Maritime surveillance in Egypt: status of vessel traffic management system and opportunities for future improvements

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MARITIME SURVEILLANCE IN EGYPT
STATUS OF VESSEL TRAFFIC
MANAGEMENT SYSTEM AND
OPPORTUNITIES FOR FUTURE
IMPROVEMENTS
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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Abstract

Title of Dissertation: Maritime Surveillance in Egypt: status of Vessel Traffic Management System and opportunities for future improvements

Degree: Master of Science

Gulf of Suez (GOS) is one of the most important waterways in the world. Therefore, maritime safety, effective navigation and protection of the marine environment in the GOS are among the high priorities of Egyptian legislators. Maritime surveillance expressed in GOS Vessel Traffic Management System (VTMS) has been established by the competent authority as a cost-effective measure to reduce and mitigate risks in accordance with international standards and guidelines. Therefore, this dissertation aims to discuss the status of GOS VTMS and opportunities for improvement.

The study utilizes qualitative primary and secondary data. Primary data were collected by employing in-depth, semi-structured interviews while secondary data were sourced from national legislations, VTS User Guide and reports issued by EAMS, IMO, IALA and UK hydrographic office publications. Thus, the distinctive features of the GOS VTMS along with its degree of compliance with international standards and guidelines have been closely examined for a comprehensive assessment.

The study revealed that GOS VTMS contributes significantly to safe, efficient navigation and protection of the marine environment however some gaps need to be filled. Finally, this dissertation provides recommendations on how to create better system performance.

KEYWORDS: Vessel Traffic Service, IALA, IMO guidelines, safety and efficiency of navigation, Gulf of Suez.
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List of Abbreviations

AIS  Automatic Identification System
AGCS  Allianz Global Corporate & Specialty
CBA  Cost Benefit Analysis
AOI  Area of Interest
AtN  Aids to Navigation
COLREG  Convention on the International Regulations for Preventing Collisions at Sea
CZ  Contiguous Zone
EAMS  Egyptian Authority for Maritime Safety
EEZ  Exclusive Economic Zone
GMDSS  Global Maritime Distress and Safety System
GOS  Gulf of Suez
IALA  International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO  International Maritime Organization
HDG  Heading
MDA  Maritime Domain Awareness
MMSI  Maritime mobile service identity
MS  Maritime Surveillance
MSS  Maritime Surveillance System
NGOs  Non-Governmental Organizations
NM  Nautical Mile
OOW  Officer of Watch
SA  Situational Awareness
SOLAS  International Convention for the Safety of Life at Sea
SC  Suez Canal
SCA  Suez Canal Authority
SMRS  Ship Mandatory Reporting System
SOG  Speed Over Ground
STCW  International Convention on Standards of Training, Certification and Watch keeping for Seafarers
TSS  Traffic Separation Scheme
VHF  Very High Frequency
VTS  Vessel Traffic Service
VTMS  Vessel Traffic Management System
CHAPTER ONE
INTRODUCTION

This chapter presents background on maritime surveillance represented by the Vessel Traffic Management System (VTMS) in the Gulf of Suez waterway (GOS). Within this chapter, the problem statement, research objectives, research questions, thesis scope and limitation are included.

1.1 Background to Maritime Surveillance (MS)

In recent years, with the constant development of the shipping industry, the density of marine traffic has continued to increase, and the maritime traffic accidents and the resulting environmental pollution have aroused widespread concern among national and international bodies. Currently, almost 90% of the world trade in volume is carried by about 60,000 merchant ships manned by more than a million of seafarers (AGCS, 2019). Therefore, international organizations issued several instruments in order to prevent and control marine pollution, safety of life at sea, security, conservation and management of natural resources. Member states have to implement these instruments in their national legislation in order to comply and enforce these regulations.

Indeed, it is well recognized that the key element to having an effective counter of any safety and/or security threat is the early detection of it. This can only be achieved if there is a continuous awareness of what has happened, what is happening and will happen in the maritime domain. To achieve this goal, a set of measures have to be taken, and its ultimate goal is to correctly identify maritime threats to take proper action at an early stage (Al-dhubhani et al., 2017). On the other hand, one of the most important aspects that must be taken into consideration is the strategic function of exercising sovereignty, national safety and security to manage and protect maritime interests. Thus, the United Nations Convention on the Law of the Sea stated the rights and obligations for member states to exercise their sovereignty.

Any maritime surveillance system in a country must first and foremost comply with the primary function of covering and providing a comprehensive maritime situation picture to control the main areas where maritime activities are carried out. MS is carried out by the coastal state to increase the safety of navigation, protect the
marine environment and its own interests. This activity is also related to maritime traffic management, including the collection of data on maritime facilities and maritime traffic and the organization of navigation. The design and structure of MSS is derived by the user objectives. Various types of sensors are used in the MSS, and these sensors can be distinguished in two types; active sensors include, but are not limited to, high-frequency surface and skywave radars and passive sensors such as optical and infra-red sensors. On the other hand, MSS can be differentiated in two types; surveillance of cooperated vessels that provide its information such as identification, position, speed either automatically or manually or both. Whereas surveillance of non-cooperated vessels is an attempt to track and gather information about such vessels to identify their existing and intentions (Ince et al., 2012).

1.2 Background to Maritime Surveillance in the Gulf of Suez

The Arab Republic of Egypt enjoys a distinct geographical location because it is overlooking the Mediterranean Sea, the Red Sea and has the Suez Canal. Throughout its history, Egypt has been a global maritime state dependent on oceans for its economy. In the modern era, the emphasis on globalization and the global economy has greatly increased this dependence. The numbers representing the geographic extent of the sea and the Egyptians dependence on it illustrate the enormous problem of maritime awareness. There are about 2500 Kilometers of Egyptian coastline and a large coastal area includes internal water, 12 Nautical miles of Territorial sea, followed by 12 NM of Contiguous zone and Exclusive Economic Zone. This enables Egypt to be classified among the countries that have the largest number of ports in the world and turn them into one of the major international logistics centers (ZHao & Hu, 2018).

The Gulf of Suez is one of the world’s most important waterways. As it connects the Red Sea with the Suez Canal (EAMS, 2020). According to Suez Canal Authority, the number of vessels that transited through SC in 2019 reached 18,880 (Suez Canal, 2020). Thus, GOS is a very high traffic area with a narrow width of 10 to 25 NM and comprises sensitive environmental areas as shown in figure 1 (Jica, 2008). Consequently, Egypt as a member state of IMO has exercised its sovereignty in the GOS by establishing measures to ensure the safety of navigation, protect the marine environment and its economic interest. These measures used for reducing
probabilities of risks and reducing consequences in critical waterways may include; Mandatory Reporting System (MRS), Traffic Separation Scheme (TSS), Aids to Navigation (AtoN) and Vessel Traffic Service (VTS). The requirements and standards of these risk control options have been mandated in the international regulations such as UNCLOS, SOLAS and STCW in addition to recommended guidelines issued by IMO and IALA.

Figure 1: GOS geographical and environmental features (source: Jica, 2008).

1.3 GOS Vessel Traffic Management System (VTMS)

According to IMO and IALA, VTS is playing an important role in improving safety and efficiency of navigation and protect the marine environment (IMO, 1997; IALA, 2016). VTS is a shore-based maritime traffic management system established
by the competent authority to assist the bridge team (IALA, 2016). In other words, VTS is classified as a socio-technical system established to manage and control maritime traffic in port approach as well as coastal areas and congested waterways that apply navigation difficulties for the bridge team (Praetorius, 2014). In the VTS center, operators analyze the information which has been integrated from multiple sources including but not limited to VHF, radar system and AIS. And then, operators provide services to the vessels according to the current situation. There are two types of VTS centers, port/harbor VTS and coastal VTS. According to Professors Dalaklis, Sioussiouras and Nikitakos (2009), three types of services are provided by VTS center to vessels, namely information service, navigational assistance and traffic organization.

VTSOs are making decisions based on data fusion from different sensors therefore, information is crucial in the VTS operation. In accordance with this importance, researchers have conducted studies in explaining the operations carried out and information required in the VTS centers. Brödje et al., (2010) research findings showed that VTSOs are using VHF, radar and AIS as a primary source for information. Also Endsley’s definition for situation awareness introduced by Wiersma and Mastenbroek (1998), results of the study depicted how the SA of VTSOs in a dynamic environment is built. Another study carried by Dalaklis et al., (2009) and de Vries, (2015) showed that decision making is based on the collected information and communication initiated between the bridge team and shore operators.

On the other hand, there are controversies in researches related to assessing the benefits of VTS. VTS is a high-cost construction, operation and maintenance, consequently, a Cost-Benefit Analysis (CBA) has to be carried out. With the completion of design and risk assessment stages, a comprehensive CBA is required to justify investments in VTS whether public and/or private. However not all costs and benefits may be expressed as monetary, CBA can help in the decision-making process rationally and comprehensively. It also indicates to the appropriate allocation of cost recovery by various beneficiaries, in addition to the determination of system requirements (IALA, 2016).

Safety of navigation in the GOS is of great importance due to the increase of national and international transportation. Egyptian Authority for Maritime Safety
(EAMS) has always realized the complexity of the maritime traffic and difficulties of navigation in the GOS. Oil wells are the main hazardous to navigation in the GOS area. Numerous oil rigs and flares exist on both shore of the gulf in addition to many oil heads and platforms. Some are marked by lights and in some cases by racons. Therefore, the implementation of VTS in the Egyptian waterways has gone through several phases (EAMS, 2020). In 1985, a system was proposed to monitor the traffic in the approaches by making the GOS exclusively a pilotage area with the support of VTS scheme of several monitoring stations. In 1988 VTS control towers were established thereafter, the system has been upgraded several times by the competent authority EAMS. GOS VTMS system aims at better utilization of human resources including pilotage support manpower, achieving the implementation of GMDSS operation and creating a database for ships frequently transiting the Suez Canal (Abdelhafiez, 1998).

1.4 problem statement

Maritime transport is one of the important backbone industries in Egypt that plays a major role in developing the national economy and exerts a profound influence on other industries, such as trade and tourism. Therefore, Egypt’s economic security is to some extent dependent on sea-borne transportation. Also the world sea-borne trade is depending on the SC and the GOS as well. GOS is a heavy traffic waterway and VTS is recognized as a tool used for enhancing the safety and marine protection in its area of interest (AOI). This thesis is exploratory research aims to discuss the role of GOS VTMS as a total maritime surveillance socio-technical system in enhancing safety of navigation and marine environment protection in the GOS in addition to define its critical problems.

1.5 Research objectives

This dissertation aims to investigate the legal framework, structure as well as the effectiveness of the GOS VTMS in the scope of contemporary safety challenges and threats that have emerged in the area in the past few years. In addition to analyze the cooperation between different entities in order to establish a successful MSS. Furthermore, this research will identify the gaps and provide proposals to enhance Egypt’s territorial waters safety and marine environment protection.
1.6 Research questions

According to Creswell & Poth (2016, p.107) “Qualitative research questions are open-ended, evolving, and non-directional; restate the purpose of the study in more specific terms; start with a word such as "what" or "how" rather than "why"; and are few in number”. This research adopted qualitative methodology thus, according to the research problem, research questions arise with what? How? On a specific topic, where the answer must be sought to discover the best solution. The following questions have been raised in this study;

1- What is the current maritime surveillance and the role of VTMS in the Gulf of Suez?

2- What are the strengths and weaknesses of maritime surveillance in the GOS?

3- How to improve the maritime surveillance system?

1.7 Scope and limitation of the study

The scope of this research is limited to GOS VTMS as total maritime surveillance socio-technical system. The legal framework, organizational structure and the three main components of the VTS will be discussed in order to find out the role of VTMS in maritime safety and marine environment protection.

