ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

POTENTIAL BENEFITS OF SATELLITE-BASED AUTOMATIC IDENTIFICATION SYSTEM IN THE CONTEXT OF INTELLIGENT TRANSPORTATION SYSTEMS

M.Sc. THESIS

Bora San TURGUT

Department of Maritime Transportation Engineering

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FOREWORD

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ABBREVIATIONS

AIS	**:** Automatic Identification System
AIS SART	**:** AIS Search and Rescue Transponder
ARPA	**:** Automatic Radar Plotting Aids
AtoNs	**:** Aids to Navigation
Beidou/Compass	**:** Chinese Regional Navigation Satellite System
CCTV	**:** Closed Circuit Television
COG	**:** Course Over Ground
COLREG	**:** Convention on the International Regulations for Preventing the Collusions
CPA	**:** Closest Point Approach
CS	**:** Carrier-sense
ECDIS	**:** Electronic Chart Display and Information System
ECS	**:** Electronic Chart System
EEZ	**:** Exclusive Economic Zone
EGNOS	**:** European Geostationary Navigation Overlay Service
EMSA	**:** European Maritime Safety Agency
e-Navigation	**:** Electronic-Navigation
EPFS	**:** Electronic Position Fixing System
ETA	**:** Estimated Time of Arrival
EU	**:** European Union
GAGAN	**:** GPS Aided Geo Augmented Navigation
Galileo	**:** European Space Agency's Global Navigation Satellite System
GLONASS	**:** Globalnaya navigatsionnaya sputnikovaya sistema
GMDSS	**:** Global Maritime Distress Safety System
GPS	**:** Global Positioning System
GRT	**:** Gross Tonnage
IMO	**:** International Maritime Organisation
IMTS	**:** Intelligent Maritime Transportation Systems
INS	**:** Integrated Navigation System
IRNSS	**:** Indian Regional Navigation Satellite System
ITS	**:** Intelligent Transportation System
ITU	**:** International Telecommunication Union
IUU	**:** Illegal, Unreported, or Unregulated
LBS	**:** Location-based Services
LPG	**:** Liquefied Petroleum Gas
LRIT	**:** Long Range Identification and Tracking
MarNIS	**:** Maritime Navigation and Information Services
MARPOL	**:** International Convention for the Prevention of Pollution from Ship
MMSI	**:** Maritime Mobile Service Identity
MSAS	**:** MTSAT Satellite Augmentation System
NATO	**:** North Atlantic Treaty Organization

OECD : Organisation for Economic Co-operation and Development
OOW : Officer of the Watch
PSD : Parcel Size Distribution
QZSS : Japan's Quasi-Zenith Satellite System
RFID : Radio Frequency Identification
Ro-Ro : Roll-on/Roll-off
SAR : Synthetic-Aperture Radar
SAR : Search and Rescue
S-AIS : Satellite-based Automatic Identification System
SBAS : Satellite-based Augmentation Systems
SO : Self-organising
SOLAS : The International Convention for the Safety of Life at Sea
SSB : Statistisk sentralbyrå (Statistics Norway)
TCPA : Time to Closest Point Approach
VTS : Vessel Traffic Services
VTMIS : Vessel Traffic Monitoring and Information Systems
VHF : Very High Frequency
WAAS : Wide Area Augmentation System
WGS84 : The World Geodetic System 1984

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POTENTIAL BENEFITS OF SATELLITE-BASED AUTOMATIC IDENTIFICATION SYSTEM IN THE CONTEXT OF INTELLIGENT TRANSPORTATION SYSTEMS

SUMMARY

Comprehension of the benefits of big data is vital for both governmental and commercial parties. Satellite-based Automatic Identification System (S-AIS) can be defined as big data in terms of its data production volume and data content. In this study, it is aimed to explain the potential benefits of Satellite-based Automatic Identification System which is within the scope of Intelligent Transportation Systems and to explain how maritime stakeholders in our country can benefit from this technology. The aim was to raise awareness of the importance of this issue in our country by presenting ideas and basic information to relevant stakeholders in maritime. As a result of the study, it was understood that Turkish public and private sector could create added value in case they use this technology, and the feedback received from the private sector in this regard supported the ideas presented in this study.

As a result of the literature review, no Turkish publication about Satellite-based Automatic Identification System was found. As can be seen from the literature review, this is the first study which provides basic information on the potential benefits of this technology in Turkey. Although there are some studies on the benefits of AIS and S-AIS technologies in the literature, no academic studies on direct commercial benefits have been found. It is tried to contribute to the maximum utilisation from S-AIS technology by Turkish maritime stakeholders through adding new ideas to the information which is obtained from various foreign publications.

Benefits of S-AIS technology are divided into five main groups: safety, security, environmental, technical and commercial. Feedback was received from the industry by asking the chartering experts how much the maritime stakeholders who are directly or indirectly involved in commercial transactions benefit from the commercial benefits of S-AIS technology. Thus, it has been tried to determine to what extent the theoretical benefit potential can be beneficial in practical applications.

