Data collected from UKHO

The study gathered AOI data from two UKHO publication versions, one published in 2016 and the other in 2022. The tables of the failed AtoN associated with each edition data were constructed, and the result was then prepared for comparison with other analyses.

4.1.7 Ethical consideration

Ethical issues were considered in this study due to the engagement of ships as participants in the questionnaire. Accepting the survey questionnaire needed intensive assessment by the WMU Research Ethics Committee to guarantee that the highest ethical standards had been adhered to. In addition, along with respecting the participants' rights and privacy, the research examined elements such as secrecy, anonymity, data protection, and the opportunity to withdraw from the study. Furthermore, the participants' contributions were purely voluntary, and no payments were involved with their participation in the study. Finally, no modifications or additions to the received data were made, and all material was erased after the submission of the dissertation.

4.2 Data Analysis

4.2.1 Questionnaire data analysis using a quantitative approach

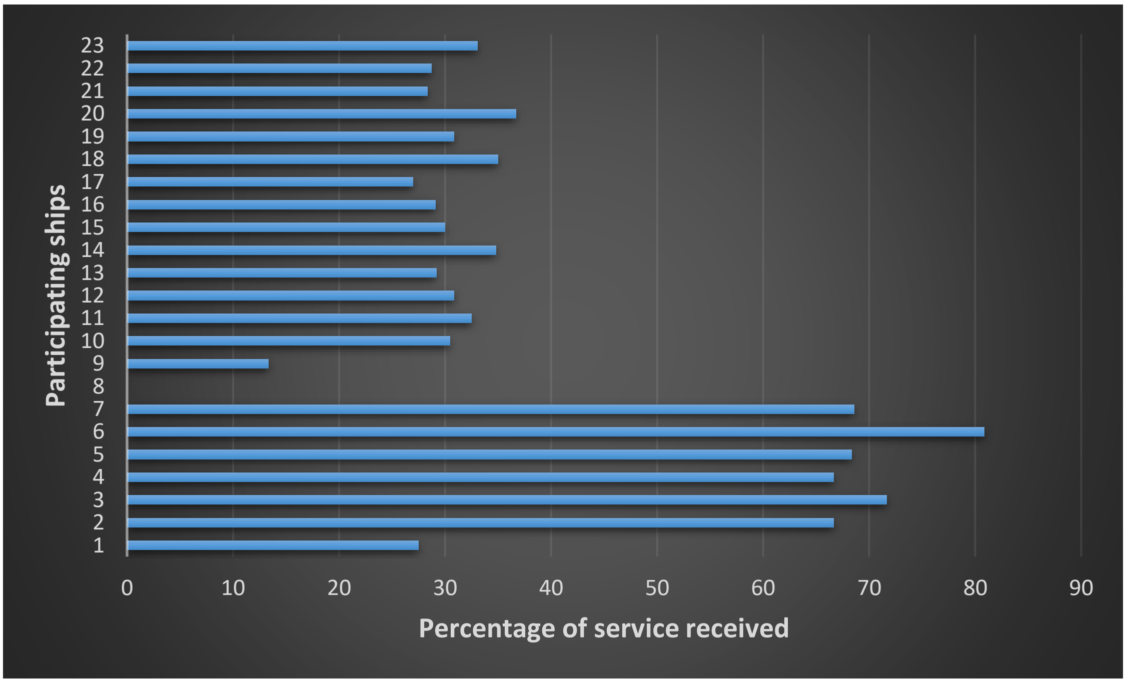
As stated previously, 23 ships participated in the survey. The questionnaire requested information on two distinct signals. The lighting signal and the racon signal are sent to ships; nevertheless, some AtoN feature lighting signals only. Therefore, two different analyses were conducted for each signal sent from each AtoN to ships. The complete responses of the 23 ships were provided in Appendix C for light signal and Appendix D for radio signal.

a- Lighting signals

First, the following analysis measures the quality of lighting service the ships received from the AtoN. According to the scope of research, 24 AtoN are involved, seven lighthouses and 17 beacons. All of them have produced light signals for ships. The descriptive analysis for the collective data showed in Figure 16 that the average service which ships received was almost 40%. In comparison, the maximum percentage of service received by ship No. 6 was 80 percent, and the minimum percentage of service received by ship No. 8 was 0 percent.

Figure 16

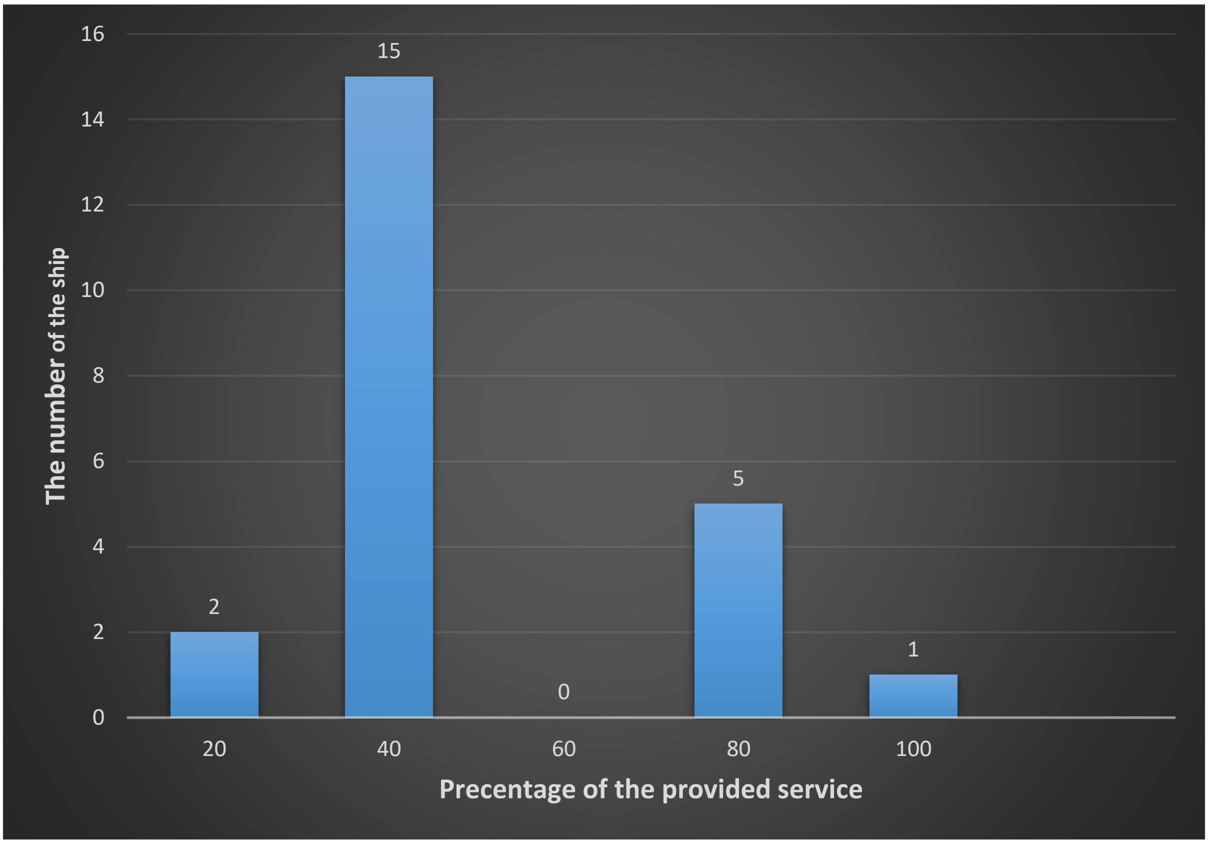
The received service by different ships



As shown in Figure 17, the numbers in the analysis seem to show that 15 of the ships that took part got between 20 and 40 percent of the service provided by the AtoN, while five got between 60 and 80 percent, two got less than 20 percent, and only one got 80 percent.