1.8 Methodology

1.8.1 Data collection

Primary and secondary sources will be used for data collection in this study. According to Igwenagu (2016), before commencing in collecting data the researcher must first define the problem to be solved and specify its objectives. Then, the researcher may have the option to collect relevant data as primary resources of data or rely entirely on existing data that has already been collected by another person as secondary sources of data. In this study, the primary data will be collected through in-depth interviews with targeted sampling techniques for VTS competent authority officials as well as highly experienced users of the GOS such as masters and chief officers in addition to service providers. The secondary data will encompass relevant literature including; national legislation and policy, VTS users’ guide and reports issued by EAMS, VTS procedures, IMO, IALA, UK hydrographic office publications, VTS job descriptions, organizational charts, and other relevant documents. This set
of data sources will mainly support research analysis in the qualitative research method.

1.8.2 Research methodology

According to Creswell & Poth (2016), the qualitative approach is suitable to be used in the study of a research problem when the problem needs to be explored; When a complex and detailed understanding is required; When the researcher seeks to write in a flexible literary style. Thus, the qualitative method is employed in fulfilling the aims and objectives of this dissertation. The research is exploratory addressing what and how questions. On the contrary, according to Kaplan (2004) quantitative method deals with mathematics and statistics to explore the correlation between variables and numbers by utilizing (why) questions. Choy (2014) summarized the weaknesses and strengthens of qualitative and quantitative research methodology approach as shown in table (1).
Table 1: weaknesses and strengths of qualitative and quantitative research methodology approach (source: Choy, 2014)

<table>
<thead>
<tr>
<th>Qualitative research methodology approach</th>
<th>Quantitative research methodology approach</th>
</tr>
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<tbody>
<tr>
<td>Strengths</td>
<td></td>
</tr>
<tr>
<td>2. Raise more issues through broad and open-ended inquiry.</td>
<td>2. Short time frame for administered survey.</td>
</tr>
<tr>
<td>3. Understanding behaviors of values, beliefs and assumptions.</td>
<td>3. Facilitated numerical data for groups and extents of agree or disagree from respondents.</td>
</tr>
<tr>
<td>Weaknesses</td>
<td></td>
</tr>
<tr>
<td>1. No objectively verifiable result.</td>
<td>1. No human perception and beliefs.</td>
</tr>
<tr>
<td>2. Skillful requirement for interviewers.</td>
<td>2. Lack of resources for large scale research.</td>
</tr>
<tr>
<td>3. Time consuming during interviewing process and intensive category process.</td>
<td>3. No depth experience description.</td>
</tr>
</tbody>
</table>

One of the most important methods used in qualitative research approaches is the qualitative interview because it allows the researcher to explore and introduce the perspective of the interviewees (Patton, 2014). This research focuses on the GOS VTMS by understanding the roles and defining the critical problem in this maritime surveillance system instead of focusing on measuring and controlling quantitative data, where the research question in a different approach is more specific. Thus, this research has been identified as a qualitative approach that is represented in exploratory research. For that reason, the main focus of this thesis is the exploration of shortfalls or critical problems of GOS VTMS in the real current situation. The following figure shows the conceptual framework for this dissertation.
Figure 2: Research conceptual framework (source: developed by the author).
CHAPTER TWO

LITERATURE REVIEW

This chapter aims to provide a relevant in-depth literature review for an extensive analysis of GOS waterway VTMS as a total maritime surveillance system.

2.1 Introduction

Maritime surveillance system (MSS) in every country must first and foremost comply with the primary function of covering its entire national maritime territory in order to control the main areas where maritime activities are carried out. On the other hand, one of the most important aspects that must be taken into consideration is the strategic function of exercising sovereignty, national safety and security to manage and protect maritime interests. MSS has been defined by many scholars, International organizations and agencies from different perspectives. For example, the Maritime Affairs of the European Commission defined it as “Maritime Surveillance is the effective understanding of all activities carried out at sea that could impact the security, safety, economy, or environment of the European Union and its’ Member States” (European Commission, 2010, p.1).

This definition is the same as the IMO definition for Maritime Domain Awareness (MDA) which is defined as “The effective understanding of anything associated with the maritime domain that could impact up on the security, safety, economy, or environment” (IMO, 2010a, p.1).

In fact, applying the definition of surveillance in the MD presents major fundamental challenges due to the vast sea areas that must be covered. However, great strides can be made in this direction by utilizing current modern technology in this field (Dalaklis et al., 2009). There are two different reporting systems are included in the maritime domain surveillance. The first system, is cooperative vessel which actively provide its information such as location and identity and this information is constantly updated such as Long Range Identification and Tracking (LRIT), satellite and terrestrial Automatic Identification System (AIS) and/or Vessel Monitoring System (VMS) which have been adopted by IMO. The second, is non cooperative system in which vessels are not providing their information therefore, coastal radars and videos
are used in order to conceal and identify the presence of such vessels (Mazzarella et al., 2013)

2.2 Mandatory reporting system

Mandatory reporting systems obligate ships when approaching a specific routing system to provide its name, cargo onboard and other information to the coastal state authorities. This allows the ship to be identified on the radar and its course throughout the system. This regime falls under the category of the cooperative reporting system. Also, there are other types of ship reporting systems such as ships report their particulars to VTS centers, port authorities and companies for various purposes. When the ship enters a VTS region, the VTS center automatically identifies and tracks the ship. Under the scope of ship reporting system, ships are obligated to report their position at regular intervals to designated authorities. IMO has included ship reporting systems in SAR and SOLAS conventions to be utilized for different purposes.

2.2.1 Ship reporting system under the scope of UNCLOS

Article 21 of the UNCLOS convention is playing an important role for coastal states which have an excessive ship’s movement transiting through its waters. Coastal states have been given rights and obligations to establish mandatory ship reporting system. This article provides powers for coastal states to enable them to adopt laws and regulations to ensure marine environment protection in general, the safety of navigation and the regulation of maritime navigation particularly. Ship traffic can be passively regulated through the use of traffic separation schemes (TSS) and the interaction between the vessel and coastal state authorities (Hughes, 2009) such as ship’s crew and VTS center.

2.2.2 SOLAS regulation for ship reporting system (SRS)

According to SOLAS 1974 V/11.1, ship reporting systems contribute to the safety of life at sea, the safety and efficiency of navigation, and the protection of the marine environment. Ships reporting systems may be established by the contracting government after they are accepted by IMO in compliance with all SOLAS requirements for a particular area. At the request of the contracting governments, IMO will evaluate the proposal according to the guidelines and standards adopted by IMO MSC under the Resolution MSC.433 (98). The contracting government’s proposal
shall comply with the resolution. Then, IMO adopt the reporting system and finally disseminate it to all member states and it becomes mandatory (IMO, 2017a). Thereafter, the ship's master is obliged to comply with the reporting system and report the ship's particulars and information to the shore-based competent authority.

2.3 National mandatory reporting system in the Gulf of Suez

The increasing traffic density combined with the ship sizes and higher speeds continues to attract the attention of researchers and their efforts to enhance the safety and efficiency of shipping specifically in areas with heavy ship traffic. According to Professors Dalakis, Sioussiouras and Nikitakos (2009), the introduction of traffic management principles is one way of accidents number reduction in those areas. An example is the traffic separation schemes (TSSs) that control traffic on ships. TSSs consist of traffic lanes, each representing directions of traffic flow within the TSS area of interest (AOI) (Pietrzykowski & Magaj, 2017).

The Gulf of Suez TSS was established to separate S-bound and N-bound shipping. The scheme position extends from 5 miles southern Ras El Adabiya to the eastern of Shaker Island. The scheme has been adopted by IMO and complies with Rule (10) of COLREG 1972 (EAMS, 2020). Rule 10 states that “This Rule applies to traffic separation schemes adopted by the Organization and does not relieve any vessel of her obligation under any other rule” (IMO, 1974). According to Sailing directions for the Indian Ocean publication 170 and Sailing directions for the Red Sea and the Persian Gulf (NP 64), ships using GOS TSS must navigate in the appropriate lane of traffic in the general direction of traffic flow for that lane; whenever possible, ships should keep clear from a traffic separation zone; normally leaving or joining a traffic lane shall be at the end of the lane, but when the vessel joins or leaves either

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1 Dover straits have been well known as one of the busiest waterways all over the world and have a traffic separation scheme (TSS) that was adopted in 1977 by IMO. Since then, IMO has adopted many other TSS in various straits around the world. Likewise, IMO is adopting more and more mandatory S.R.S which includes a T.S system with most if not all regions operating from the VTS center. Another example is the adoption of IMO Resolution MSC.161(78) where the Australian authority has been given the approval for looking after the Torres strait and great barrier reef areas by providing navigational information to help the decision-maker onboard.
side shall do so at as small an angle to the general direction of traffic flow as possible; also ships should, as much as possible avoid crossing traffic lanes but if they are obliged to do so, they must cross as closely as practically possible at right angles to the general direction of traffic flow (Directions, 2020; UK Hydrographic Office, 2019a).

2.4 Aids to Navigation (AtoN)

An AtoN is defined by IALA as "A device or system external to vessels that is designed and operated to enhance the safe and efficient navigation of vessels and/or vessel traffic" (IALA, 2018, p.5).

AtoN including lights, Racons, light beacons, and light floats are established throughout the GOS to aid safe navigation of the TSS and approaches to the major terminals. The disposition and range of the lights are such that, under normal conditions of operation and visibility vessels should be within sight of at least two fixing marks at all times whilst transiting the TSS. Any information regarding faults or changes to the AtoN is broadcast by Serapeum Radio (SUZ). Bridge team are required to watchkeeping of SUZ radio broadcasts and to report any malfunctioning or off-position navigation aids, but have not already been mentioned in the broadcasts (UK Hydrographic Office, 2019b; EAMS, 2020).

2.5 Maritime surveillance technologies

Typically, a range of different techniques of surveillance are used that include fixed cameras, visual sighting, radar, closed-circuit television (CCTV), and infrared imaging (Siousiouras & Dalaklis, 2009). Although the effectiveness of these systems may be affected by the lack of information that can be provided such as small vessels that are not subjected to the reporting system and/or carriage requirements of Automatic identification system the combination of these sensors and components can lead to the formation of an adequate maritime traffic image.

2.5.1 Vessel Traffic Service (VTS)

According to Professors Dalaklis, Siousiouras and Nikitakos (2009) VTS is a shore-based maritime traffic management system established by coastal states and VTS operations are similar to aircraft air traffic control centers. Typical VTS systems use radar, closed-circuit television (CCTV), VHF radiotelephones and AIS to track ship movements and provide safe navigation in a limited geographical area (Allen, 2009). The system is designed to improve the safety of life at sea, navigation
efficiency and the protection of the marine environment including the adjacent shore area and offshore installations from the potentially harmful effects of maritime traffic (Siosiouras & Dalakis, 2009; IMO, 1997). In terms of international law, the legal regime for VTS is SOLAS Regulation V/12 supplemented by IMO Resolution A.857(20) guidelines for VTS. Both are stating the basic principles of VTS and define it as:

A service implemented by a Competent Authority designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area (IMO, 1997, p. 3).

2.5.2 Types of VTS

Basically, there are two types of VTS; coastal VTS and harbor/port VTS. Port VTS is dealing with vessels entering and exiting the port not only to provide safe and efficient traffic within the port area but also it is playing an important role in avoiding undue delays and accidents (Dalakis et al., 2009) which in turns effect on the economic (Wennink, 1992). Coastal VTS is primarily involved in facilitating the passage of vessels across coastal waters or straits. Its purpose is to provide efficient traffic flow, safety of navigation, security, in addition to environmental protection in a specific area. Coastal VTS is therefore more concerned with legal concerns because it extends beyond the territorial waters of the country (MacWilliam & Cooke, 2006).