Considering the literature review and the ideas presented, it is clear that AIS and S-AIS technologies have many different benefits. Since most maritime stakeholders can benefit from S-AIS technology, various military organizations, commercial companies and research organizations are working on this. The systems and technologies in S-AIS require considerable expertise. Knowledge and experience support should be obtained from different fields of expertise on how to make use of S-AIS technology and cooperation should be established.

In order to understand the Satellite-Based Automatic Identification System, the terrestrial AIS is mentioned and basic information is given first about how this system can be extended into space.

UYDU TEMELLİ OTOMATİK TANIMLAMA SİSTEMİNİN AKILLI ULAŞIM SİSTEMLERİ KAPSAMINDAKİ POTANSİYEL FAYDALARI

ÖZET

Dijitalleşmenin önemi ve büyük veri olgusu denizcilik endüstrisinde yavaş yavaş anlaşılmaya başlanmaktadır. Büyük verinin faydalarının anlaşılması hem kamu hem de özel sektör için hayati öneme sahiptir. Uydu Tabanlı Otomatik Tanımlama Sistemi (U-OTS) de veri üretimi ve veri içeriği bakımından büyük veri olarak tanımlanmaktadır. Yapılan literatür taraması sonucunda, Uydu-temelli Otomatik Tanımlama Sistemi hakkında Türkçe herhangi bir yayına rastlanılmamıştır. Dolayısıyla, bu çalışma Türkiye'de bu teknoloji hakkında temel bilgileri veren ilk çalışmadır. Bu çalışma vasıtasıyla bu teknoloji ile ilgili Türkiye'deki çalışmalara öncülük etmeye çalışılmıştır. Dünya literatüründe ise OTS ve U-OTS teknolojilerinin bazı faydaları üzerine mevcut çalışmalar bulunmakla birlikte, yapılan literatür taraması sonucunda bu teknolojinin doğrudan potansiyel ticari faydaları üzerine akademik herhangi bir çalışmaya rastlanılmamıştır.

Türkiye önemli ticaret rotalarının ortasında ve coğrafi olarak kritik bir konumda yer almaktadır. Bu nedenle; kendi sularında meydana gelen denizcilik faaliyetlerini daha iyi takip etmesi, durumsal farkındalığını arttırması ve bunları başarabilmek için gerekli bilinci kazanması Türkiye'nin çıkarları için hayati öneme haizdir. Yoğun gemi trafiğine sahip bir bölgede bulunan ülkemizin çevresindeki sularda farkındalığımızı ve kontrol gücümüzü arttırmak için kendi Uydu temelli Otomatik Tanımlama Sistemlerimizi kurmak ve geliştirmek bilhassa büyük önem arz etmektedir.

Akıllı Ulaşım Sistemleri'nde potansiyel ve mevcut kullanımlara sahip olan U-OTS teknolojisi, bu çalışmada bahsedildiği gibi, OTS sisteminin kapsamını genişleterek ve OTS aracılığıyla elde edilen faydaları artırarak çok çeşitli faydaları sağlamakta ve birçok faydayı da sağlama potansiyeli taşımaktadır. Bunlar arasında "Güvenlik", "Emniyet", "Çevresel", "Teknik" ve "Ticari" faydalar incelenmiştir fakat potansiyel faydaların bu çalışmada listelenen faydalarla sınırlı olmadığı unutulmamalıdır. Teknoloji geliştikçe, OTS ve U-OTS teknolojilerinin yeni kullanımları ortaya çıkacak, mevcut faydalar daha da geliştirilecek ve bu iki sistem bugün olduğundan daha faydalı hale gelecektir.

Bu çalışma ile; Akıllı Ulaşım Sistemleri kapsamına giren ve bir büyük veri kaynağı olan Uydu-temelli Otomatik Tanımlama Sistemi'nin potansiyel faydalarını tespit ederek ülkemizdeki denizcilik paydaşlarının bu teknolojiden hangi faydaları nasıl elde edebileceklerini açıklamak amaçlanmıştır. Denizcilikteki ilgili paydaşlara fikir ve temel bilgiler sunularak ülkemizde bu konunun önemi hakkındaki bilincin arttırılmasına çalışılmıştır. OTS ve U-OTS teknolojileri hakkında temel bilgiler verildikten sonra, OTS ve U-OTS faydalarının çok boyutluluğu ele alınmıştır. Uydu-temelli Otomatik Tanımlama Sistemi'nin anlaşılabilmesi için öncelikle Kara-temelli

Otomatik Tanımlama Sistemi'nden bahsedilmiş ve bu sistemin uzaya nasıl uzatılabildiği konusunda temel bilgilere yer verilmiştir.