Figure 17

The number of ships and the percentages service received



Second, the subsequent analysis evaluates the performance of the AtoN lighting service to which the ships contributed. As indicated in Figure 18, only one beacon performs more than 90%, while the remaining AtoN fall between 65% and 10%. The graph displays the operational performance of AtoN from highest to lowest performance.

Figure 18

The analysis of The lighting performance of each AtoN

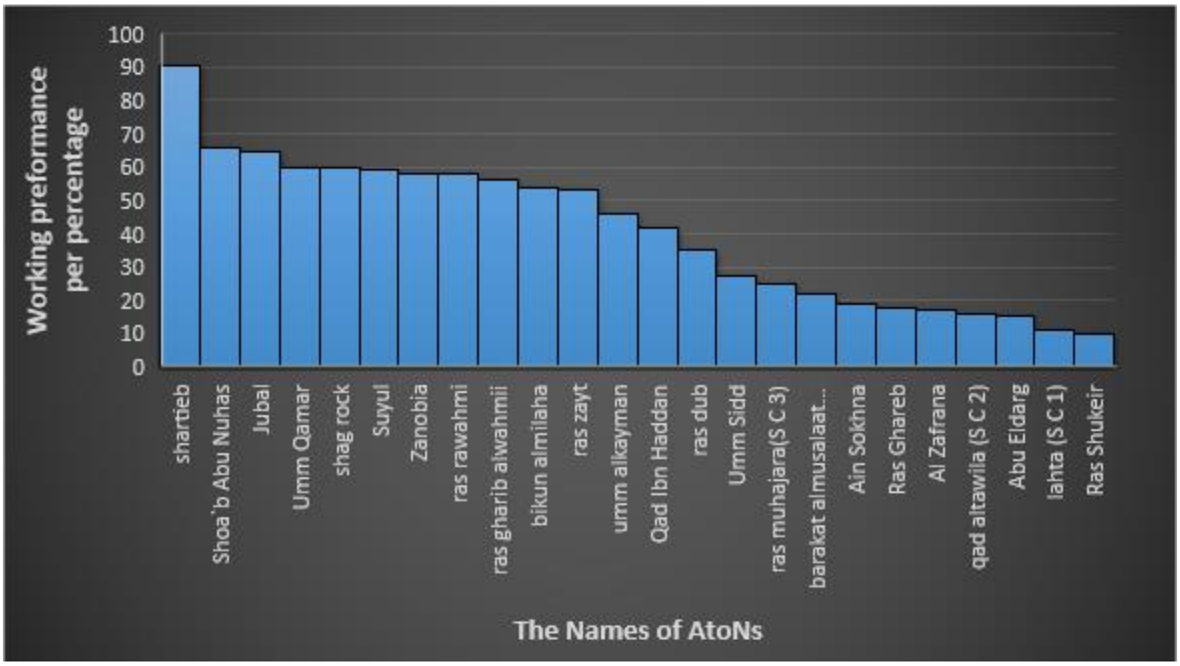
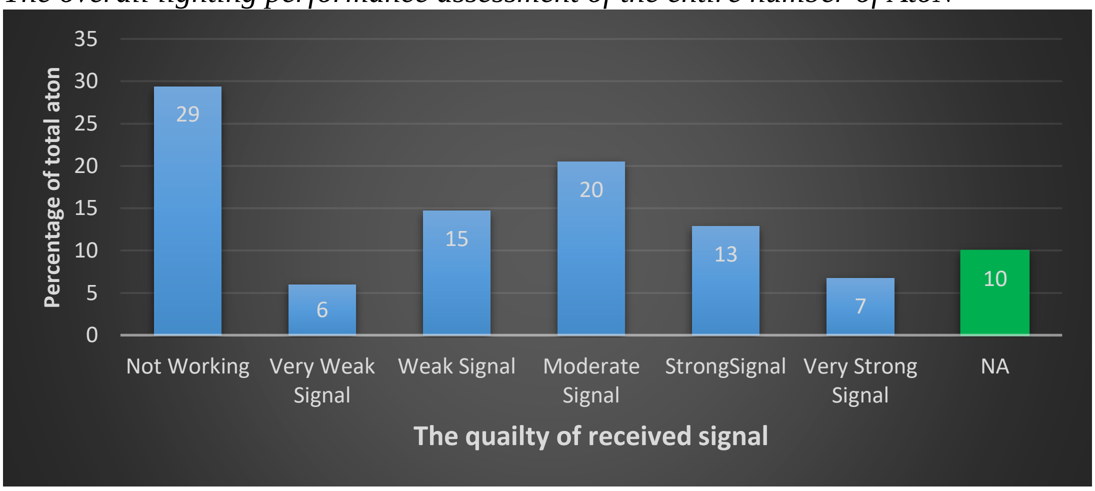


Figure 19 depicts the overall evaluation of lighting signals supplied by AtoN to participant ships. Twenty-nine percent of the total AtoN are not operational; 6 percent sent a very weak signal, 15 percent sent a weak signal, 20 percent of moderate signal, 13 strong signals, seven percent of very strong signals, and 10 percent of AtoN were not recognized by the ships.