2.5.3 Services provided by VTS

According to IALA (2016), VTS provides three services;

- **Information services (INS)** is a service where Vessel Traffic Service Operator (VTSO) provides when necessary all vessels in the region with necessary safety-related information (Dalakis et al., 2009). The information varies from hydro-meteorological to the location information, intent and identity of other ships in the area (Costa et al., 2018). Mainly, INS seeks to ensure that all parties are familiar with the current situation of the area to help them in building situational awareness. Basically, this service is standard and provided by VTS centers.
- **Traffic Organization Service (TOS)** is a traffic management service inside the VTS coverage area (Siosiouras & Dalaklis, 2009). It regulates traffic to prevent hazardous situations such as problems related to conflicting travel routes and space allocation that may lead to crowding or grounding or in the worst case collisions (Blokus-Roszkowska & Smolarek, 2014). It works by allowing maneuvers, preventing entrance into specific areas, set the speed limits and grant permits. It ensures the safety and efficiency of traffic flow within the coverage area of VTS.

- **Navigational Assistance Service (NAS)** is explained by Professors Dalaklis, Siosiouras and Nikitakos (2009) as the provision of maritime assistance services provided to ships have problems and/or difficulties in navigating safely on its own and seeks the benefits of VTS assistance. The lack of onboard navigation equipment or other internal/external problems may lead the decision-maker onboard ships to request the service (van Westrenen & Praetorius, 2014). By actively providing the ship's crew with information about other ships' positions, currents, obstacles, and factors to consider when navigating in a limited area, the goal of the VTSO providing NAS is to assist in making navigational tactical decisions onboard ships. (Siosiouras & Dalaklis, 2009; IMO, 1997). After giving the advice the VTSO monitors the outcomes through the decision support system. The service is almost rendered exclusively at the request of the ship and the instructions provided must be results-oriented, which means that execution details are left to the shipmaster.

### 2.6 VTS international legal framework

Member states of IMO have generally acknowledged that VTS is playing an important role in the MD, but in terms of governance based on national preparedness, states are still different. Therefore, the international framework for VTS as a multilateral agreement that sets the standards and requirements obliged by the member states is required. IMO and IALA are jointly cooperated to develop

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2 For example, international standards governing VTS among others are; IALA V-127 VTS operations, IALA V.103 Operator Training, IALA Guideline 1089, Types of
provisions related to VTS and its performance standards (Siosiouras & Dalakis, 2009). VTS legal framework can be illustrated as shown in figure 3.

![VTS Legal Framework Diagram]

Figure 3: VTS LEGAL frame work (developed by the author).

**2.6.1 State sovereignty under the scope of UNCLOS**

In order to promote a consistent, coherent, and effective approach to VTS, it has to be obtained in international law and internationally agreed on guidance documents. Also to control activities that may impact upon safety, security, environment, or economy the state should carry out MS and install its assets on the basis of sovereignty approach. UNCLOS adopted in 1982 and entered into force in 1994, the convention is well known as the constitution of the sea. The provisions of the Convention applicable to the management and control of ship traffic are primarily concerned with ocean areas measured from the baseline of the coastal State (Allen, 2009). UNCLOS is the international multilateral agreement that specifies the limits of the territorial seas of states and the regions in which they can exploit marine natural

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resources (Østhagen, 2020). The General Assembly of UN recognized the role of the Convention to strengthening peace, security, cooperation and decent relations between all nations. In addition to promoting sustainable development of the oceans and seas and provide their legal framework (Allen, 2009).

Article 94-3 (a), (b) and (c) of UNCLOS stipulates the responsibilities of flag states to ensure the safety of ships flying their flag in terms of crew, training and equipment. Also coastal and port states’ rights and obligations have been stated in Article 201 to exercise sovereignty in the territorial sea, CZ and EEZ. Although It has been argued that there are no clear provisions mandating the establishment of VTS, the state may establish VTS to fulfill the protection of the environment and safety of navigation through claiming and exercising its sovereignty (Segar Abdullah, 2000).

2.6.2 VTS under the scope of IMO

IMO has been empowered to regulate maritime safety provisions and the protection of the marine environment as stipulated in UNCLOS statute. The two major IMO conventions governing VTS are the International Convention for the Safety of Life at Sea (SOLAS) and the Convention on Standards of Training, Certification and watchkeeping (STCW). In which they regulate the establishment and organization of VTS, conducting VTS operations, training and accrediting VTS personnel and those onboard Ships (Amphanthongpaphakul, 2018).

2.6.3 VTS requirements in STCW 78 convention as amended and Code

STCW Convention amendments 3 required deck officers to be familiar with Standard Marine Communication Phrases (SMCP) as well as ship reporting systems including VTS procedures to maintain safe navigation control and watch as stated in table A-II/1 in the STCW code (IMO, 2010b, p.101).

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3 The Convention sets international standards for seafarers’ qualifications, competencies and training. STCW convention was adopted in 1978 and encountered two major amendments in 1995 and the most recent 2010 as well known by Manilla amendments.
2.6.4 VTS IN SOLAS 1974

When there is a significant change to SOLAS convention such as adding a chapter or when changes are applied to all chapters due to accident or developing in technology then IMO introduces the modification as a protocol such as SOLAS protocol 1978 and 1988. Those amendments are binding only states ratified the protocol. SOLAS 2000 amendments chapter V Regulation 12 has broadly defined the requirements of Contracting Governments that intend to establish VTS as following:

1. Vessel traffic services (VTS) contribute to safety of life at sea, safety and efficiency of navigation and protection of the marine environment, adjacent shore areas, work sites and offshore installations from possible adverse effects of maritime traffic.

2. Contracting Governments undertake to arrange for the establishment of VTS where, in their opinion, the volume of traffic or the degree of risk justifies such services.

3. Contracting Governments planning and implementing VTS shall, wherever possible, follow the guidelines developed by the Organization. The use of VTS may only be made mandatory in sea areas within the territorial seas of a coastal State.

4. Contracting Governments shall endeavor to secure the participation in, and compliance with, the provisions of vessel traffic services by ships entitled to fly their flag.

5. Nothing in this regulation or the guidelines adopted by the Organization shall prejudice the rights and duties of Governments under international law or the legal regimes of straits used for international navigation and archipelagic sea lanes (p. 364).

Within the framework of SOLAS requirements related to vessel Design, Construction, Equipment and manning (DCEM), Officers of Watches (OOWs) and shipmasters testified a rapid and integrated deployment of sensors such as radar, GPS, gyrocompass, infrared, in addition to work stations such as electronic chart

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4 After the disaster of Titanic, the international convention on safety of life at sea (SOLAS) was adopted in 1914 later on many amendments have been applied.
display and information systems (ECDIS), automatic radar plotting aids (ARPA), radar and AIS. At the same time, there was an effort to connect and display these sensors in ship-to-shore information systems. Therefore, IMO and IALA worked together to harmonize the collection, exchange, integration, analysis and present maritime information on the shipboard and onshore (Allen, 2009). The current models of VTS are the achievements of this cooperation between IMO and IALA.

2.7 IALA perspective for VTS

IALA ⁵ has participated in the drafting of all IMO guidelines on VTS since 1985. Member states had a decision to keep Resolution A.857 (20) without changing in future, and IALA will publish updated information as appropriate in the VTS manual (IALA, 2016). IMO urged member states to consider recommendations issued by IALA relating to VTS authorities. Consequently, IALA guidelines and recommendation has been considered as VTS standards for training and certification of VTS personnel. IALA VTS manual implies that when planning VTS, powers and delegated authority to individual VTS personnel shall be defined by the VTS authority; emphasizes the need for VTSOs to be informed of the legitimate justification on which they operate and from which they obtain the authority to interact with maritime traffic (Amphanthongpaphakul, 2018).

2.8 National legal framework for VTS

Due to the presence of the Suez Canal that connects the Mediterranean with the Red Sea, the maritime traffic in Egyptian waters is very congested and considered as a geopolitical choke area for the world sea born trade. According to the report of the SCA in 2020 ships transited with a daily average of 50 ships and a total tonnage of approximately 1.14 billion tons, which represents about 14 percent of the total

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⁵ The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a non-profitable, nongovernmental international technical association established in 1957. IALA acts as an observer and consultative organization among 81 NGOs with the IMO

⁶ IALA VTS manual recommended a specific training module for each position of VTS personnel as following:
- Model Course V-103/1 – VTS Operator Basic Training
- Model Course V-103/2 – VTS Supervisor Advancement Training
- Model Course V-103/3 – VTS On-the-Job Training
- Model Course V-103/4 – VTS On the Job Training Instructor
global seaborne trade (Suez Canal, 2020). Therefore, maritime safety, efficiency and protection of the marine environment in the GOS are among the priorities of Egyptian legislators. GOS VTMS has been assigned the responsibility of ensuring safe navigation as well as marine environment protection. It has the duty of controlling and providing information and assisting users based on data received from all parties and sources involved in the navigation within the waterway (Abdelhafez, 1998).

2.8.1 Competent authority and VTS authority

According to IALA, competent authority is the authority delegated fully or partially by the government to have the responsibility of safety and efficiency of vessel traffic including protection of the environment. While VTS Authority is the authority responsible for managing, operating and coordinating VTS, interacting with participating ships and providing service safely and efficiently (IALA, 2016). In Egypt, the Competent Authority is not the VTS authority. EAMS is the governmental agency that regulates the maritime industry and ensures the protection of the marine environment. GOS VTMS entered into service in 2002 and upgraded in 2019 to assist the vessels in the GOS area. VTMS legal basis for implementation and enforcement is Presidential Decree 399/2004 on establishing the Egyptian Authority for Maritime Safety and Law 232 of 1989 on ship safety. Abdullah (2011) explains that although there are no established procedures in creating and exercising VTS in national legislation from previous literature, contracting governments that already have VTS regulations must adhere to IMO and IALA recommendations and guidelines. EAMS signed an agreement with ministry of defense as VTS authority, where MOD operate and coordinate with EAMS to improve maritime traffic within the VTS area as well as the coastal navigation (EAMS, 2020).
CHAPTER THREE

THE ROLE OF VTMS AS A TOTAL MARITIME SURVEILLANCE SYSTEM IN IMPROVING NAVIGATION SAFETY AND ENVIRONMENTAL PROTECTION IN THE GULF OF SUEZ (GOS)

This chapter discusses Egypt’s sovereignty over the establishment of MSS represented by VTMS in the GOS waterway. The current VTMS system will be explained and analyzed with regard to coverage area, infrastructure, existing equipment and its functional operations. As mentioned in the research methodology the information and analysis of data are concluded under the scope of national legislations, investigations into IMO publications, literatures and in-depth interviews with targeted sampling techniques for VTS competent authority officials. EAMS as the maritime administration has the responsibility to establish VTS, Coastal stations and AtoN. Also interviews include two different stakeholders of highly experienced users of the GOS such as masters and chief officers in addition to service providers.

3.1 Egypt’s sovereignty to establish total maritime domain surveillance

According to Professors Dalakis, Siousiouras and Nikitakos, (2009, p.36) “Due to the international and interconnected nature of the maritime economy any action taken towards improvement in all aspects of maritime activities is far more effective if taken collectively rather than individually”.

Therefore, Egypt ratified the UNCLOS in 1983 for collective cooperation in promoting the maritime industry. Egypt has also attached its ratification of the Convention with seven declarations relating to the territorial sea and the passage of nuclear ships or similar of it in the Egyptian territorial sea, in addition to the passage of warships in the Egyptian territorial sea, the contiguous zone and practice of Egypt's rights in the economic zone.

3.1.1 Territorial sea declaration

The maritime zones of the Arab Republic of Egypt including its internal waters and a territorial sea of twelve nautical miles measured from straight baselines were set out in two annexes attached to the decision of the President of the Arab Republic of Egypt No. 27 of 1990 of January 9, 1990 (Presidential Decree 27, 1990).
The Declaration was followed by maps showing the baselines from which the territorial sea of the Arab Republic of Egypt is measured in the Mediterranean, Red Sea and the lines that define the outer limits according to the convention (Decree concerning the Territorial Waters of the Arab Republic of Egypt of 15 January 1951, as amended by Presidential Decree, 1956).