Çalışmada; çeşitli yabancı kaynaklardan elde edilen bilgilere yeni fikirler eklenerek potansiyel faydalar sıralanmaya çalışılmıştır. S-AIS teknolojisinin sağladığı faydalar; güvenlik, emniyet, çevresel, teknik ve ticari olmak üzere beş ana gruba ayrılmış ve ticari işlemlere doğrudan veya dolaylı olarak müdahil olan sektör paydaşlarını ilgilendiren faydaların bu paydaşların işine ne kadar yarayabileceği gemi kiralama uzmanlarına sorularak sektörden geribildirim alınmıştır. Böylelikle teorik olarak sunulan fayda potansiyelinin pratikteki uygulamalarda ne oranda fayda sağlayabileceği tespit edilmeye çalışılmıştır. Her biri farklı kiralama taraflarını temsil eden kiralama uzmanlarına ticari işlemlerde doğrudan veya dolaylı olarak yer alan paydaşların bu teknolojiden ne kadar faydalanabilecekleri sorularak sektörden çok boyutlu geri bildirimler alınmıştır. Uzmanlar tarafından doldurulan formdaki tüm faydalar, uzmanlar tarafından önemli kabul edildi ve katkı payları farklı olsa da, her birinin deniz paydaşlarının bazılarına katkıda bulunduğu belirtildi. Bunun yanı sıra, insan hayatının güvenlik ve güvenlik yararları ile doğrudan ilişkisi, S-AIS teknolojisinin hayati öneme sahip olmasına neden olmaktadır.

S-AIS teknolojisi denizcilik paydaşlarının birçoğu için fayda sağlayabildiğinden dolayı çeşitli yabancı askeri kurumlar, ticari şirketler ve araştırma kuruluşları bu konu üzerinde çalışmaktadırlar. Türk denizcilik sektöründeki kamu ve özel paydaşlar bu sistemi çok geç olmadan kullanmalıdır. Ülkemizdeki paydaşlar da bu teknolojiden faydalanmalı ve bu alanda geride kalınmamalıdır. Ülkemizde önemi henüz tam olarak anlaşılmayan ve birçok denizcilik paydaşının varlığından haberdar olmadığı bu teknolojiyi daha fazla araştırmak ve uzaya gönderilecek uydularımıza OTS alıcısı ve anteni eklemek faydalı olacaktır. Ülkemizde bu konunun önemi hakkındaki farkındalık artarsa, bu teknolojiyi kullanarak katma değer yaratmak mümkündür. Bu alanda faaliyet gösteren şirket, kurum ve kuruluşların sayısı arttıkça, bu alanda hem rekabet hem de ilerleme katlanarak artacaktır.

Bu çalışmanın bir başka yararı ise; araştırmacıların odaklanmak isteyebilecekleri konuları ana hatlarıyla belirtmek ve onları bu konular hakkında daha ayrıntılı araştırmalar yapmaya yönlendirmektir. Türkiye'de Pirisat ve KILICSAT gibi bazı projelerden veri alınmaya başlanması durumunda, ülkemizde U-OTS ile ilgili sayısal çalışmalar yapmak mümkün hale gelecektir. Bu tür çalışmaların artmasıyla ülkemizdeki denizcilik paydaşları bu teknolojiden azami fayda elde etme imkanına kavuşacaklar ve özellikle bu teknolojinin teknik özellikleri üzerine yapılacak çalışmalar ülkemizin bu teknolojiden yararlanan ülkeler arasında yer almasına yardımcı olacaktır.

U-OTS içerisinde bulunan sistem ve teknolojiler ciddi uzmanlıklar gerektirmektedir. U-OTS teknolojisinden nasıl faydalanılacağı konusunda farklı uzmanlık alanlarından bilgi ve tecrübe desteği alınmalı, işbirlikleri oluşturulmalıdır.

Yapılan literatür taraması ve bu çalışmada sunulan fikirler göz önünde bulundurulduğunda AIS ve S-AIS teknolojilerinin geniş uygulama alanları ve çok çeşitli mevcut ve potansiyel faydalarının olduğu ortaya çıkmaktadır. Çalışmanın sonucunda Türk kamu ve özel sektörünün bu teknolojiyi kullanmaları durumunda katma değer oluşturabilecekleri anlaşılmış ve bu konuda özel sektörden alınan geribildirimlerin bu çalışmada sunulan fikirleri desteklediği görülmüştür.

Bu çalışmanın başlangıcındaki en temel amaç; OTS cihaz üretimi mevcut olan ülkemizdeki paydaşlara bu teknolojiyi tanıtıp Türkiye'deki denizcilik paydaşlarının bu teknolojiden azami şekilde nasıl faydalanabileceklerini anlatarak bu alanda farkındalık yaratmak, bilgi birikimini arttırmak ve girişimlere başlanmasını sağlamaktı. Bu çalışmaya başlandığında bu alanda başlamış bir proje bulunmamaktaydı fakat çalışma devam etmekteyken başlayan projeler sayesinde ülkemizde de bu alanda faaliyetlere girişilmiş olması sevindiricidir. "Pirisat" ve "KILIÇSAT" projeleri ile Türkiye'de de bu teknolojiden yararlanmak ve tecrübe etmek için adımlar atılmaktadır. Bu tür projelerin sayısını ve kapsamını genişleterek, ülkemizdeki denizcilik paydaşlarının çıkarlarına çözümler üretmek ve ülkemizdeki denizcilik paydaşlarının bu teknolojiden faydalanmasını sağlamak mümkün olacaktır.