Figure 19

The overall lighting performance assessment of the entire number of AtoN

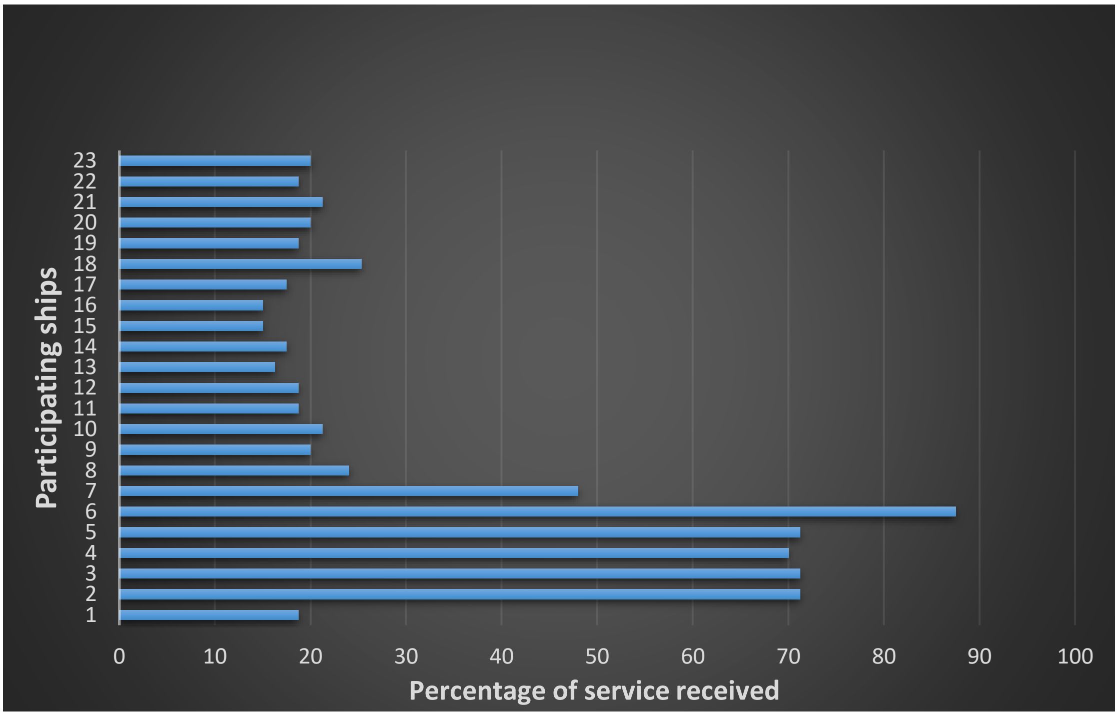


b- Racon signal

First, the following analysis measures the quality of radio service the ships received from the AtoN. According to the scope of research, 16 AtoN from the 24 AtoNcope of research are provided the radio signal by racons. The descriptive analysis for the collective data shows in Figure 20 that the average service ships received was almost 33%. In comparison, the maximum service received by ship No. 6 was 80 percent, and the minimum percentage of received service was ship No. 15,16 was 15 percent.

Figure 20

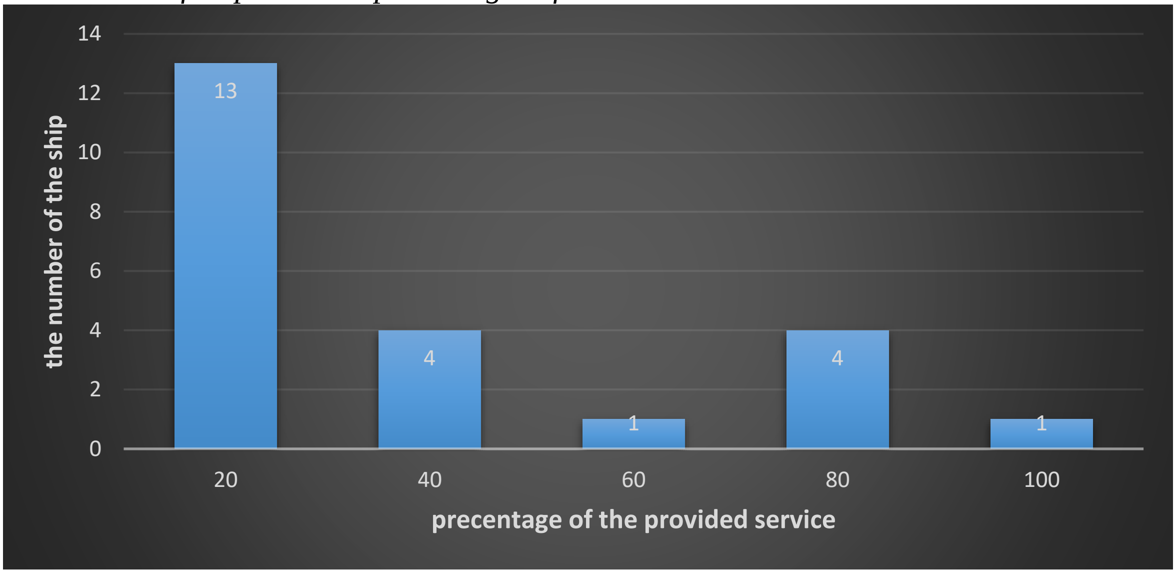
The received service by different ships



As shown in Figure 21, The statistics of the analysis appear to show that 13 ships out of the total participants received less than 20 percent of the total radio service provided by the AtoN, while four ships received between 20 and 40 percent, one ship received between 40 and 60 percent, four ships received between 60 and 80 percent, and only one ship received more than 80 percent of the total service provided.

Figure 21

The number of ships and the percentages of service received



Second, the subsequent analysis evaluates the performance of the AtoN radio service to which the ships contributed. As indicated in Figure 22, four beacons have more than 60% performance, while the remaining AtoN fall between 60% and 9%. Figure 22 displays the operational radio performance of AtoN from highest to lowest.

Figure 22

The analysis of The radio signal performance of each AtoN

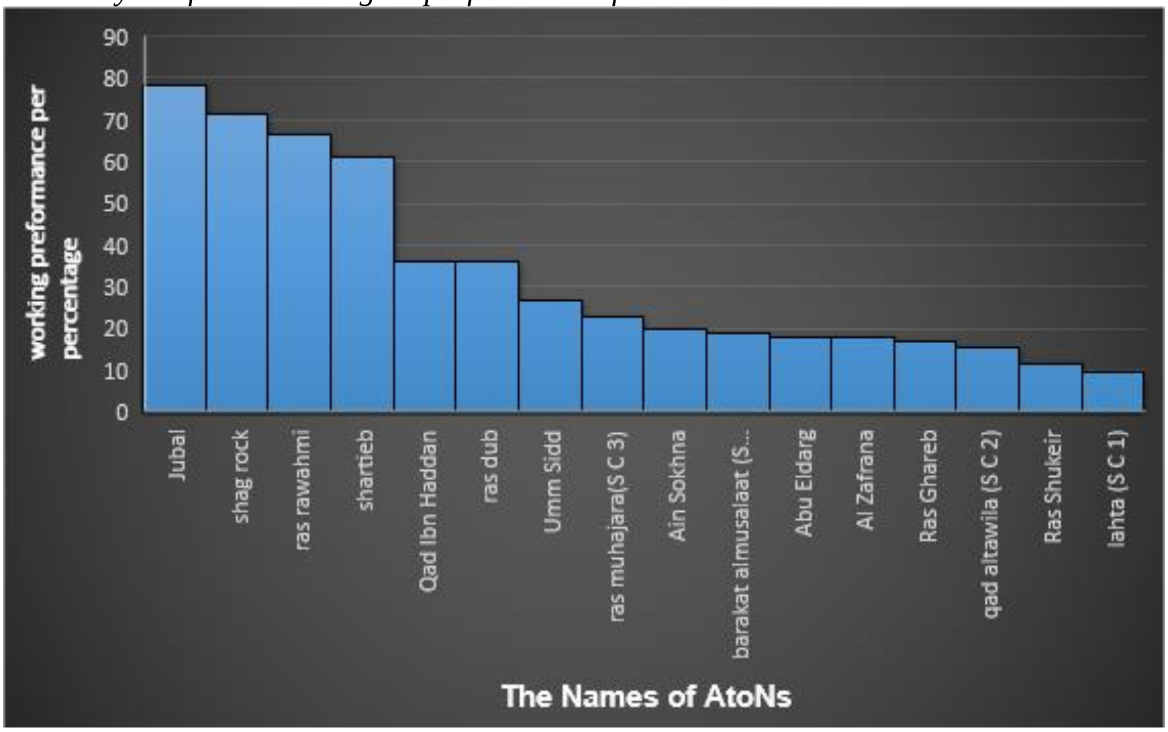
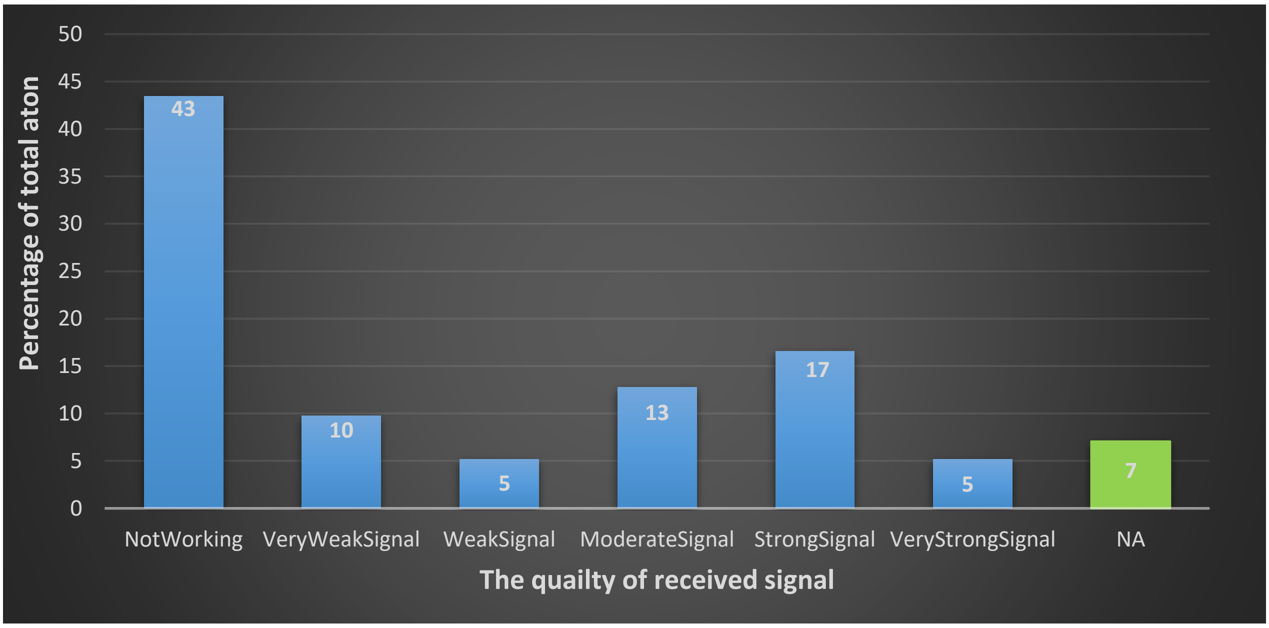