3.1.2 Rights of innocent passage
Declamation No. 27 of 1990 also mentioned the passage of nuclear-powered and similar ships through the territorial sea of Egypt. It is clear from the Egyptian declaration that Egypt will not abide by any agreement that is not a party to it regarding the preventive measures that the nuclear ships have to take. Moreover, the innocent passage of warships in the territorial sea is guaranteed on the basis of the prior notification.

3.1.3 Contiguous zone declaration
The Arab Republic of Egypt decided to extend its CZ to 24 nautical miles from the baselines from which the breadth of the territorial sea is measured, as stipulated in Article 33 of the Convention (Decree concerning the Contiguous zone of the Arab Republic of Egypt of 18 January 1951, as amended by Presidential Decree of 17 February, 1958).

3.1.4 Exclusive Economic Zone Declaration
The jurisdiction of the state in the EEZ adjacent to its territorial sea depends on the issuance of a statement or declaration on its part specifying the extent of the expansion of these zones, in addition to expressing its tendency to practice the jurisdiction of its sovereignty on its natural resources. Therefore, it is clear that the declaration which was made was necessary. Egypt has established an exclusive economic zone (EEZ) in the Mediterranean on the borders of (potential) exclusive economic zones of Libya, Greece, Cyprus and Israel. On 17 February 2003, Egypt and Cyprus signed agreement on the delimitation of the Exclusive Economic Zone. (Agreement between the Republic of Cyprus and the Arab Republic of Egypt on the Delimitation of the Exclusive Economic Zone 17 February 2003).
3.2 Governmental and non-governmental agencies involved in the Gulf of Suez Maritime Domain surveillance

Maritime surveillance includes interaction between many maritime agencies that face the challenge of ensuring security, safety, environmentally friendly and clean seas (Chiantoan-uta & Silva, 2017). Commercial vessels are monitored by maritime administrations, Fisheries administrations track fishing vessels and the Coast Guard or law enforcement agencies other border undertake to monitor other activities at sea. Each one of these entities/administrations has developed its possess of MSS that compiles and processes the information in relation to their needs (Tikanmäki, 2017). GOS VTMS as MSS and data collection is performed by different organizations. The following part shows entities involved in MS in Egypt in general and in the GOS in particular through national legislation in order to enforce each entity to implement and carry out the assigned responsibility;

3.2.1 Marine Survey Department (Navy)

Ministry of defense represented by the Navy-Marine Survey Department has the legal basis for application and enforcement under the Law 232/1989 on the safety of ships to provide hydrographic services in Egyptian territorial waters. Its responsibilities are the collection, classification, circulation, and update of all hydrographic data necessary for safe navigation. Also preparation and issuance of paper and electronic charts and sailing routes, lists of lights, tide schedule and other publications, the production of Marine booklets (publications) and Notices to Mariners to meet the needs of safe navigation.

3.2.2 Egyptian Authority for Maritime Safety (EAMS)

The legal basis of application and enforcement is Presidential Decree 399/2004 on the establishment of the Egyptian Authority for Maritime Safety and law 232 of 1989 on the safety of ships. EAMS is the maritime administration acts as competent authority of coastal state, Flag State and Port State Control. EAMS provides navigational aids in Egyptian coastal and territorial waters, promulgate Publications and navigational alerts, Investigation of marine accidents and monitoring of VTS (Maritime Transport Sector, n.d.).
3.2.3 National Telecom Regulatory Authority (NTRA)

The legal basis for application and enforcement is Telecommunications Law 10/2003. The Directive regulating the procedures of maritime communications services. Responsibilities of NTRA is being the National Data Provider by registering the data of distress devices of Egyptian ships using COSPAS SARSAT System, issuing radio licenses for Egyptian vessels, registration of Egyptian ships data at ITU (List of Ship Stations), issuing General Operators Certificate (GOC) to radio operators in accordance with STCW 78, Operation of Inmarsat devices pertinent to Safety of Maritime Navigation under (PSA) agreement.

3.2.4 Telecom Egypt (TE)

The legal basis for application and enforcement was provided under the scope of the Telecommunications Law 10/2003 in addition to license No. 1/2006 issued by the NTRA to TE and the cooperation protocol signed between Telecom Egypt and the Meteorological Authority. TE has the responsibility to operate coastal radio stations for communication and distress services, broadcast radio navigational alerts and weather forecast services to ships in Egyptian territorial water including the Gulf of Suez.

3.3 Maritime traffic features and cost-benefits of maritime surveillance in the Gulf of Suez

The high costs of a high-tech surveillance system are one of the main problems which the Maritime Administration may face and consequently, the lack of an economical and operational criterion is an obstacle to establish and put into operation a well-developed surveillance system. For that reason, costs must be in balance with the benefits which will be achieved by the system and those benefits may be monetary and/or other immaterial valued benefits. MS is required due to increased maritime unsafe conditions as well as insecurity and a wide range of threats, risks and vulnerabilities. The heavy maritime traffic within the Mediterranean Sea, Red Sea as well as Suez Canal is associated with safety, security and environmental challenges to Egypt. According to the World Economic Forum “Global Competitiveness Index (2019)”, the global competitiveness of Egypt’s liner shipping connectivity and seaport infrastructure rank 18 and 41 respectively among 141 countries and regions (Schwab, 2019).
Ports in Egypt are located mainly around the Gulf of Aqaba, the Mediterranean and the Red Sea, among which more than 100 have public codes and 59 can act as maritime ports (Maritime Transport Sector, n.d.). Egypt’s main ports include Alexandria Port which is the largest port for cargo transport in Egypt, Port Said, Suez Port and Port Damietta. Egypt’s Ports have achieved 6.24 billion Egyptian pounds of surplus in 2016. While the annual holding capacity of Alexandria port is 1.613 and Port Said is 3.050 million TEUs, according to Lloyd’s List, in 2018 Alexandria port has been ranked 94 and in 2019 port said has been ranked 57 among the top 100 international ports (Lloyd’s List, 2018, 2019).

The Suez Canal which is the main artery of global navigation links East and West. It connects Europe, Africa and Asia and holds eight percent of international trade shipment and 14% of the international seaborne trade in volume (Egypt Economic Development Conference, 2015). SC is one of the pillars of Egypt’s economy, its annual revenue is around six billion USD. In 2019 the Suez Canal revenue accounted for 2.4% of the Egyptian GDP and the foreign direct investments it attracts account for up to 8% of the total volume (The Egyptian Center for Economic Studies, 2020).

Table 2: Total vessels calls on Egyptian seaports during 2018-2019 (source: EMDB, 2019)
<table>
<thead>
<tr>
<th>Port</th>
<th>year 2018</th>
<th>year 2019</th>
<th>Variation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexandria</td>
<td>2,937</td>
<td>2,994</td>
<td>2%</td>
</tr>
<tr>
<td>El Dekheila</td>
<td>1,192</td>
<td>1,159</td>
<td>-3%</td>
</tr>
<tr>
<td>Damietta</td>
<td>3,011</td>
<td>3,257</td>
<td>8%</td>
</tr>
<tr>
<td>Suez</td>
<td>96</td>
<td>94</td>
<td>-2%</td>
</tr>
<tr>
<td>Petroleum Basin</td>
<td>82</td>
<td>23</td>
<td>-72%</td>
</tr>
<tr>
<td>Safaga</td>
<td>876</td>
<td>794</td>
<td>-9%</td>
</tr>
<tr>
<td>Nuweiba</td>
<td>810</td>
<td>766</td>
<td>-5%</td>
</tr>
<tr>
<td>Sharm El-Shaikh</td>
<td>67</td>
<td>105</td>
<td>57%</td>
</tr>
<tr>
<td>Hurghada</td>
<td>186</td>
<td>210</td>
<td>13%</td>
</tr>
<tr>
<td>West Port Said</td>
<td>2,262</td>
<td>1,966</td>
<td>-13%</td>
</tr>
<tr>
<td>East Port Said</td>
<td>1,476</td>
<td>1,504</td>
<td>2%</td>
</tr>
<tr>
<td>Adabiya</td>
<td>580</td>
<td>549</td>
<td>-5%</td>
</tr>
<tr>
<td>Sokhna</td>
<td>374</td>
<td>324</td>
<td>-13%</td>
</tr>
<tr>
<td>Specialized ports</td>
<td>-</td>
<td>282</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13,949</strong></td>
<td><strong>14,027</strong></td>
<td><strong>1%</strong></td>
</tr>
</tbody>
</table>

Table 3: Total cargo handling in the Egyptian seaports during 2018-2019 (source: EMDB, 2019)

<table>
<thead>
<tr>
<th>Port</th>
<th>year 2018</th>
<th>year 2019</th>
<th>Total 1,000 Ton</th>
<th>Variation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexandria</td>
<td>24,783</td>
<td>23,798</td>
<td>85</td>
<td>4%</td>
</tr>
<tr>
<td>El Dekheila</td>
<td>22,870</td>
<td>21,522</td>
<td>121</td>
<td>-6%</td>
</tr>
<tr>
<td>Damietta</td>
<td>17,191</td>
<td>13,403</td>
<td>7,282</td>
<td>-7%</td>
</tr>
<tr>
<td>Suez</td>
<td>84</td>
<td>173</td>
<td>0</td>
<td>17%</td>
</tr>
<tr>
<td>Petroleum Basin</td>
<td>463</td>
<td>0</td>
<td>0</td>
<td>-63%</td>
</tr>
<tr>
<td>Safaga</td>
<td>1,980</td>
<td>1,591</td>
<td>0</td>
<td>2%</td>
</tr>
<tr>
<td>Nuweiba</td>
<td>146</td>
<td>378</td>
<td>0</td>
<td>2%</td>
</tr>
<tr>
<td>West Port Said</td>
<td>2,281</td>
<td>1,835</td>
<td>1,644</td>
<td>23%</td>
</tr>
<tr>
<td>East Port Said</td>
<td>626</td>
<td>208</td>
<td>23,908</td>
<td>26%</td>
</tr>
<tr>
<td>Adabiya</td>
<td>5,458</td>
<td>4,710</td>
<td>0</td>
<td>-10%</td>
</tr>
<tr>
<td>Sokhna</td>
<td>7,563</td>
<td>3,911</td>
<td>26</td>
<td>-11%</td>
</tr>
<tr>
<td>Specialized Ports</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83,445</strong></td>
<td><strong>40,729</strong></td>
<td><strong>33,066</strong></td>
<td><strong>9%</strong></td>
</tr>
</tbody>
</table>
3.4 Gulf of Suez Waterway features and status of ship casualties

The Gulf of Suez is a waterway that lies at the north of the Red Sea. The area of interest (AOI) which encompasses the entire Gulf is approximately 175nm. The GOS is a narrow waterway in most areas being only 10-15nm wide and at the widest being about 25nm (Jica, 2008)

According to the master of a container ship with an experience of more than 20 years, the interviewee's statement stated that

“for hundreds of times navigating in the GOS, oil rigs and fishing vessels are the main hazards to navigation in the GOS waterway. Numerous oil rigs, flares and platforms exist on both shores of the gulf some marked by lights and in some cases by racon as well. Also mariners are warned that some of these structures are temporary; they should not rely on the charted positions; due caution is required when navigating in their vicinity and entry into certain areas containing oil fields is prohibited”.

Professors Dalaklis, Siousiouras and Nikitakos (2009) also stated that although maritime accidents occurred in the past and could continue in the future, utmost effort must be made to ensure safe and efficient shipping operations. In order to evaluate these statements and identify the risk in the GOS area, further investigation in trends of casualties has been carried out.