1. INTRODUCTION

1.1 Introductory Remarks

The demand for goods and volume of commodity and human transportation flows by all transport modes has been vastly increasing due to factors such as population growth, increasing urbanization and urban population, rising living standards, globalization, increasing mobility and vehicle ownership and competition that lowers cost to consumers etc.

It is predicted that international trade will continue to increase which causing to an increase in vessel movements at waters and ports. Rising demand for transportation of goods and persons which is contributing to traffic jam, pollution, and incidents puts considerable pressure on all transportation nodes and links such as the traffic at seaports, airports, rail yards, roadway systems, warehouses/distribution nodes and so on to improve their practices to meet higher demand (Ioannou, 2008).

Adding capacity by building new infrastructure is not a feasible short- or even medium-term alternative for managing increased cargo and passenger transportartion demands, especially in metropolitan areas where the freight transportation infrastructure is already saturated. Cost, social, and environmental constraints and lack of adequate space make it difficult, if at all possible, to expand the infrastructure using the traditional approach of "more land more capacity." Building new infrastructure faces numerous constraints: lack of funding, land scarcity, environmental concerns, community opposition, and others. The planning and review process for major projects can take a decade or more. Solving transportation problems will require better utilization of existing infrastructure and more efficient flows throughout the goods movement supply (Ioannou, 2008). Here, Intelligent Transportation System (ITS) is the exact solution that can be used to meet the needs of this point.

Along with the increase in transportation demand, changes in technology and increasing sensitivity to the environment have caused the need for Intelligent

Transportation Systems. Demand for environmentally friendly technologies and applications, and the increasing number of smart devices with Internet connection, contribute to addressing the use of Intelligent Transport Systems.

It is stated that there is a need for an intelligent transportation system due to high costs, insufficient infrastructure, insufficient supervision, high carbon dioxide emissions, accidents and lost lives.

1.2 Brief Description of ITS

ITS consists of applications that provide an advanced transportation service integrates infrastructure, vehicle, computer, communication, control, electronics, software, computer-based algorithms, detection, robotics, signal processing, hardware, informatics, space, communication and information technologies. Advanced data collection and processing, planning, operation, optimization, operation and control methods should be used with these technologies (Crainic et. al 2009). Thanks to ITS applications; the components of the transport system, ie drivers, passengers, pedestrians, infrastructure and vehicles, are integrated into each other through sensors, microchips and wireless technologies to communicate and share information. With advances in technology, the scope of ITS has expanded and has become an area where different sciences work on. As it is seen, ITS benefits from technological developments and research activities in many different areas. Therefore, the future of Intelligent Transport Systems is closely related to the developments in these areas and technology. As technology develops and becomes cheaper, the development of ITS applications and the use of Intelligent Transport Systems are also increasing.

ITS applications can cover all modes of transportation and ITS is a multidisciplinary area which include technology, policy, socioeconomic, political, environmental, human etc. A collaboration and contribution of various disciplines that have understanding could lead to solutions of intelligent transportation problems that are so vital to society. Intelligent Transport Systems are multidisciplinary transport solutions, and this multidisciplinary nature offers an improved transportation technology network as well as increasing the complexity of problems as it requires the data transfer and collaboration between different research areas (Figueiredo et al. 2001). Since many different parties are involved in the processes in Intelligent

Transportation Systems applications, the coordination between these parties is crucial for the success of the whole system.

Any system that allows human, infrastructure and vehicles to exchange information between them by using electronic, computer, internet, communication and communication technologies, is called as ITS which is basically a data sharing system (UDHB, 2014).

Speed detection radars, talking signs and automatic plate reading systems have been put into use and these systems are called telematics, which is the combination of the words: “telecommunication” and “informatics”. The term “transportation telematics” which was invented in 1990 was short-lived and was replaced by the term “intelligent transportation systems”, which were introduced in the following year (UDHB, 2014).

1.3 ITS Technologies

The seven key technologies are listed in the National ITS Strategy Document that published in 2014 by Turkish Ministry of Transport, Maritime and Communications. These Technologies include:

- Global Navigation Satellite Systems (GNSS)
- Wireless Networks
- Mobile Communication Tools
- Infrared Communication
- Closed Circuit Television (CCTV)
- Close Range Communication Technologies (RFID, DSRC, NFC)
- Sensing Technologies (Vehicle, Road, Weather Sensors and Environmental Sensing Systems) (UDHB, 2014).

1.4 Intelligent Maritime Transportation Systems (IMTS)

Due to the fact that maritime transport is mainly active in international areas, it has become obligatory to comply with international standards and thus it has become one of the most intensive used transportation modes. In the maritime sector, many

intelligent transport systems are already being used as compulsory. In addition, ships are equipped with a large number of technological devices, which produce “big data”. Therefore, it is perfectly possible to produce intelligent transportation systems solutions in maritime transport.