Figure 23 depicts the overall evaluation of radio signals supplied by AtoN to participant ships. Forty-three percent of the total AtoN are not working; 10 percent sent a very weak signal, 5 percent sent a weak signal, 13 percent of moderate signal, 17 strong signals, 5 percent of very strong signals, and 7 percent were not recognized by the ships of AtoN.

Figure 23

The overall radio signal performance assessment of the entire number of AtoN



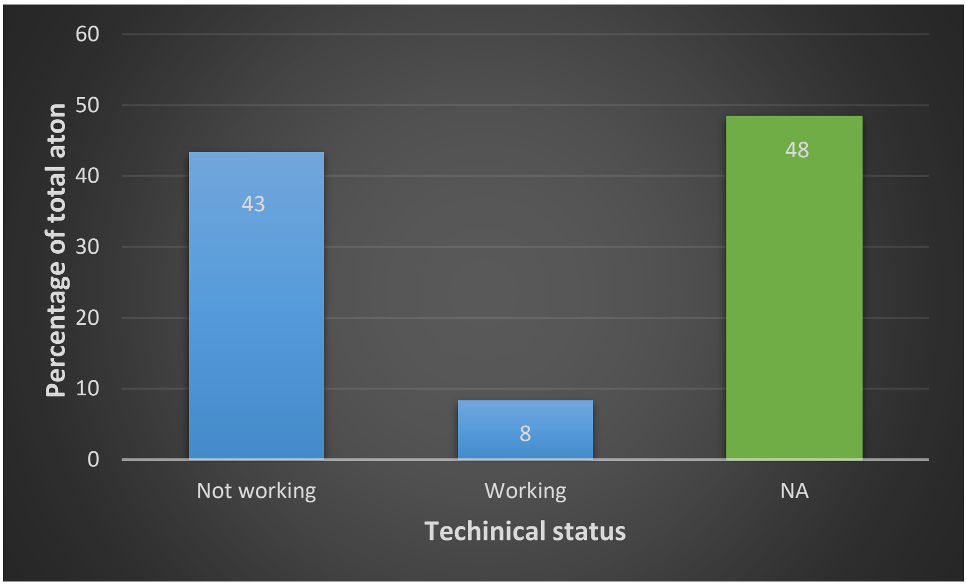
4.2.2 Governmental data analysis using quantitative approach

The researcher analyzed data obtained by the government ship from five voyages the ship conducted between 2019 and 2021 and evaluated the technical status of AtoN in GOS. The data provided is data that shows whether the AtoN is working or not for both signals (lighting or radio signal).

First, from the perspective of the lighting signal, as seen in Figure 24, greater than forty percent of AtoN were not working, while fewer than ten percent were operational. The technical status of lighting for the remaining AtoN was not acknowledged.

Figure 24

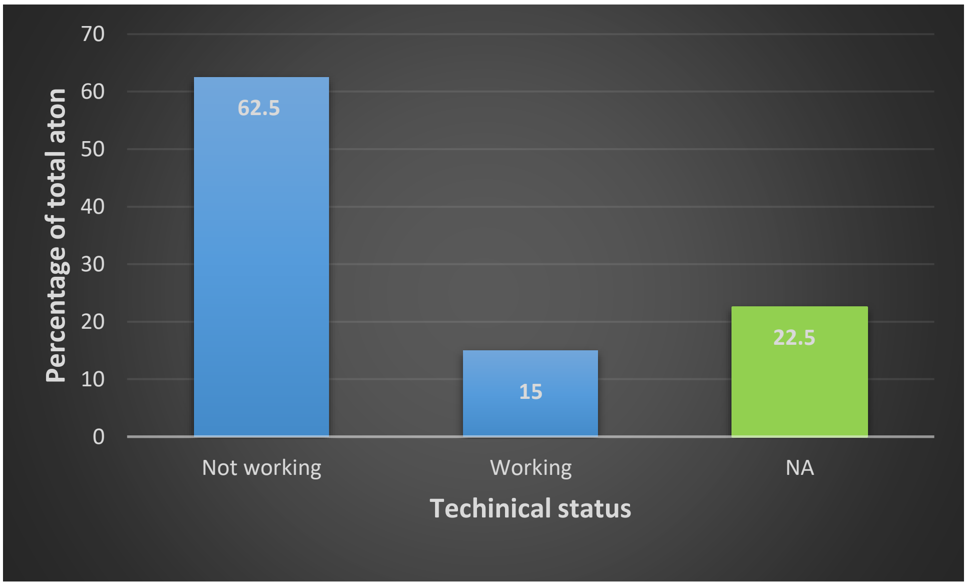
The overall lighting signal evaluation of the entire AtoN



Second, from the perspective of the radio signal, as seen in Figure 25, greater than 60 percent of AtoN were not working, while fewer than 20 percent were operational. The technical status of radio signals for the remaining AtoN was not acknowledged.

Figure 25

The overall radio signal evaluation of the entire AtoN



4.2.3 UKHO publication data analysis

Using two versions of the UKHO publications, "Admirals List of lights and log signals: eastern Atlantic, western Indian Ocean, and Arabian Sea. NP 77 volume D". The researcher observed that this type of publication highlighted the technological status of AtoN in the case of not working by informing the mariner for not following AtoN in this area. The following tables show the AtoN listed in the section of Egypt that had a technical problem.