In 1990 the number of causalities accounted for 7, while in 1997 the number of casualties increased to 16 accidents. Between 1990 and 1997 the total number of casualties reached 88 with different types of casualties such as oil pollution, collision and grounding (Abelhafez, 1998).

GOS is the region most at risk of pollution in the Red Sea, particularly oil pollution (Ghalwash & Elkawam, 2004). In 2003, Al-AGAMY tanker collided with No. 3 SALAM in the GOS, resulting in an oil spill from 8 to 20 tons to the sea. The Red Sea Ports Authority responded to this incident and the dispersants were used. Many resort areas and beaches have been affected by the drifting oil spills that have been manually removed from the beaches (Dewina & Yamauchi, 2009).

In 2014 collision between a fishing boat and Kuwaiti flagged container ship leading to 25 fatalities in the GOS between Ras Ghareb and el Tor (Ahram Online,
2014). The researcher tried to find officially recorded data related to casualties and one of the interviewee participants stated that “There is no accident official statistics available, according to national legislations EAMS has the responsibilities to carry out accident investigations. Causality investigation department is not implemented properly”. Therefore, the next part of this thesis includes more investigations related to the safety of navigation in the GOS to understand rules and traffic separation scheme for ships navigating in the GOS.

3.4.1 Traffic separation scheme (TSS)

Maritime traffic rules are typically limited to national legislations and confined by the IMO-approved routing scheme which is implemented as a TSS. At the northern end of the GOS vessels enter and leave the Suez Canal. In the central area of the GOS, there is intense marine oil field related activity and in the south of the GOS there is an increase in the recreational traffic due to expanding tourism related to the coral reefs.

Five areas have been identified as critical traffic management areas in the GOS. From north to south they are:

1. Entrance to Suez Bay; anchorage areas; and transhipment zone.
2. Morgan oil fields; ports of Abu Zenima and Ras Budran.
3. Ras Shukheir Terminal and oil fields.
5. Strait of Tiran, Sharm El Sheikh.
6. Ain Sukhna; anchorage areas; Single Point Mooring (SPM) buoys; Traffic Separation Scheme (TSS) gates and transhipment zone (UK Hydrographic Office, 2019c).
Figure 4: Traffic Separation Scheme in the northern of GOS (source: IMO, 2019, p.IV/1-3).
Figure 5: Traffic Separation Scheme in the southern of GOS (source: IMO, 2019, p.IV/1-3).
3.4.2 Rules for ships navigating in the Gulf of Suez

For safe navigation in the routes of GOS, navigation rules are issued by EAMS then, routes have been endorsed by IMO which published them in part F of "SHIP'S ROUTEING MANUAL". All ships should take into account throughout their passage in the GOS the following rules; All ships must have their radar in operational mode day and night across the passage between Shaker Island and Suez Port as assistance to achieve maximum compatibility with the lane and avoid collision risks. Ships transiting the GOS are required to watchkeeping broadcasts of traffic information in the GOS and inform “SUZ” if any aids to navigation are out of position or malfunctioning (IMO, 2019).

3.4.3 Aids to Navigation in the Gulf of Suez

As discussed earlier in the literature review, EAMS has the responsibility to establish and maintenance of AtoN. The GOS AtoN are including lights, racons, light beacons and light floats that are established throughout the GOS to aid safe navigation of the TSS and safe entrance and approach to ports and major oil terminals (IALA, 2013a). As stated by the senior engineer in the department of aids to navigation and communication, for many years EAMS had invested in major projects in the Red Sea and GOS to establish, renew, maintain and upgrade visual and radio aids systems for navigation in the GOS. Lighthouses, buoys, shapes and marks are the main components of AtoN. The operational status of these components are monitored by EAMS engineers via GSM and satellite monitoring system in order to keep AtoN functional properly. The type, number and range of AtoN operating in the GOS are as follow;

Table 4: Aids to Navigation in the GOS

<table>
<thead>
<tr>
<th>Navigation Aids</th>
<th>Number</th>
<th>Range in NM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Houses</td>
<td>7</td>
<td>Between 15-22 NM</td>
</tr>
<tr>
<td>Beacons</td>
<td>11</td>
<td>Between 7-18 NM</td>
</tr>
<tr>
<td>Safe water buoy</td>
<td>5</td>
<td>Between 9-12 NM</td>
</tr>
<tr>
<td>Isolated danger buoy</td>
<td>2</td>
<td>9 NM</td>
</tr>
</tbody>
</table>
To understand the current situation of AtoN in the GOS in more detail an overview has been carried out on “Admiralty LIST OF LIGHTS AND FOG SIGNALS NP77 volume D”. This publication is weekly updated from the notice to mariners. Any information regarding faults or changes to the aids to navigation is broadcast by Serapeum Radio. But on the other hand, seafarers are warned that AtoN in the GOS are unreliable and may be missed, unlit, or off-position. Navigation officers must navigate with great caution (IMO, 2019b)

3.5 VTMS as total maritime surveillance and its role as a cost-effective safety barrier

According to Skellt (2006), a safety barrier is a tool used to control, prevent and/or reduce unwanted events and accidents. The objective 7 of the GOS VTMS is to provide safe and efficient operation of the GOS ports and waterways through real-time monitoring and analysis of vessel movements, types of cargo with an accent on hazardous cargo, environmental conditions and other vital information needed (EAMS, 2020).

GOS VTMS as a single safety barrier includes a multiple of technical, human, organizational and operational barrier systems (Hollangel, 2016). GOS VTMS provides advice on navigation service, and supplies vessel with information in case of emergency or Search and Rescue (SAR) operation (ICAO, 2018). As stated earlier, SC is a geopolitical choke area for the world seaborn trade. Consequently, GOS VTMS improves the performance of ports and the waterway and thus facilitates commerce, reduces the risk and severity of accidents, and protects the environment in the area (EAMS, 2020).

In order to understand the compliance of GOS VTMS with international regulations related to the services provided by VTS, the interviewee participant statement is recalled here which is concluded in the next table.

---

7 The GOS VTMS objective is realized through integration, processing and analysis, distribution and presentation of information from various sensors.
Table 5: service provided by GOS VTMS

<table>
<thead>
<tr>
<th>Service</th>
<th>Definition</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Service</td>
<td>Ensure essential information is available to the ship to allow the shipboard navigational process to work. The information is distributed at regular intervals or at the request of a specific vessel.</td>
<td>Operator Workstation which includes: Nautical Chart Radar Images</td>
</tr>
<tr>
<td>Traffic Organization</td>
<td>Prevent the development of situations that could cause danger to vessels in the VTMS area. Plan for safe and efficient traffic flow in the area.</td>
<td>Tracs Automatic Dependent Surveillance (ADS)</td>
</tr>
<tr>
<td>Navigational Assistance</td>
<td>Assist navigational decisions on an individual ship. VTMS contributes to this by giving position information of a ship and adjacent ships. Additionally, warnings are given to individual vessels.</td>
<td>Radio Direction Finder ( RDF) Ultra High Frequency (UHF) Voice Communications Very High Frequency (VHF) Voice Communications CCTV</td>
</tr>
</tbody>
</table>

Table (5) shows the Service Matrix that defines services and elements of the VTMS employed to provide those services. Thus, in accordance with IMO Resolution A.857(20) GOS VTMS services comply with the guidelines.

Basically, GOS VTMS provides comprehensive information on the maritime traffic for ships. It consists of three main services including information Service (INS), Traffic Regulation Service (TOS), and Navigational Aid Service (NAS) (IALA, 2016; Dalaklis et al., 2009).

Also GOS VTMS meets the functional objectives outlined in the guidelines for VTS which include collecting and recording pre-arrival and pre-departure information about all vessels in the surveillance area as well as target acquisition and continuous tracking of ships in the AOI to enable; detection, supervision and control of inbound and outbound traffic, monitoring vessel traffic within the surveillance area and coordinate traffic, search and rescue activities and all subsidiary services, provide information to ongoing ships to enable safe and expeditious navigation, provision of pollution control tools, store ship information for statistical analysis and provide evidence in case of an accident or incident.
3.5.1 GOS, Port of Safaga and Sharm El Sheikh VTS area Boundaries

The GOS VTMS is a multiple Vessel Traffic Center system that utilizes four VTCs. The northern VTC is located in Ras El Adabiya; the southern one is in False Ras Gharib, VTC in the Port of Safaga and Sharm El Sheikh VTC\(^8\).

Two VTCs are used to monitor the GOS Vessel Traffic Service Area (VTSA) Ras El Adabiya (RAB) and False Ras Ghareb (FRG). The GOS VTSA boundaries extend from a position about 5 nautical miles south of Ras El Adabiya to a position East of Shaker Island (IMO, 2019b).

\(^8\) In normal operations the northern VTC is responsible for Vessel Traffic Service operations concerning the northern sectors of the GOS; the southern VTC is responsible for operations in the GOS in the southern sectors; the Safaga VTC is responsible for the port and the area around Safaga; Sharm El Sheikh VTC is responsible for the Gulf of Aqaba and Strait of Tiran.
3.5.2 VTS Organizational Concept

The basic components of VTS can be categorized into four parts: hardware, personnel, procedures and training. Another classification would classify the components into three; People, procedures and hardware (Ustaoglu & Furusho, 2002). The three-component model was adopted in this study because it is possible to discuss the training needs of staff within the category of personnel.

The first component is personnel and according to the IALA VTS manual, the personnel component may include VTS supervisors, managers and operators (IALA, 2016). In line with the IALA manual, figure 7 and table 6 respectively illustrate EAMS conceptual VTS organization and job responsibilities.

Figure 7: GOS VTS conceptual organizational structure (Source: EAMS, 2019).
Table 6: VTS personnel job responsibilities (source: EAMS, 2019)

<table>
<thead>
<tr>
<th>VTC Position</th>
<th>Typical Assigned Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations Supervisor</td>
<td>Sensor Control / employment</td>
</tr>
<tr>
<td></td>
<td>Strategic Traffic Organization / Planning</td>
</tr>
<tr>
<td></td>
<td>Emergency management</td>
</tr>
<tr>
<td></td>
<td>Watch section training</td>
</tr>
<tr>
<td>Operator</td>
<td>Traffic Monitoring</td>
</tr>
<tr>
<td></td>
<td>Ship contact / Database linking</td>
</tr>
<tr>
<td></td>
<td>VTS to Ship communications</td>
</tr>
<tr>
<td></td>
<td>Incident Reporting</td>
</tr>
<tr>
<td></td>
<td>Database Operations</td>
</tr>
<tr>
<td>Maintenance Supervisor</td>
<td>VTMS System / Equipment Maintenance Oversight</td>
</tr>
<tr>
<td></td>
<td>Maintenance training</td>
</tr>
<tr>
<td>System Administrator</td>
<td>Computer System Administration</td>
</tr>
<tr>
<td></td>
<td>User Permissions management</td>
</tr>
<tr>
<td>System Administrator</td>
<td>Software management</td>
</tr>
<tr>
<td>Engineer</td>
<td>Hardware management</td>
</tr>
<tr>
<td></td>
<td>Database management</td>
</tr>
<tr>
<td>VTS Maintenance Support</td>
<td>VTMS System / Equipment Maintenance</td>
</tr>
<tr>
<td>Team</td>
<td>Perform Corrective Maintenance</td>
</tr>
<tr>
<td></td>
<td>Perform Scheduled Maintenance</td>
</tr>
<tr>
<td></td>
<td>Perform Warranty Maintenance</td>
</tr>
<tr>
<td></td>
<td>Manage system maintenance budget / replacement kit</td>
</tr>
</tbody>
</table>

The second element of VTS that have been stated by IMO Res A.857(20) is procedures. There are two types of operating procedures the first is internal procedures and the second is external procedures (IMO, 1997). GOS VTS internal procedures are the acquiring of data to provide an overall image of the traffic situation in the coverage area. There are different sources of data such as sensors including radar, RDF, AIS and VHF radio. VTSOs carry out the process of analyzing and evaluating the information to create a traffic picture of the area and take appropriate decision according to the assessment.