Systems used within the scope of Intelligent Maritime Transportation Systems include, but are not limited to, the following examples:

- Automatic Identification System (AIS),
- Vessel Traffic Services (VTS),
- Long Range Identification and Tracking (LRIT),
- Satellite Automatic Identification System (S-AIS),
- e-Navigation (ECDIS etc.),
- Radio Frequency Identification (RFID)
- Maritime Navigation and Information Services (MarNIS)

The Closest Point Approach (CPA), going off-course and waypoint arrival alarms, more efficient use of containers by using RFID and the self-launching of the autopilot available on the advanced technology ships in the UN Ro-Ro Corporation when it comes to the ship's waypoint is only a few of the Intelligent Transportation Systems.

In this study; GNSS and S-AIS, which are two of the Intelligent Transport Systems Technologies and their benefits to maritime stakeholders were examined. Therefore, this study will only focus on GNSS Technologies out of the Intelligent Transportation Systems Technologies. But what should be kept in mind here is that; S-AIS technology is not a system that directly identifies the position of ships. Information which is broadcasted by a ship to the other ships in its AIS device’s range and to the shore stations on Very High Frequency (VHF) waves can be collected by S-AIS satellites. A ship's AIS signals also contain its own position information obtained by the ship via its Global Positioning System (GPS) device. Therefore, S-AIS technology is not a system that determines the position information of the ships, but rather a system that collects the information obtained by GPS technology.

1.5 Global Navigation Satellite Systems (GNSS)

Intelligent Transportation Systems have the opportunity to develop when positioning technology is introduced. Between 1960-1970, it is a prelude to the development of technologies such as microprocessors and GPS. Therefore, this period has an important role in the historical development of ITS (Figueiredo et al. 2001).

GNSS technology is a radio navigation system that allows a user with a GNSS receiver in his or her vehicle to determine its position, speed and time in three dimensions in any place and time, in any weather condition, in a common coordinate system such as the World Geodetic System 1984 (WGS84), in high accuracy, economically and in real time. Also, GNSS is the main technology behind many in-car navigation, location-based services (LBS) and route guidance systems enabling sharing of information about traveled distance, route identification and instant traffic situation. Satellite based positioning systems such as GPS, Globalnaya navigatsionnaya sputnikovaya sistema (GLONASS), European Space Agency's Global Navigation Satellite System (Galileo), Chinese Regional Navigation Satellite System (Beidou/Compass), Japan's Quasi-Zenith Satellite System (QZSS), Indian Regional Navigation Satellite System (IRNSS) etc. and Satellite-based Augmentation Systems (SBASs) are called as GNSS.

SBAS defines supporting systems for positioning satellites such as Japan's MTSAT Satellite Augmentation System (MSAS), European Union's European Geostationary Navigation Overlay Service (EGNOS), United States' Wide Area Augmentation System (WAAS) and India's GPS Aided Geo Augmented Navigation (GAGAN) are defined as systems to support real-time accuracy and positioning satellites which augment coverage area and enhance real-time accuracy.

1.6 Global Tracking Systems for One's Own Ship

Ships are able to detect their own positions wherever they are in the world, thanks to the Global Navigation Satellite System (GNSS).

Global Positioning System (GPS) used by most of the global commercial and military maritime sector (Rowbotham, 2013). Because of S-AIS and LRIT use GPS-based position data, it is focused only on fundamental GPS information rather than to focus on all positioning systems.

Some of the information provided by GPS can be listed as time, location, movement direction, speed, track, total distance travelled, Estimated Time of Arrival (ETA), waypoint etc.

1.7 Tracking Ships Which Belong to Someone Else via Satellites all over the World

There are two systems for tracking and identification of second parties' ships in the long range namely S-AIS and LRIT. In both systems, ships determine their position via GPS. However, in the LRIT system, information reaches to the centers on land via the INMARSAT satellites. On the other hand, S-AIS technology send information via AIS receiver-fitted low orbital satellites.

S-AIS technology is derived from AIS technology so in order to understand S-AIS it should be explained what the AIS is. Thats why AIS will be explained first in this study.

2. INTRODUCTION TO AUTOMATIC IDENTIFICATION SYSTEM (AIS)

2.1 A Brief Introduction to AIS

The Automatic Identification System (AIS) works on the AIS devices. The AIS device is an automatic and digital data/information exchange transponder/transceiver (the device that sending and receiving signals) between AIS stations for identifying, locating and tracking vessels by transmissions that take place using VHF radio waves which is a form of wireless communications that uses the transmission and reception of electromagnetic waves.

AIS continuously transmit information to all other AIS stations within its range. AIS stations include ships, non-SOLAS craft, shore stations (such as Vessel Traffic Services centers), search and rescue (SAR) aircraft, AIS aids to navigation (AIS AtoNs) and AIS Search and Rescue Transponder (AIS-SART).

AIS enables information exchange in real time (Cheng, 2014). AIS data is used for real time displays of ship movements via Electronic Chart Display and Information System (ECDIS) or Automatic Radar Plotting Aids (ARPA-RADAR) etc.

The AIS provides data that can be presented on the minimum display or as additional information on any suitable display device such as Integrated navigation system (INS), Electronic Chart System (ECS)/ECDIS or a radar/ARPA display (Url-1). In this way, the ships in the range of shipboard AIS transponder can be shown on the screen with position, heading, course and speed information. Ship name information assist to identify the vessels in the surronding. By choosing a particular vessel on the screen via clicking on this vessel, its further detailed information can be displayed in a text box immediately (Rowbotham, 2013; Norris, 2008).