According to the UKHO 2022, the listed 13 AtoN in Table 3 had technical issues. The publication addressed it by temporarily extinguishing (TE). However, the rest of the AtoN in the scope of this study are shown in normal conditions.

Table 3

The AtoN which have technical issues and the recorded date (created by Author according to UKHO (2022)

	The Name of AtoN	Status
1	Abu Eldarg	TE 2009
2	Al Zafrana	TE 2006
3	Ras Ghareb	TE 2009
4	Jubal	TE 2010
5	Suyul	TE 2010
6	Umm Qamar	TE 2010
7	Shag rock	TE 2006
8	Barakat almusalaat	TE 2009
9	Ras rawahmi	TE 2009
10	Almilaha	TE 2007
11	Ras dub	TE 2006
12	Ras zayt	TE 2006
13	Umm alkayman	TE 2010

According to UKHO 2016, the listed 19 AtoN in Table 4 had technical issues. The publication addressed it by Temporarily extinguished (TE) and Temporarily

Discontinued (TD). However, the rest of the AtoN in the scope of this study are shown in normal conditions.

Table 4

The AtoN which have technical issues and the recorded date (created by Author according to UKHO (2016)

	The Name of AtoN	Status
1	Ain Sokhna	TE 2009
2	Abu Eldarg	TE 2009 &TD 2009
3	Al Zafrana	TE 2006
4	Ras Ghareb	TE 2009
5	Ras Shukeir	TE 2006
6	Qad Ibn Haddan	TE 2006
7	Umm Sidd	TE 2004
8	Jubal	TE 2010
9	Suyul	TE 2010
10	shag rock	TE 2006 & TD 2006
12	lahta (S C 1)	TD 2007
13	ras muhajara(S C 3)	TE 2009
14	barakat almusalaat (S C 4)	TE 2009
15	ras rawahmi	TE 2009
16	bikun almilaha	TE 2007
17	ras dub	TE 2006
18	ras zayt	TE 2006
19	umm alkayman	TE 2004

4.3 Findings and Discussion

4.3.1 Summary of the Main Findings

a- Main findings in questionnaire analysis

The overall lighting signal service arriving at the ships of the participants with an average of 40% of the entire service was nearly weak. The majority of ships that participated in this survey received between 20 and 40 percent of the service supplied by AtoN. The analysis elucidated that around 30 percent of AtoN are ineffective although a handful are doing well. On the other hand, the overall radio signal service arriving at the ships of the participants, comprising an average of 33% of the total service, was so poor. The majority of ships participating in this poll received fewer than twenty percent of the services offered by AtoN. The investigation revealed that around 43% of AtoN are not working a few are performing effectively.

b- Main finding governmental ship data analysis.

During the five trips the government ship made between 2019 and 2021, data showed that 43% of AtoN did not send out signals for light, and 62% did not send out signals for radio.

c- Main finding in the data gathering from UKHO publication

The study of data from two versions of UKHO in 2016 and 2022 revealed that the majority of AtoN had technical faults, ranging between 79 percent and 54 percent of AtoN, respectively in AOI.

4.3.2 General observations on the questionnaire analysis

Considering the significant results mentioned in the preceding section, the diversity of the ships that participated in the questionnaire drew attention to several points that may contribute to several conclusions that help explain the lack of AtoN services. For instance, the beacon named Sharatib achieved high technical efficiency in terms of sending a light signal to the majority of participating ships, approximately 90% performance, which may raise the question of whether it is the only site with high efficiency, as the remaining sites have an efficiency of less than 60%. This site is located above an oil platform belonging to a private company, which makes Bacon's work permanent as a result of the company's follow-up because it always works in the interest of the site's safety without the occurrence of marine accidents, especially involving the ships frequently sailing in the area. It means that the petroleum company responsible for the site is keen to work this site efficiently permanently, follow up and facilitate maintenance work, and report any malfunctions on the site as soon as they occur. Thus, it can be stated that the site's continual monitoring, frequent maintenance, and timely reporting of defects contribute to the site's efficient operation.

In addition, about 10% of the locations were not recognized or found during the evaluation of how well the lighting worked. It is due to numerous factors, including the daytime transit of the participating ship. Therefore, it is reasonable that there is no light, so the ships cannot establish their location, or the ship's journey is far from the range of the AtoN light, making location determination difficult.

On the other hand, 10% remains enticing for study on ship consensus in an unknown AtoN group context. Thus, all of the locations of AtoN in the area need to be re-evaluated, as well as the value of each site on its own, while stopping the AtoN, which is no longer critical because of changes in how ships move and the environment at sea.

4.3.3 Research questions discussion

a- Research question No. 1: Are the lighthouses in GOS currently fulfilling the essential purpose for which they are designed? Or are there any weaknesses identified?

To answer this question, the three results that can be drawn from the different data collected should be analyzed. The data sources were diverse and contained both old and recent information. The common result of the three analyses is that some AtoN have many technical difficulties. Assuming the best result is at least 30 percent were not working; however, few of these work. In general, the service provided to ships is of poor quality. In addition, the data indicate that a small number of AtoN were unknown to the vessels. As indicated in the literature study, AtoN should operate in full compliance with international treaties and national laws to ensure the safety of navigation and prevent pollution in the GOS.

b- How can lighthouses in GOS enhance their performance in coastal state duties?

To enhance the performance of AtoN, EAMS should plan for a comprehensive strategy. The strategy should be divided into three stages of action taken as follows:

First, maintenance as a short-term action is a limited solution but fast to enhance the AtoN. Maintenance is necessary to guarantee that AtoN equipment and systems continue to function at the levels required for sailors to traverse the world's waterways safely. To guarantee that AtoN assets offer the desired performance while minimizing overall ownership costs, a maintenance system should be implemented. This performance is often described as the needed level of availability. Depending on the criticality or category of the AtoN, the same AtoN type may require different maintenance procedures at a specific site in order to achieve the desired availability result (IALA, 2009b).

Second, the repair should be the mid-term treatment of faulty AtoN. During maintenance, defects are first identified, then the search for how to correct them begins. Equipment and devices can be repaired by providing replacement components or reconnecting wiring in case of damaged connections or faults related to electrical sources such as batteries, and defective solar cells, which can be replaced. On the other hand, the device may be expired, and no spare parts may be available on the market. Therefore, it cannot be repaired, which necessitates a reassessment of the possibility of purchasing other types of equipment with modern equipment and suitable for work on the site, taking into account the climatic conditions of the site such as temperature and humidity. According to IALA (2004), Mean Time For Repair (MTTR) can be reduced by using modular systems that rapidly replace faulty parts and devices that improve service technicians' comprehension and quick discovery of faulty components.

Finally, development and modernisation are the long-term objectives. One of the most essential initiatives to increase the efficiency of AtoN is to upgrade equipment and gadgets to the current technology. Consideration should be given to the fact that the ships traversing the GOS are diverse and unique, and that the density of ships increases over time due to the presence of the Suez Canal and other factors mentioned earlier in this research; consequently, the AtoN should be equipped with the latest technology. For instance, the lighting system in all AtoN should be converted to the LED lighting system, as stated in the chapter of the literature review on the benefits of the LED lighting system, which include an easy-to-install and connect system, reduced energy consumption, and a long lifespan.