External procedures are related to interaction and services provided to users of the VTS area. Operating procedures must be explicitly defined to deal with operational procedures and related duties of VTS personnel. This procedure shall
constitute the procedures to be taken concerning interactions with ships and other related parties as well as emergency situations externally and internally to manage liability effectively (IALA, 2016). In line with these guidelines, GOS VTMS Internal and external procedures have been established and implemented jointly between EAMS and MOD (EAMS, 2020). In the following chapter, the researcher will present the third component of VTS.
CHAPTER FOUR
THE APPROACH OF GOS VTMS TO IMPROVE SITUATIONAL AWARENESS

The previous chapter presented the first two components of VTS, personnel and procedures. This chapter will present the third element of VTS including equipment and sensors that have been used in the GOS VTMS and how the Situational Awareness (SA) of the VTSOs is built.

SA has been defined and discussed by many scholars in different fields such as Air traffic, Oil and Gas, and maritime domain. Although there are several debates relating to the definition of SA, this research adopted the definition provided by Brödje et al. (2010) which stated that SA is the concept used to describe how people are formulating their mental picture in a dynamic environment. Also this thesis considered the SA definition in the VTS domain provided by Endsley (1995; as cited in Wiersma & Mastenbroek, 1998, p. 36) which stipulates that “Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future”.

As per this definition, when discussing SA as a perception of elements in the VTS domain, there are two approaches to be explained.

The first is the SA of VTS operators which is strongly related to;
- Their personnel abilities such as competency and professionalism
- Equipment such as sensors, work stations and data processing available in the VTS center.

The second is the SA of the shipboard crew which mainly depend on;
- The instruments available onboard such as radars, AIS and VHF
- Information provided by the shore side from the operators of VTS.

Exchanging and updating information between the VTS center and vessels is playing a dominant role in improving situational awareness for both sides in a complex
environment which in turn improves safety of navigation and protects the marine environment. The type of information used by VTSOs as well as how, when and why it is used is crucial to understand the cognitive status of the operators. It reveals the operator's SA leading to constructing a holistic traffic image in all VTS AOI in Egypt in general and in the GOS in particular.

4.1 GOS VTMS maritime surveillance sensors

The GOS VTMS is based upon the latest technologies and best practices in terms of its system design architecture (EAMS, 2019). It offers many features and functions that are designed to enable the VTSO to provide a more efficient and effective service to shipping within the GOS through improving the SA of the OOWs. The system includes equipment for data acquisition, processing, storage and delivery to users (EAMS, 2019). This equipment is the technical tool that enables the VTS center to carry out its external and internal duties providing tracking and information on the maritime traffic in the GOS. Figure 8 shows the GOS VTMS including four centers constituting the system backbone in addition to ten remote sites sensors.
4.1.1 Radar sensor characteristics

Radar is the primary sensor of VTMS. It detects the targets within the radar coverage area for further presentation to VTSO (Bukhari et al, 2013). Radar target detection and tracking of smaller targets normally represent a compromise between detection and tracking of real, small targets and avoiding detection and tracking of false targets. This balance is a very important factor in understanding the parameters of tracking and the way the Extractor and Tracker system works. The amount of false targets is a function of detection time. The longer detection time represented by the number of radar scans for target confirmation the less false targets. The situation is not exactly simplified when more factors like long-range, small target size, waves and rain are taken into consideration (Panagopoulos & Soraghan, 2004).

Given the traffic situation in the GOS and the importance of monitoring both the Gulf entrances from the Red Sea and SC, VTS radars should cover the entire

Figure 8: GOS VTS centers and remote sites sensors (source: developed by author adopted from EAMS, 2019).
VTS region. Twelve Radar Sensor Sites (RSS) as shown in Figures (6) and (8) are covering the entire VTS area. In the northern part of the Gulf, there is complex traffic from the Suez Canal, Adabiya port, the Suez port, and Ain Sukhna. While in the southern part, traffic enters the system from the Red Sea and the Gulf of Aqaba (EAMS, 2019). The interviewee participant stated that

“Several factors must be taken into consideration, such as the nature of the Gulf Coast that affects the line of sight of radars, the different sizes of some targets such as leisure boats or small fishing boats and the width of the Gulf in some areas that restrict the distance of passing between ships when they meet each other. To meet these requirements, at each specific radar site, a dual X-band radar transceiver subsystem has been installed to ensure 24/7 operation through redundancy”.

The X-band radar has excellent accuracy properties that combine good long-range performance with very good angular discrimination and completely adequate resistance to sea clutter and rain effects. Radar sensor and Radar processing subsystem consists of radar antenna, dual transceivers, waveguide and two radar data processors configured to provide reliable remote site operations. The radar antenna height above sea level for each radar site is chosen to allow the detection of targets at distances that satisfy the system’s performance.

4.1.2 Automatic Identification System (AIS)

AIS is a system that utilizes VHF maritime mobile communication band, to exchange navigational data which in turn enhance navigation safety, protecting the environment and increase situational awareness. Benefits of AIS including automatic reporting in the mandatory and voluntary reporting schemes and improve ship-to-ship and ship-to-shore communication. AIS transponder unit is designed to automatically broadcast the vessel’s position course and speed over ground together with static and voyage related information (Eriksen et al., 2006). This enables the OOW to be aware of other ships long before visual contact is established allowing appropriate action to be taken in good time.
4.1.2.1 AIS mobile stations

Requirements for the installation of AIS onboard ships are specified in SOLAS convention. AIS enhances navigation safety by providing efficient ship navigation, environmental protection, and assistance in VTS operations. The purpose of AIS can generally be categorized into; first, in ship-to-ship mode to avoid collisions, and secondly, for coastal states to obtain information about ships and its cargo, third, as a VTS tool for traffic management (IALA, 2007). Resolution A.1106 (29) is the revised guidelines for operational use of the AIS system adopted by IMO and stipulates that AIS can be used to assist in decision-making to avoid collisions as an additional source of information that supports radar aids and radar tracking (IMO, 2015).

4.1.2.2 AIS onshore base stations

However, it should be noted that there is no text in IMO on any competent authority to implement VTS nor to implement AIS in existing VTS. Nevertheless, as stated by IMO, that AIS improves the safety of navigation and the operation of VTS, the competent authorities should consider implementing AIS in the VTS. From this, the IMO provision of AIS shore infrastructure can be inferred. Recommendation ITU-R M.1371 addressed the provision by IMO of establishing AIS coastal infrastructure which included the so-called AIS base station. AIS base stations offer the chance to form an AIS network along a country’s coastline. Its main purpose is to transmit and receive data from AIS-equipped ships navigating within the base station coverage area. This would allow for the effective monitoring and tracking of ship movements (IALA, 2004). AIS base station is responsible for allocating time slots to repeat and transmit the message to and from the AIS mobile station (ships). It is essential that the AIS base station ensures that messages sent do not reduce available ship time periods to the ship collision avoidance function (IALA, 2016a).

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3 The International Convention for Safety of Life at Sea, 1974 (SOLAS 74), Chapter V, requires all ships with a gross tonnage of 300 tons and above engaged in international voyages, cargo ships of 500 GT and above engaged in international voyages and passenger ships regardless of its size engaged in international voyages to install AIS
The information transmitted by AIS can be divided into three main groups static, Dynamic and Voyage related besides safety-related messages that could be transmitted when needed.

1- The static information provided by AIS is set on installation and consists of own ship data; Maritime Mobile Service Identity MMSI, Call Sign and name, IMO number, ships length and beam, type of ship and location of positioning fixing antenna.

2- The dynamic information except navigational status is automatically updated by AIS. the dynamic data May consist of the following parameters; ship's position with accuracy indication and integrity status, position time stamp in Universal time coordinated UTC, course over ground, speed over ground, ship's heading, navigational status and rate of turn.

3- The voyage related data must be manually entered into the system from the operator’s panel and may consist of the following parameters; ships draft, type of cargo, destination an estimated time of arrival ETA, route plan and short
safety-related messages (IMO, 1998). Table (7) shows the different classes, types, their identification number and description of AIS.

**Table 7: types of AIS stations (source: IALA, 2016)**

<table>
<thead>
<tr>
<th>AIS Station</th>
<th>MMSI format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS class A</td>
<td>MIDXXXXXXX</td>
<td>Shipboard mobile equipment that complies with the carriage requirements and performance standards adopted by the IMO.</td>
</tr>
<tr>
<td>AIS class B</td>
<td>MIDXXXXXXX</td>
<td>Shipboard mobile equipment that are compatible with other AIS stations but do not comply with the performance standards adopted by IMO.</td>
</tr>
<tr>
<td>AIS base station</td>
<td>00MIDXXXXX</td>
<td>These are shore-based stations used by competent authorities to facilitate ship-to-shore and shore-to-ship information transmission by managing the VDL.</td>
</tr>
<tr>
<td>AIS Aids to Navigation</td>
<td>99MIDXXXXX</td>
<td>These stations are used to provide the status and position of an aid to navigation. They may be fixed (i.e. attached to lighthouse) or floating (i.e. attached to a buoy).</td>
</tr>
<tr>
<td>AIS of Search and Rescue (SAR) aircraft</td>
<td>111MIDXXX</td>
<td>Aircraft mobile equipment, used for search and rescue operations, and safety of navigation.</td>
</tr>
<tr>
<td>AIS-SART</td>
<td>970YYYYXX</td>
<td>It is used for homing itself during a search and rescue operation. It provides greater range than a radar SART.</td>
</tr>
<tr>
<td>MOB-AIS</td>
<td>972YYYYXX</td>
<td>Man-Overboard AIS transmitters are used to indicate the position of an individual in water.</td>
</tr>
<tr>
<td>EPIRB-AIS</td>
<td>974YYYYXX</td>
<td>It is used to assist in locating.</td>
</tr>
<tr>
<td>AIS Repeater</td>
<td>00MID45XX</td>
<td>It is used to increase the range of other AIS.</td>
</tr>
</tbody>
</table>

4.1.2.3 limitations of AIS

The VTSO should always be aware that vessels, particularly leisure boats, fishing boats and warships, may not be equipped with AIS. As a mandatory requirement, other ships equipped with AIS can also turn off AIS under certain conditions through the professional judgment of the master (IMO, 2001). The transmission of false information involves risks to VTS operations as well as other
ships, as users remain responsible for all information entered into the system as well
as information added by sensors. Poorly calibrated or configured ship sensors may
transmit incorrect information. Falsified or incorrect information about a vessel shown
to VTSoS or on the bridge of another vessel can be seriously confusing. Another
major problem with AIS is that in high traffic areas, the system may be saturated due
to a large number of ships (Ford et al., 2018). Therefore, data of Radar is more reliable
than AIS for operators and when radar and AIS data do not match, radar data is the
preferred source. Although radar signals can be adversely affected by bad weather
conditions, operators overcome the lack of accuracy through experience and
evaluation of AIS data, which can be manipulated.

4.2 Multi-sensors Data fusion and its role in situation awareness and
decision making

According to the argument raised by Kharchenko & Vasiliev (2004; as cited in
Brödje et al., 2010), they argued that in order to take decisions the VTSoS needs to
have a consistently available traffic image as provided by the VTS system and this
image serves as the primary resource of information for VTSoS decisions.

Since the ship calls VTS, VTSoS determines the ship’s position using available
sensors (Dalakis et al., 2009). Usually, sensors are radars and in most cases, the
AIS information is fused and presented onto Electronic Chart Display and Information
System (Brödje et al., 2010). As stated by the interviewee, GOS VTS centers receive
the data from radars along the GOS coast. Operators consider radar readings as the
most important visual data, and that radar is the primary source of ship localization,
address headings, and other floating objects found.