2.2 Purpose of AIS

AIS was originally developed for collision avoidance to improve the Officer of the Watch (OOW)’s information about his/her surrounding environment.

Even though the ships were able to detect the locations of the targets in their surroundings by radar before the appearance of AIS, if range of visibility is low they did not know what these targets were. They were also unable to gain access to information on the identity and the port they were heading to. After the AIS emerged, the ships had access to more information about the AIS-fitted targets in their surroundings.

Thanks to AIS, a step was taken to reduce collisions, particularly due to the ease of access to the maneuvering and other navigational information of the surrounding vessels. Thus maritime safety is increased.

The main purposes of the AIS are traffic monitoring, collision avoidance and improving safety at sea.

Vessel tracking and monitoring system is necessary for port control purposes, commercial tracking and monitoring purposes.

With the integral minimum display and keyboard unit, the AIS would be able to operate as a stand-alone system. A stand-alone graphical display or the integration of the AIS data display into other devices such as INS, ECS/ECDIS or a radar/ARPA display significantly increase the effectiveness of AIS. The minimum mandated display provides not less than three lines of data consisting of bearing, range and name of a selected ship. Other data of the ship can be displayed by horizontal scrolling of data, but scrolling of bearing and range is not possible. Vertical scrolling will show all the other ships known to the AIS (Url-2).

2.3 AIS and S-AIS Architecture

The architecture of AIS and Longe Range Identification and Tracking systems namely S-AIS and LRIT is illustrated in the Figure 2.1 below:

As it seen, S-AIS enables shore stations to monitor the maritime activity which takes place out of their terrestrial AIS range.

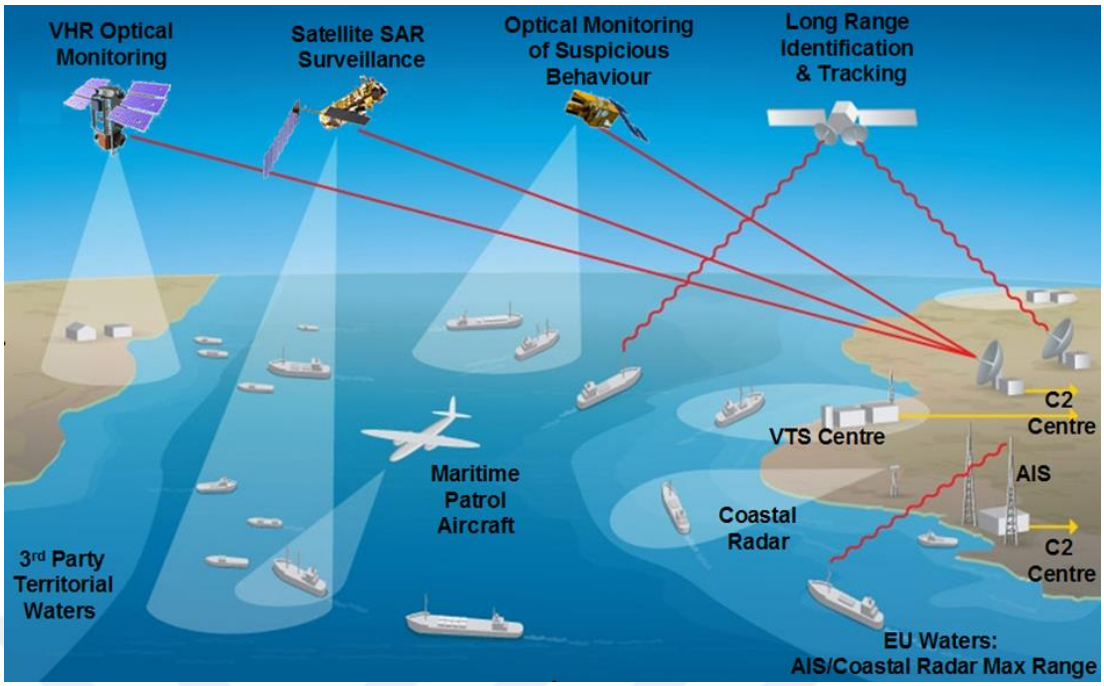

Figure 2.1 : Maritime surveillance architecture (Url-3).

2.4 Introduction Date of AIS

Developments for AIS technology has been going on since 1990s through various maritime stakeholders such as International Maritime Organisation (IMO) and International Telecommunication Union (ITU) (Url-4).

The AIS is mandatory by law since 2004 as part of Regulation 19 of the International Convention for the Safety of Life at Sea (SOLAS) Chapter V.

2.5 The Carriage Requirements of AIS

SOLAS (1974/1980) mandated shipboard carriage requirement for class A shipborne mobile equipment include all passenger ships, tankers and other ships of 300 GRT engaged in international voyages, as well as all ships of 500 GRT for more in national voyages.