Further, it is conceivable to add a new signal to specific AtoN that play the most crucial roles in maritime safety in the region. AIS signals are among the most recent technologies for AtoN. An AIS AtoN service permits AtoN providers to broadcast data such as AtoN type, name, position, position, physical and virtual AtoN identification, dimension of the AtoN and reference positions, and status of the AtoN systems (IALA, 2021). AIS AtoN can give identification, state of health, and other navigational information like meteorological and hydrological data to ships and shore authorities. It may also be used to analyze traffic types and patterns to help offer the right degree of service (IALA, 2021). The AIS AtoN can improve situational awareness and aid in collision avoidance (Balduzzi et al., 2014).

EAMS should develop a system compatible with AtoN and monitoring centers based on sharing information. The exchanged information may include AtoN technical data or ship data sailing along the shore. A modern information system utilizing information, computer network, and modern communication navigation are vital for modernizing AtoN monitoring and management, ensuring the accuracy of AtoN, facilitating user access to information about it, and improving navigation services (Zhang et al., 2010). The network also may include other relevant authorities with AtoN such as VTS center, port authorities and ENHD. To preserve navigational safety, it is essential that all relevant entities manage AtoN with defined objectives while also planning for future developments (Hasbullah et al.,2022).

5. Recommendations and Conclusions

5.1 Recommendations

The study assessed the operation of AtoN, which appears to be poor. Consequently, the government should implement several measures to enhance the function of AtoN in GOS without the following being executive; indicative examples include:

1- Observance of proper maintenance procedures

Continuous evaluation of equipment dependability, maintainability, and supportability should be conducted, so that equipment design and maintenance processes may be continually enhanced. Consistent input on the operation of the equipment from the maintenance staff is essential to this procedure. Keeping track of maintenance is essential for measuring and enhancing the efficiency of a system (IALA, 2009b).

2- Development and improvement

As it mentioned in the discussion section, several devices and equipment can be added or developed for AtoN. For instance, all AtoN lighting systems could be replaced with LED lighting systems. In addition, a new AIS AtoN radio signal to specific AtoN should be provided. The AIS AtoN is considered to be one of the last AtoN technologies. Using the VHF transponder, it transmits a symbol that is easily detected by the ship's equipment. Ships receive AIS messages by AIS receiver and display them on radar or Electronic Chart Display and Information System (ECDIS). In addition, the present monitoring system should be upgraded with a monitoring and remote control system that will allow for the remote treatment of specific failures, such as a change in lighting character or racon code.

3- Reconsider the distribution of lighthouses in the GOS

According to the analysis of the study, some of the ships that responded to the questionnaire did not recognize specific few lighthouses that may have lost their significance due to changes in the maritime environment and surrounding dangers or the modification of the shipping routes of passing ships. Therefore, the administration should reconsider the distribution of AtoN and eliminate AtoN that have little impact on the safety of navigation.

4- Environmental consideration

Despite its role in environmental protection, AtoN equipment and operations have the potential to cause considerable environmental damage through waste production, excessive energy use, pollution, and habitat disruption. It is crucial to limit these adverse effects so that the advantages of AtoN are not outweighed by the unintended negative environmental implications of their functioning. Responsible environmental management and incorporating environmental concerns into all stages of AtoN operations (design, installation, administration, and maintenance) can minimize the consequences. To control the impact of AtoN operations on the environment, organizations should promote a culture of environmental conservation and stewardship of natural resources. All engineering, planning, decision-making, and operating procedures should incorporate environmental issues (IALA, 2017a). According to scope of research, the Egyptian administration should rely solely on renewable energy and discontinue the use of diesel to generate electricity, as well as disposing of obsolete equipment and devices in sites where they have been replaced by newer equipment, transporting them to storage facilities for later disposal, and installing sewage treatment units at guarded sites.

5.2 Limitations and Recommendations for Future Research

AtoN are widely used in GOS; hence, the research is restricted to assessing the operation of lighthouses and beacons in AOI. Therefore, the research did not analyze the functioning of buoys in the GOS, a topic that requires more study. On the other hand, the study provided suggestions for improving the performance of AtoN in GOS. Some of these proposals require a technical analysis to guarantee their efficacy. For example, the relevance of establishing an AIS data network in GOS employing real or virtual AIS AtoN in enhancing navigational safety is demonstrated. In addition, research must review the function of each AtoN in this study, identify unnecessary ones, and delete them. Consequently, this will lower the expenditures associated with the upkeep and development of other sites. Furthermore, the research on the influence of AtoN design, installation, maintenance, and development on the maritime environment is considered one of the significant research areas in GOS.

5.3 Conclusion

This study evaluated the functionality of the lighthouses and beacons in the GOS region, which is considered one of the world's most significant and dangerous passages due to the passage of all ships crossing the Suez Canal. Geographically, the GOS is complex because coral reefs are distributed randomly throughout the region, posing a threat to navigation. The AtoN guide ships inside the GOS, making them one of the most effective tools for ensuring maritime safety and preventing pollution. It is essential to ensure that lighthouses and beacons operate well to fulfill their functions effectively. The researcher used the quantitative method to analyze data received from three sources. The researcher developed a questionnaire, and 23 ships operating in or transiting the GOS participated. Furthermore, the researcher used several voyage data collections gathered between 2019 and 2021 for a government ship to review the technical issues of AtoN. Finally, the list of AtoN in AOI was obtained from two different versions of the UK hydrographic office publications, 2016 and 2022.

As a result of the analysis, the performance of the AtoN is abysmal in the GOS region. The majority of them do not work, some ships do not recognize them, and the rest are not sufficient for safe navigation throughout the GOS. Therefore, the researcher proposed various solutions for improving AtoN efficiency, taking relevant environmental issues into account. The analysis indicated that the sites need to be maintained and repaired urgently. The study also emphasized the need for a comprehensive strategy for developing and upgrading lighthouses and beacons following the most recent technological advances. It is also suggested that additional devices could be added to the existing system. In addition, using the AIS network installed in AtoN to build a data exchange system can provide information about safety and weather conditions, among other topics related to marine safety.

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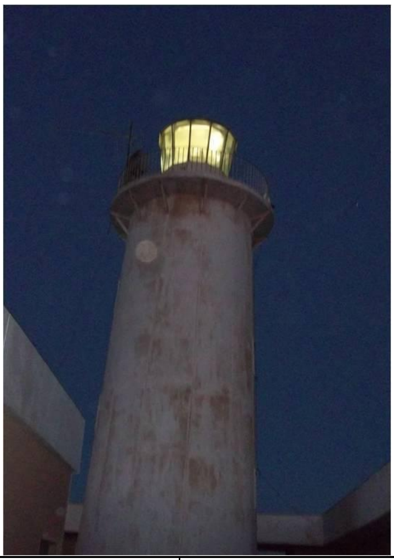
Appendices

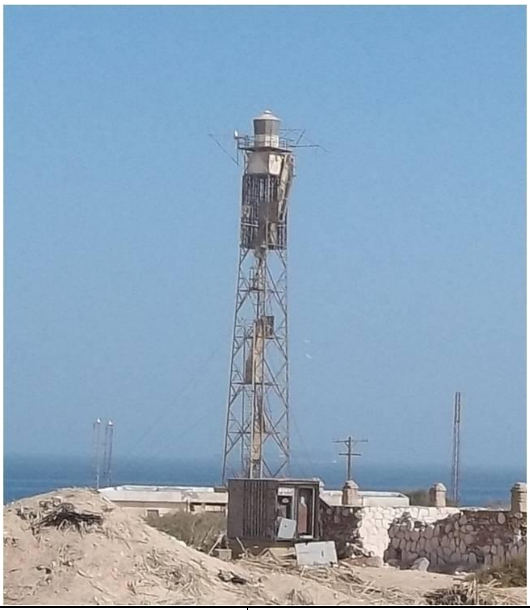
Appendix A: The list of the AtoN (The Scope of research) with some photos and brief data (Source: EAMS, 2021c; UKHO, 2022).