However, AIS is not usually used for navigation and detection purposes, but
for identification, because operators generally access information that ships send in
terms of name and identification numbers such as MMSI, call sign and IMO number.
VTSoS centers benefit widely from operators who monitor AIS and radar data that
overlays on electronic maps. AIS data is displayed on the main system screen,
therefore, both the reported AIS locations and radar detection are displayed on the
main geographical map (Riveiro & Falkman, 2014). For more clarification of this
statement, an investigation has been carried out in the literature.
Brödje et al., (2010) introduced a study of how the operators of VTS use available sensor data and he argued that VHF radio and radar are the most frequently used sources of information, while AIS data is essentially complementary, providing information such as ship name, call sign and speed. Also other scholars argued that VTSOs are not trusting data provided by AIS (Wiersma & Padje, 2005). On contrary to these findings, Van Dam et al. (2010) argued that AIS may replace radar and VHF.

Connecting the previous investigation findings with the current situation of the GOS VTMS, it is obvious that all sensors provide the data about targets using absolute coordinates and UTC timestamp. This allows the integration of the data into a unified target table. Each target in the overlapping coverage area will be tracked by several sensors and will be supplied to the multi-sensor tracker from different sources as shown in figure 10 (EAMS, 2019).

![Figure 10: the concept of multi sensor tracking (source: EAMS, 2019).](image-url)
CHAPTER FIVE
DISCUSSIONS, RECOMMENDATIONS AND CONCLUSIONS

This thesis has employed a range of data collection. The previous chapters introduced and summarized the data collected from different primary and secondary sources including national legislation, literature review, governmental publications and interviews with participants from different entities utilizing qualitative methodology. Also data have been collected, analyzed and the researcher introduced the major findings that have been found out during the different phases of this research. In order to answer the research questions, this chapter will critically discuss the main findings in comparison with the international requirements as previously reviewed in the literature review and best practices. The main objective of this research is to understand and evaluate the current MS in the GOS in addition to highlight the main challenges and regulatory framework that combining governmental and non-governmental agencies involved in MS and how to improve safety of navigation and provide efficient shipping in the GOS.

5.1 RESEARCH QUESTION 1 What is the current Maritime Surveillance and the role of GOS VTMS?

5.1.1 VTMS for the safety of navigation and marine environment protection

The analysis of the collected data shows that MS in the GOS as expressed in VTMS has several roles in enhancing safety of navigation and efficiency of shipping operations. Egypt has practiced its sovereignty on its territorial water through the rights and obligations stated in the UNCLOS and SOLAS to coastal states in order to ensure safety of navigation as well as protect the marine environment. Therefore, TSS, VTMS and MSRS have been established in the GOS. Also AtoN have been established to aid navigation safety of the T.S.S and safe approach to oil fields and terminals located in the GOS.

The ship reporting system was adopted by IMO and entered into force in 1983. Its objectives are to enhance safety of navigation, marine environment protection.
Ships of 300 gt and upward are under the scope of GOS VTMS. To transit the GOS, ships should request permission from the appropriate VTC\(^1\). The VTCs monitor the north and south areas of interest (AOI). Each of the remote sensors sites is configured with a radar system designed to provide full coverage of the Traffic Separation Scheme (TSS) within the gulf.

The radar system consists of dual X-band transceiver and dual radar data processors to ensure that radar sensor coverage is always available. Safety of navigation is enhanced through the use of extensive voice, radio direction finding (RDF), meteorological sensors are located at several sites throughout the gulf to allow operators in the VTC to apprise vessel operators of weather conditions through the TSS. A fiber-optic network is used to connect all remote site sensors data to the command and control systems located in the VTCs. Each VTC on the gulf contains a command and control system that consists of operator stations, dual integrated database processors with automatic data sharing and backup between them, redundant correlation and tracking processors and digital audio data recording and playback system (EAMS, 2019).

Recalling the literature review in chapter Two, it is obvious that VTS is a service provided by competent authorities is playing an important role in improving the safety of navigation and protecting the environment. Thus, according to data collected, GOS VTMS components enable the operators to monitor maritime traffic and communicate the necessary information to vessels to promote safe and efficient passage avoiding potential accidents. GOS VTMS is complying with IMO requirements and this result is also supported by studies of Dalakis, Siousiouras and Nikitakos (2009); Pietrzykowski & Magaj (2017); Hughes (2009); Allen (2009); MacWilliam &amp and Cooke (2006).

\(^{10}\) GOS VTMS consists of two Vessel Traffic Centers (VTCs) as coastal VTS (Adabeya & Fals Rasgharib), two harbors VTS (Sharm Elsheikh & Safaga) and eight remote sensor sites (RSS)
5.1.2 The role of VTS as a cost-effective risk control option

Approximately 14% of the world’s seaborne trade in volume is carried by sea through SC 11. Therefore, GOS is a very congested waterway with a width of 10 to 15NM and playing an important role in the world economy in general and in the maritime industry particularly 12.

Any accident in this confined waterway will lead to economic losses expressed in delays of ships, loss in property, life and environmental damage as explained in the case of (ALAGAMY) fishing vessel accident in Chapter 3.

IMO member states are required to take essential measures to reduce the probabilities of risks in addition to reducing consequences in critical waterways such as collisions and groundings. VTMS is a tool for risk reduction established by EAMS as a competent authority in accordance with SOLAS V/12, III code para 48.7 (IMO, 2013) and IMO Resolution A.857(20) (IMO, 1997).

VTMS is complemented by onboard ship navigation and communication equipment such as AIS and VHF installed according to SOLAS regulations. If an accident has already taken place and immediate action is needed, consequences reduction measures are established in the GOS represented by Maritime Rescue Sub Centers (MRCSC) in Hurghada and Ismailia which have the same responsibilities of JRCC but on a smaller scale (ICAO, 2018).

Although GOS VTMS is a high-tech with a high-cost surveillance system, it improves the performance of ports and GOS waterway and thus facilitates commerce and Egypt’s economy. Where in 2016 ports of Egypt achieved 6.24 billion EGP of surplus also the annual revenue of Suez Canal is approximately 6 billion USD.

In general, one of the main features of the GOS is the intensity of traffic, oil wells, prohibited areas and a large number of non-SOLAS vessels. Recalling Zhang, Pedersen, & Villavicencio, (2019) study which stated that reducing the frequency

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11 Suez Canal is one of the most important channels in the world, it connects Europe, Africa and Asia in addition to being one of the pillars of Egypt’s economy.
12 GOS is connecting the Red Sea and Suez Canal and is considered as a geopolitical choke area for the world seaborne trade.
of ship grounding and collision is the ultimate cost-effective control option. Thus, it is obvious that GOS VTMS is playing a role as a cost-effective safety barrier.

5.1.3 GOS VTMS approach to increase situational awareness onboard ships and onshore

The third finding of the GOS VTMS role is the increased awareness of incoming and outgoing vessels in a dynamic environment where the current situation and relevant information is constantly changing. Recalling the definition of SA, there are two approaches to be explained. The first is the SA of the shipboard crew which is strongly related to the available sensors onboard the ship and the information provided by the VTS. The second approach is the SA of the VTS operators which is mainly dependent on the operator’s competency and professionalism in addition to the available equipment and sensors.

From the ships’ crew perspective, this can be discussed when looking at the service ranges including TOS, INS, and NAS provided by the VTMS. INS ensures essential information is available to the ship to allow the shipboard navigational process to work, the information is distributed at regular intervals or at the request of a specific vessel. TOS prevents the development of situations that could cause danger to vessels in the VTMS area by planning for safe and efficient traffic flow in the area. NAS is assisting navigational decisions on an individual ship, GOS VTMS contributes to this by giving position information of a ship and adjacent ships in addition to warnings are given to individual vessels.

Consequently, GOS VTMS is in line with the international guidelines issued by IALA in relation to services that should be provided by VTS.

Moreover, it is obvious that increasing situational awareness of the ship’s crew by providing comprehensive information on maritime traffic is enhancing navigation safety and efficiency. This result can be supported by the findings of Dalakis, et al (2009); Costa et al., (2018); Blokus-Roszkowska & Smolarek (2014); Van Westrenen & Praetorius (2014) and Wiersma (2010).

Also chapter Four described the role of VTS equipment in increasing the situational awareness of the VTS operators. Information communication between the ship’s bridge and VTC in addition to data fusion of multiple sensors from different remote sites enables VTSO to configure and construct a holistic traffic image in the
waterway and supporting the decision-making process. The GOS VTMS operators are mainly depending on radar sensors network located along the coast of the GOS as well as VHF communication, while AIS is considered to be a secondary source of information. This finding is in line with the study carried by Brödje et al., (2010) which stated that radar readings are the most important visual data and AIS is not usually used for navigation and detection. This finding contradicts with Van Dam et al., (2010), they argued that AIS may replace radar and VHF. This dissertation explained that there are several limitations and shortcomings of AIS therefore, VTSOs are mainly depending on radar sensors for detection and tracking and the data are overlaid on AIS data then displayed on the main electronic geographical map to allow the operator confirm the vessel’s position and identifying the vessel by receiving ship’s particular such as MMSI, ETA, destination, type of cargo and other static and dynamic data.

In conclusion, it is clear that MS expressed in the GOS VTMS is playing a number of roles to enhance safety of navigation, protect the marine environment and improve shipping operation efficiency. The following figure summarizes and shows the GOS VTMS Environmental, safety and economic benefits.
5.2 RESEARCH QUESTION 2 What are the gaps and shortcomings of the MS in the GOS?

The preliminary analysis and results from both documents and interviews in chapters 3 and 4 indicate the existing gaps and limitations in the MS as expressed by GOS VTMS. By comparing the current situation of the VTMS with the international requirements and guidelines the limitations and shortcomings can be observed.

5.2.1 Towards integrated Maritime Surveillance

As explained in chapter Three, MS and monitoring data within and around Egyptian waters are gathered by a number of agencies for a range of different purposes including promoting safe navigation, environment protection, managing fisheries, and monitoring borders and migration control.

Each of these maritime stakeholders are working independently and each entity follows a sectoral approach to MS and the absence of a multidisciplinary approach. Each agency has its own organizational culture, bureaucracy and legal
basis for the application and enforcement under national legislation. Since different authorities have a variety of competencies, and thus, different information is needed to be collected which is very specific to those competencies where only some of this information within these systems will be useful to other users. That is why separate or single-sector systems were needed. Changes in the scope and focus of MS over recent years have been accompanied by technological developments that allow large amounts of data to be obtained, processed and exchanged in real-time. Therefore, it is necessary to establish a national cross-sectoral information sharing environment. Although there are several separate systems are running, the existing surveillance systems have to be consolidated and move to a higher degree of integration of MS information.

In fact, to make data integration and aggregation is a difficult process due to differences in data formats and technical systems specifications as well. This dilemma can be solved by following one of the best practices implemented by European member states. Since 2010 integrating the MS approach has been adopted by European Member states expressed in Common Information Sharing Environment (CISE). (European Commission, 2010).
5.2.2 Non-SOLAS ships governance

Vessels less than 300 tons of gross tonnage are not under the provisions of the GOS VTMS and according to rules as discussed earlier they are not mandated to the mandatory reporting system. As stated by the interviewee participant, the main challenge in the GOS is the existence of oil fields, prohibited areas and the large number of non-SOLAS vessels including fishing and service vessels. This dynamic environment hinders the VTSO to give the advice and guide ships navigating through the GOS waterway and consequently applies a negative effect on the traffic image and situational awareness of both sides onboard ships (OOWs) and onshore (VTSOs). Also one of the participants stated that large numbers of small vessels are not installing AIS and/or carrying radar reflector consequently, they are not identified or displayed on ships’ radars.