AIS applies to merchant ships – it appears, not officially, to refer to warships or submarines of any national navy, which, in any case, are not subject to commercial maritime traffic requirements other than passage through certain international straits such as the Strait of Dover and the Öresund between Sweden and Denmark. However, warships and other vessels used by government departments involved in maritime protection such as fisheries may be fitted with AIS in order to monitor the

movements of other vessels, especially fishing vessels. Fishing vessels used in deep waters are already fitted with passive AIS, enabling them to detect other vessels in the vicinity without displaying their own position. In the interests of fishery protection, particularly in the areas bounded by the European Exclusive Economic Zone (EEZ), such fishing vessels are monitored by the fishery protection vessels of each European Union (EU) maritime nation in order to enforce the maintenance of strict fishing quotas laid down by the EU as part of the common fisheries policy. Those fishing vessels deemed to be contravening the quota regulations may be boarded, arrested and escorted to the nearest port. In this respect, AIS may be used for governmental monitoring purposes, as well as general monitoring within the commercial sector. Vessels used by government agencies for these purposes will often have their own AIS systems switched off for some of the time to avoid being detected by commercial vessels for a variety of reasons, especially those relating to security. Naval vessels, customs vessels and fishery protection vessels fall into this category, as they are operating at sea on activities relating to matters of national security, and require a level of secrecy as part of their operations (Rowbotham, 2013).

2.6 Types of AIS Transponders

There are two type of AIS transponder for vessels namely Class A and Class B. While Class A device is for large ships, Class B device is designed to be less expensive than Class A to make fitting of it reasonable for small ships.

Fixed and floating navigation markers such as buoys can be AIS-fitted for aids to navigation (A to Ns) purposes. Aircrafts that are used for Search and Rescue (SAR) operations are also fitted with AIS transponder. AIS Search and Rescue Transponders (AIS-SARTs) have also AIS transponders.

Certain National Maritime administrations have included the fitting of Class B (or Class A) to certain classes of non-SOLAS vessels in their local carriage requirements. Two examples in Europe are that all fishing vessels must fit Class A transponders now and all commercial craft on the European waterways must fit an Inland AIS transponder or a Class A transponder. The relative affordability and the potential safety benefit to users of AIS B devices will undoubtedly make them very popular and increasing numbers can be expected over the years (Norris, 2008).

2.7 Range of Terrestrial AIS

We can split the AIS range into “horizontal” and “vertical” range. Horizontal range of AIS signals is different for ship-to-ship and shore-to-ship communications. Because AIS technology is working on VHF waves based on line-of-sight communication.

Similar to VHF radio signals, the range of AIS signals is mainly dependent on line-of-sight communication between the transmitting and receiving station. Because the Earth is round, the “horizon” is the limit for an AIS signal. The AIS signals follow a straight line while ships follow the curvature of the Earth during its voyage. Imagine watching a ship sail off on the horizon. If you keep watching, eventually the ship will drop out of view as it follows the curvature of the Earth (Ball, 2012).

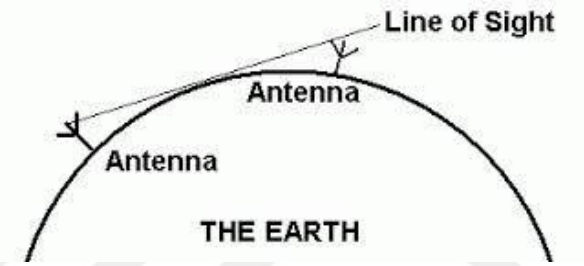

Figure 2.2 : Line of sight illustration (Ball, 2012).

The “line of sight” range is dependent on the height of receivers and transmitters from sea level. The higher the height of the receiver and the transmitters from the sea, the greater the range of the signals. Since the antenna of the coastal AIS stations is usually at a much higher point than the ships' antennas, the range of AIS signals shared between the ship and the coastal AIS station is greater than the range of AIS signals shared between ships.

Although the AIS system works on VHF radiocommunications system, the AIS range is differs from VHF radio range. Its transmission power differs from standard marine VHF radios, being 2 watts (low power) and 12.5 watts (high power). Typically, VHF marine radio works on 1 watt (low power) and 25 watts (high power). Simple theory indicates that a power reduction of 50% results in an effective range reduction of 25%. Therefore on the high power mode the range will typically be 25% less than with VHF radio operating at 25 watts (Norris, 2008).

The typical horizontal reach (range) of Class A AIS signals is around 20-30 nautical miles depending on antenna height for ship-to-ship communication (Url-2). On the other hand, the horizontal range of Class A AIS signals for ship-to-shore communications is around 200 nautical miles (Fournier et al. 2018). However, as with radar, under certain unusual atmospheric conditions, VHF range can extend to hundreds of miles (anomalous propagation) (IMO, 2006). Also, with the help of repeater stations, the coverage for both ship and VTS stations can be improved (Url-2).

The actual location of the AIS VHF antenna on a ship can affect AIS range significantly. If the antenna is shielded by the ship's superstructure its range will be compromised. This may mean that in some directions AIS range is minimal, perhaps down to a few miles or less, while in other directions good range is still possible (Norris 2008).