<table>
<tr><td colspan="3">1- Ain Sokhna
</td></tr>
<tr><td colspan="2">Category : Lighthouse</td><td>Location: 29° 36.12' N 32° 20.52' E</td></tr>
<tr><td>Character</td><td colspan="2">White color – range 22 nm - pulse /5sec - iron structure –
44 m height – Racon included</td></tr>
<tr><td colspan="3">2- Abu Eldarg
</td></tr>
<tr><td colspan="2">Category : Lighthouse</td><td>Location: 29° 22.86' N 32° 34.06' E</td></tr>
<tr><td>Character</td><td colspan="2">White color – range 19 nm - pulse/20sec – concrete structure –
50 m height - Racon included</td></tr>
</table>

3- **Al Zafrana**

Category : Lighthouse		Location: 29° 06.71' N 32° 39.93' E
Character	white color – range 19 nm - pulse /10sec - stone structure – 25 m height - Racon included	

4- **Ras Ghareb**

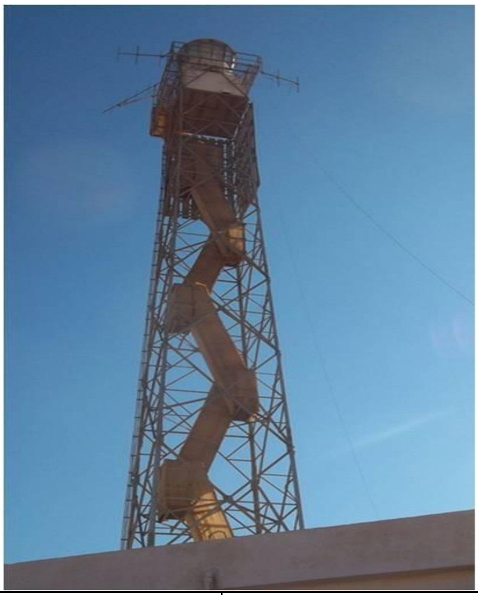


Category : Lighthouse		Location: 28° 21.10' N 33° 06.66' E
Character	white color – range 20 nm - pulse/20sec – iron structure – 46 m height - Racon included	

5- Ras Shukeir

Category : Lighthouse	Location: 28° 07.88' N 33° 16.52' E
Character	white color – range 15 nm - pulse /20 sec - iron structure – 85 m height - Racon included

6- **Qad Ibn Haddan**



Category : Lighthouse	Location: 27° 48.28' N 34° 06.00' E
Character	white color – range 22 nm - pulse/10sec – iron structure – 47 m height - Racon included

7- Umm Sidd

Category : Lighthouse	Location: 27° 51.00' N 34° 18.88' E
Character	white color – range 23 nm - pulse /20 sec - iron structure – 45 m height - Racon included

8- **Zanobia**

Category : beacon	Location: 29° 53.11' N 32° 33.08' E
Character	white color – range 10 nm - pulse/5 sec – iron structure – 17 m height

9- Jubal 		
Category : beacon		Location: 27° 40.80' N 33° 48.42' E
Character	white color – range 15 nm - pulse /5 sec – fibre glass structure – 24 m height - Racon included	
10- **Suyul** 		
Category: beacon		Location: 27° 33.619' N 33° 52.746' E
Character	white color – range 15 nm – 4 pulse/ 20 sec – fibre glass structure – 15 m height	

11- Umm Qamar

Category : beacon	Location: 27° 21.504' N 33° 54.484' E
Character	white color – range 15 nm - pulse / 3 sec - fibre glass structure – 24 m height

12- **Shoa`b Abu Nuhas**

Category : beacon	Location: 27° 34.552' N 33° 55.986' E
Character	white color – range 6 nm – 3 pulse/10 sec – iron structure – 6 m height

13- Shag rock

Category : beacon	Location: 27° 46.477' N 33° 53.164' E
Character	white color – range 6 nm – 9 pulse /15 sec – iron structure – 12 m height - Racon included

14- **Shartieb**

Category: beacon	Location: 28° 30.89' N 32° 57.60' E
Character	white color – range 6 nm – 10 pulse/ 15 sec- iron structure – 11 m height

15- Lahta (S C 1)

Category : beacon	Location: 29° 40.38' N 32° 41.23' E
Character	white color – range 12 nm – 3 pulse /15 sec - iron structure – 47 m height - Racon included

16- **Qad altawila (S C 2)**

Category : beacon	Location: 29° 47.81' N 32° 38.42' E
Character	white color – range 12 nm - pulse/10 sec – iron structure – 47 m height

17- Ras muhajara(S C 3) 		
Category : beacon		Location: 29° 48.61' N 32° 28.18' E
Character	white color – range 12 nm – 4 pulse /15 sec – iron structure – 43 m height - Racon included	
18- **Barakat almusalaat (S C 4)** 		
Category: beacon		Location: 27° 33.619' N 33° 52.746' E
Character	white color – range 12 nm –pulse/ 3 sec – iron structure – 42 m height - Racon included	

19- Ras rawahmi

Category : beacon		Location: 28° 43.20' N 32° 49.41' E
Character	white color – range 15 nm -3 pulse / 20 sec - fibre glass structure – 22 m height	

20- **Ras gharib alwahmii**

Category : beacon		Location: 28° 37.2' N 33° 06.7' E
Character	white color – range 15 nm –pulse/5 sec – fibre glass structure – 10 m height	

21- Almilaha

Category : beacon	Location 28° 14.79' N 33° 09.65' E
Character	white color – range 15 nm –pulse /10 sec – fibre glass structure – 12 m height

22- **Ras dub**

Category: beacon	Location: 28° 01.80' N 33° 24.93' E
Character	white color – range 15 nm –pulse/ 5 sec - fibre glass structure – 45 m height

23- Ras zayt

Category : beacon	Location: 27° 56.96' N 33° 30.68' E
Character	White color – range 15 nm - 2pulse /20 sec - fibre glass structure – 28 m height

24- umm alkayman

Category : beacon	Location: 27° 49.63' N 33° 34.88' E
Character	White color – range 15 nm - pulse/10 sec – concrete structure – 24 m height

Appendix B: The questionnaire and the participates

Questionnaire

Aids of Navigation(AtoN) Services in Gulf of Suez(GoS)

General information: -

Ship Name	
IMO NO.	
Gross tonnage	
Flag state	
Departure port	
Destination Port	

In preparation for conducting a study to assess the effectiveness of Aids to Navigation and the possibility of their development, please carefully read this guide before completing the attached questionnaire (Table 2).

Column 2 of Table 2 contains the names of 24 sites in the Gulf of Suez. At each site, there are normally two types of signals, a light signal (which can be visually observed) and a Racon signal (which is received by X-band radar). The questionnaire aims to determine the function and service quality (signal strength) of aids to navigation at each site.