More investigation has been carried out to find out the root causes of this dilemma. In 2010 EAMS as the maritime authority submitted a proposal for the
amendments of the presidential decree on safety of ships No.143 thereafter, the parliament approved the proposal and the ministerial decree no. 287 was published in the gazette. The amendments include safety, communication and navigation equipment carriage requirements among other requirements. But to this date the ministerial decree no. 287 has not yet entered into force due to implementation problems.

Various stakeholders such as fisheries and ship-owners rejected the decree, claiming that it contained many articles that could not be practically applied to different types of ships. It is observed that the owners of the ships and fisheries did not participate in the legislative process and expressed their opinion, and therefore the decree contained many shortcomings.

This reason has hindered the inclusion of fishing vessels in regulations established by EAMS as the Maritime Administration. This finding can be supported by the FAO report which concluded that representatives of the fishing industry have succeeded in lobbying, in some cases, for exemptions for various reasons. This reflects the fishing industry’s reluctance to be subject to a comprehensive regulatory regime (Petursdottir et al., 2001).

5.2.3 Unreliable Aids to Navigation (AtoN)

As discussed earlier VTS is an active safety barrier while AtoN are passive safety barriers and both are cost-effective risk control options. Egypt as a coastal state has the obligation and rights as stipulated in SOLAS V/13 and III code paragraph 48.8 to implement AtoN with regard to the traffic density and risk degree in accordance with IALA guidelines and maritime buoyage system. According to national legislations, EAMS as the competent authority has the legal basis of application and enforcement to the establishment and maintenance responsibilities of AtoN in the Egyptian MD.

"Admiralty List of lights and fog signals eastern Atlantic, western Indian ocean, Arabian sea. NP 77 volume D" have warned seafarers that AtoN in the GOS are not reliable and encouraged them to report any malfunctioning and/or out of position AtoN they encounter while transiting the waterway. In addition to watching channel 16 where SARAPEUM radio broadcasting safety messages related to AtoN. Also the interviewee participant as the primary source of data supported the warning issued by the UK hydrographic office to the seafarer as the secondary source of data,
he complained that AtoN in the GOS are playing an important role for safe navigation but unfortunately most of the time they are out of order.

5.3 Research question 3 How to improve GOS maritime surveillance (RECOMMENDATIONS)

In the previous section research questions 1 and 2 have been critically discussed against literature review regarding the role of the VTMS as an MSS in addition to its shortfalls and limitations. Although international guidelines are not obligatory, IMO urged member states to follow in order to apply these guidelines as a global standard. Hence, with the above-identified gaps, it is possible to discuss how to fill the gaps to ultimately improve the standard, marine environment protection and enhance the safety and efficiency of navigation.

5.3.1 Policy harmonization

The administrative organizational structure in Egypt, which includes several entities, needs to approach the appropriate level of preparedness to respond on demand. This can be achieved through integrated policies that gather competent authorities and harmonization of policies, laws and regulations to avoid contradictions and gaps. MS is carried out by national authorities to identify and deter security and safety threats. A cost-effective decentralized interconnection of several information layers will improve the efficiency of MSS by bridging information gaps that exist throughout Egypt MD while avoiding duplication of data as shown in figure (13).

Figure 13: Information layers improve maritime surveillance (source: EMSA, 2007)
MS integration aims to create an added value through additional relevant surveillance cross-sectoral data which will enhance the existing sectoral maritime awareness image among users of the Egyptian maritime domain (figure 14).

Figure 14: A need to know information sharing among MD stakeholders (source: developed by the author).

As a consequence, better situational awareness will be achieved which in turn influences maritime safety and security, marine pollution, fisheries management, borders control and economic interest of the Egyptian MD particularly and world economy in general. In other words, sharing information is affecting Egypt as coastal state efficiency and improve the cost-effectiveness of MSS. Certain government agencies are given the power to enforce regulations in a specific area and to undertake surveillance for that purpose 13. Therefore, when several authorities carry out surveillance in the same area with different systems, the integrity of their data leads to a more complete and better management picture of maritime traffic, for the benefit of all.

13 In order to perform their operational task as effectively and efficiently as possible, they have made choices about which monitoring systems to use, and how to deploy them. This results in the use of different surveillance systems. No single system has a complete overview of all ships within a given region. Instead, different current systems cover different subsets of maritime traffic according to their needs.
5.3.2 Technical proposal to establish national AIS network and Integrate VHF coast stations and VTS

This proposal can be supported by promoting best practices among EU VTS centers such as the Finnish experience and the Helsinki VTS (figure 15). According to Paragraph 2, Article 9 of Directive 2002/59 (EMSA, 2007).

“The process of building up all necessary equipment and shore-based installations for implementing this Directive shall be completed by the end of 2007. Member States shall ensure that the appropriate equipment for relaying the information to, and exchanging it between, the national systems of Member States shall be operational at the latest one year thereafter.” (p.16)

Figure 15: EMSA promoting best practices, improving Safety Sea Net (source: EMSA, 2007).

GOS VTMS has overcome the limitation of Line of Sight sensors such as VHF radio, AIS in the VHF band and radar in the microwave band by utilizing VPN and fiber optic communication between remote sites (figure 16). The operator in Aladabeya VTS can communicate and track the southern bound vessels and vice versa.
As stated earlier GOS encompasses different authorities carrying out MS. Telecom Egypt under the supervision of National Telecom Regulatory Authority has the responsibility of operating coastal radio stations for communication and distress services, broadcast radio navigational alerts and weather forecast services to ships. According to the GMDSS master plan, there are 25 main and monitor stations along the coast of the Mediterranean Sea, Red Sea and GOS (IMO, 2017b). Figures (17) and (18) are showing the current location and the range of the coverage area of VHF radio stations. The figures also illustrate the proposed location to install AIS base stations utilizing the existing infrastructure such as the towers and premises. This step shall be the cornerstone to establish a national and regional AIS network connecting the Mediterranean Sea, the Red Sea and GOS.

Sharing (a need to know) information between VTMS and coast stations will complete the traffic image in the Egyptian MD. Also it increases the coverage area of the GOS VTMS which in turn enables the operator to early detect critical situations providing them time to take proper action before a potential threat occurs. The integrated policies that gather competent authorities and establishing a cost-effective national cross-sectoral information sharing environment will improve the efficiency of MSS by bridging information gaps that exist throughout Egypt MD while avoiding duplication of data.
Figure 18 Red Sea VHF coast stations locations and coverage area (source: Developed by the author).
5.3.3 Towards a more reliable AtoN

Frame, (2003) discussed that risk management is to select the appropriate measures for risk reduction. AtoN are classified as passive barriers established by EAMS as proactive risk controls. In accordance with paragraph No. 50.1 of III Code and IALA Guideline No. 1008 on AtoN Remote Monitoring and controlling, the coastal state is required to monitor and maintain AtoN. Thus, EAMS shall carry out barrier management as an integral part of risk management.

Barrier management is to maintain AtoN and monitor their function degradation consistently to fulfill their functions. By applying international standards and guidelines, IALA guidelines 1081 “PROVISION OF VIRTUAL AIDS TO NAVIGATION” may be recalled as a technology solution (IALA, 2013). Installing AtoN AIS allows it to be controlled remotely from the shore station network as a part of AIS network. The remote monitoring system uses a web-based application to receive AIS data relayed from AtoN. AIS AtoN will transmit its identification such as name, type and position of the AtoN to the vessels within the AIS network coverage in addition to meteorological and hydrological data. If any AtoN is malfunctioned or off position, telemonitoring of AtoN enables EAMS to take immediate action and AtoN will be more reliable than the current situation as explained earlier.

In general, the researcher’s recommendations are interrelated. The integration and harmonization of competent authorities’ policies will ensure an integrated MSS and an information sharing environment among stakeholders in addition to facilitate the establishment of a national AIS network.
5.4 Conclusions

This thesis is meant to emphasize the importance and role of maritime surveillance in the GOS in particular and in Egypt in general to enhance the safety of navigation and protect the marine environment. Through the explanatory inductive research, the qualitative research method was utilized with the use of in-depth interview techniques in addition to observations to collect primary data. While secondary data were utilized for data analysis and conclude the findings. Secondary data comprises of relevant literature including various Egyptian government legislation and policies, VTS user's guide and organizational charts issued by EAMS, IMO, IALA and UK Hydrographic office publications. This combination of data sources mainly supported research analysis in the qualitative research method.

Data collected and analyzed indicated that several governmental and non-governmental agencies are involved in the surveillance of Egypt’s maritime domain. Also, this thesis explained that Egypt has exercised its sovereignty and the GOS VTMS was established by EAMS as the competent authority.

Due to the extensive existence of oil wells, offshore Rigs and heavy traffic of non-SOLAS and SOLAS ships transiting the waterway, GOS is one of the hot spots of oil pollution in the Middle East region. Consequently, GOS VTMS is a cost-effective risk reduction and mitigation safety barrier established in a very important narrow waterway that connects Africa, Asia and Europe. Fourteen percent of world seaborne trade is carried by ships transiting the GOS waterway. Also data collected and analyzed showed that Egypt's economy mainly depends on the maritime industry. Although not all costs and benefits may be expressed as monetary, Cost-Benefit Analysis (CBA) can aid in the decision-making process rationally and comprehensively. It also indicates the appropriate allocation of cost recovery and returns on investment (ROI).

GOS VTMS plays important roles in managing maritime traffic approaching and departing from the waterway and the ports of Safaga and Sharm El Sheikh through monitoring by total surveillance system supported by accurate and timely data that collected from different sensors installed in remote sites along the Gulf coast.
Also this dissertation discussed how exchanging and updating information between VTS centers and vessels is playing a dominant role in improving situational awareness for the shipboard crew as well as the onshore VTSOs in a complex dynamic traffic image. Consequently, the improved SA is leading to construct a holistic traffic image which in turn will facilitate the safety of navigation and protect the environment.

Also this research introduced two different approaches. The first is how VTSOs use available sensor data and have argued that VHF radio and radar are the most used sources of information, while AIS data is mainly complementary. However, AIS provides information such as vessel name, call signal and speed, VTSOs are not trusting data provided by AIS. The second argument is that AIS may replace radar and VHF.

Although there are gaps and limitations in the AIS system, the researcher demonstrated that AIS data are essential to complete the GOS waterway traffic image. Basically, radar, AIS and VHF sensors data fusion are the primary sources to assist VTSOs in the decision-making process.

However, the research results also indicate that there are a number of gaps, in comparison with international regulations and guidelines.

The lack of a multidisciplinary approach for maritime surveillance is one of the main gaps. Where governmental and non-governmental agencies are working independently and each entity follows a sectoral approach to maritime surveillance. This thesis recommended that it is necessary to establish national cross-sectoral information-sharing environments. This can be achieved through integrated policies that gather competent authorities and harmonization of policies, laws and regulations to avoid contradictions and gaps.

Also the lack of national legislation governing non-SOLAS vessels which negatively affects the safety of navigation and the maritime environment in the GOS specifically and in the maritime domain of Egypt in general. The researcher recommended the necessity of the participation of all stakeholders in the legislative process.
Unreliable Aids to Navigation also one of the main gaps in the GOS. Therefore, the researcher recommended to EAMS to implement barrier management as an integral part of risk management.

The elements of technology have always attracted a researcher’s curiosity to find a better use of it to improve the work process. AtoN shall be maintained and their function degradation monitored using technical solutions such as AIS AtoN within the AIS network using a web-based application. Moreover, the researcher proposed installing AIS base stations as a cornerstone for establishing a national AIS network.

These gaps potentially affect the quality of services provided by GOS VTMS as a total maritime surveillance system. Thus, this thesis proposed the recommendations in order to bridge gaps by following the conformity of the standard provided by IMO, IALA and best practices. This will contribute to the safety, efficiency of navigation and environmentally sound in the Egyptian maritime domain.
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