Table 1 below shows you how to complete the questionnaire in Table 2.

Table 1: Questionnaire instructions

<table>
<tr><th rowspan="2">Site name</th><th rowspan="2">Received signal</th><th colspan="5">Service quality</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td rowspan="2">Aids to Navigation name</td><td rowspan="2">Light ☐
(√ if a light has been visually observed)
Racon ☐
(√ if a signal has been received on X-band)</td><td colspan="5">Circle the number corresponding to the observed signal strength</td></tr>
<tr><td>Very weak signal</td><td>Weak signal</td><td>Moderate signal</td><td>Strong signal</td><td>Perfect signal</td></tr>
</table>

Table 2: Service Quality in Gulf of Suez Lighthouses & beacons

Please complete the table according to the instructions provided in Table 1.

	Aids to Navigation Name	Received signal	Service quality				
			1	2	3	4	5
1	**Ain Sokhna**	Light ☐					
		Racon ☐					
2	**Abu Eldarg**	Light ☐					
		Racon ☐					
3	**Al Zafrana**	Light ☐					
		Racon ☐					
4	**Ras Ghareb**	Light ☐					
		Racon ☐					
5	**Ras Shukeir**	Light ☐					
		Racon ☐					
6	**Qad Ibn Haddan**	Light ☐					
		Racon ☐					
7	**Umm Sidd**	Light ☐					
		Racon ☐					
8	**Zanobia**	Light ☐					
		Racon	N.A.				
9	**Jubal**	Light ☐					
		Racon ☐					
10	**Suyul**	Light ☐					
		Racon	N.A.				
11	**Umm Qamar**	Light ☐					
		Racon	N.A.				
12	**Shoa`b Abu Nuhas**	Light ☐					
		Racon	N.A.				
13	**shag rock**	Light ☐					
		Racon ☐					
14	**shartieb**	Light ☐					
		Racon ☐					
15	**lahta (S C 1)**	Light ☐					
		Racon ☐					
16	**qad altawila (S C 2)**	Light ☐					
		Racon ☐					
17	**ras muhajara(S C 3)**	Light ☐					

		Racon ☐					
18	**barakat almusalaat (S C 4)**	Light ☐					
		Racon ☐					
	Aid to Navigation Name	**Received signal**	**Service quality**				
			1	2	3	4	5
19	**ras rawahmi**	Light ☐					
		Racon ☐					
20	**ras gharib alwahmii**	Light ☐					
		Racon	N.A.				
21	**bikun almilaha**	Light ☐					
		Racon	N.A.				
22	**ras dub**	Light ☐					
		Racon ☐					
23	**ras zayt**	Light ☐					
		Racon	N.A.				
24	**umm alkayman**	Light ☐					
		Racon	N.A.				

What are the challenges you faced sailing in the Gulf of Suez? (ex: - coral reef area without Aids to Navigation signal - dangerous sailing area - shallow water area)
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

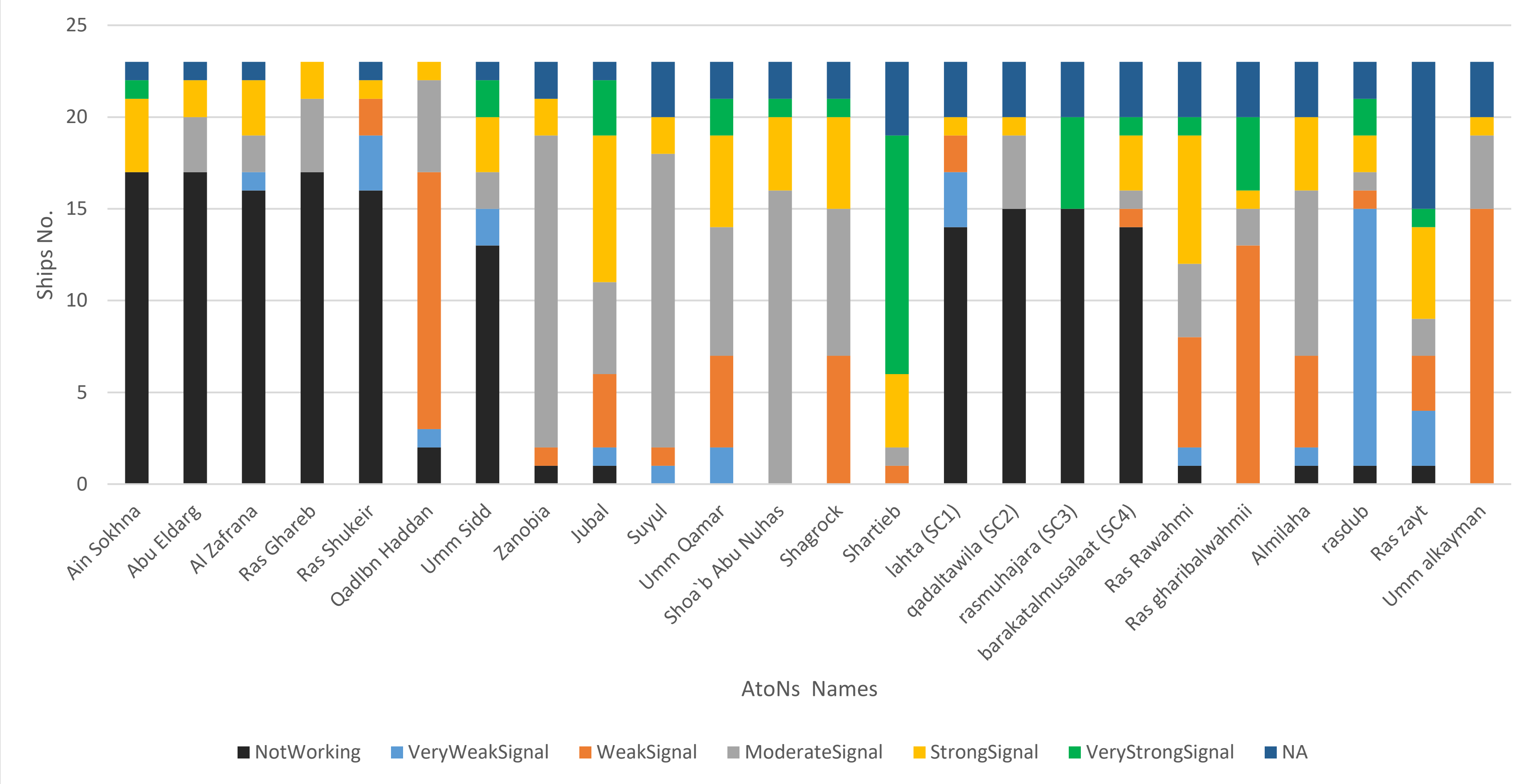
What are your suggestions to improve Aids to Navigation in the context of safety of navigation in Gulf of Suez? (ex: - Proposal for add new lighthouse, buoy in a specific area or any new technology)
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Any general additional notes (ex: Suggestion of for increasing the signals in Aids to Navigation such add light signal, racon or AIS Aids to Navigation)
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Signature
Ship Captain

Ship stamp

Appendix C: The response of 23 participants to a questionnaire regarding the lighting signal from 24 AtoN at GOS



Appendix D: The response of 23 participants to a questionnaire regarding the radio signal from 16 AtoN at GOS