The AIS range is not normally affected by weather conditions but it is affected by shielding of the transmitted signal by land masses and buildings. However, AIS will often give a signal from a target that is shielded by line of sight, such as around a headland (Norris 2008). The AIS is able to detect ships within VHF range around bends and behind islands, if the landmasses are not too high (Url-2).

2.8 The Information Types Broadcasted by AIS

Transmission of some data by an onboard AIS device depends on the type of the AIS transponder. For instance, Class B AIS transmits a narrower range of AIS data than Class A AIS.

The information that can be transmitted by a ship is of wide variety, but broadly speaking it can be categorised into four different types as per the information it contains:

- static information (ship related information which rarely changes), which is entered into the AIS on installation and need only be changed if the ship changes its name, Maritime Mobile Service Identity (MMSI), location of the Electronic Position Fixing System (EPFS) antenna, or undergoes a major conversion from one ship type to another;

- dynamic information (data which is frequently changing), which, normally changing according to the ship's motion and apart from "Navigational status" information**,** is automatically updated from the ship sensors connected to AIS; and
- voyage-related information, which, specific to voyage, might need to be manually entered at the start of the voyage and kept updated during the voyage as details change.
- safety-related information, which might need to be manually entered in the case of any safety-related event and updated during the event if it is necessary.
- Details of the data sent by a Class A AIS transponder fitted ship are given in table Z below:

Table 2.1 : Data sent by Class A AIS transponder (Url-2).

Message type	***Information item***	**Information generation, type and quality of information**
Static	MMSI (the unique referenceable identification number of the vessel)	Set on installation Note that this might need amending if the ship changes ownership
	Name and (International Radio) Call sign	Set on installation Note that this might need amending if the ship changes ownership
	IMO Number	Set on installation
	Length and beam	Set on installation or if changed
	Type of ship	Select from pre-installed list
	Location of electronic position fixing system (EPFS) antenna (location on ship where reference point for position reports is located) (referred to bow and centerline)	Set on installation or may be changed for bi-directional vessels or those fitted with multiple antennas

Table 2.1 (cont.) : Data sent by Class A AIS transponder (Url-2).

Message type	**Information item**	**Information generation, type and quality of information**
Dynamic	Ship's position (latitude and longitude) with accuracy indication and integrity status	Automatically updated from the position sensor connected to AIS. The accuracy indication is approximately 10 m. Automatically updated from ship's main position sensor connected to AIS
	Position Time stamp in UTC (the exact time the information was generated)	Automatically updated from ship's main position sensor connected to AIS, if that sensor calculates COG This information might not be available
	Course over ground (COG) (relative to north)	Automatically updated from the position sensor connected to AIS. This information might not be available
	Speed over ground (SOG)	Automatically updated from the ship's heading sensor connected to AIS
	True Heading (0–359 degrees)	Navigational status information has to be manually entered by the OOW and changed as necessary, for example: - underway by engines - at anchor - not under command (NUC) - restricted in ability to manoeuvre (RIATM) - moored - constrained by draught - aground - engaged in fishing - underway by sail In practice, since all these relate to the COLREGs, any change that is needed could be undertaken at the same time that the lights or shapes were changed
	Navigational status	
	Rate of turn (ROT) (port or starboard)	Automatically updated from the ship's ROT sensor or derived from the gyro. This information might not be available
	Ship's draught	To be manually entered at the start of the voyage using the maximum draft for the voyage and amended as required (e.g. – result of de-ballasting prior to port entry)

Table 2.1 (cont.) : Data sent by Class A AIS transponder (Url-2).

Message type	**Information item**	**Information generation, type and quality of information**
	Hazardous cargo (type)	To be manually entered at the start of the voyage confirming whether or not hazardous cargo is being carried, namely: - DG (Dangerous goods) - HS (Harmful substances) - MP (Marine pollutants)
Voyage-relate	Destination and ETA	To be manually entered at the start of the voyage and kept up to date as necessary
	Route plan (waypoints)	To be manually entered at the start of the voyage, at the discretion of the master, and updated when required
Safety-related	Short safety-related messages	Free format short text messages would be manually entered, addressed either a specific addressee or broadcast to all ships and shore stations

In addition to the information listed in Table 2.1, “the number of persons on board” and “height over keel” information are included in some of the Class A AIS devices. However, these information are not a requirement of IMO so not all AIS devices on board have function to send this message and they may not be in the menu of an AIS device.

Different types of ships may give entirely different data. For instance, since drivers of some of the vehicles transported on Ro-Ro ships are also on board during the voyage, data could be entered on the “Number of persons on board” section, unlike other cargo ships.

The danger level in respect of the cargo’s nature is entered in AIS transponder. However, the exact details of cargo (name of the cargo(s) etc.) is not entered in AIS transponder.

Class B AIS devices send a limited information compared to Class A AIS device because Navigational Status, Draught, Destination, ETA, Rate of Turn, IMO number are not included in Class B AIS devices. A Class B AIS device will send the position, Call Sign, MMSI, Name, ship type, time, beam, length, course over ground (COG), speed over ground (SOG), Heading.

2.9 AIS Information Broadcasting Frequency

The information sharing frequency of AIS devices (Class A AIS devices) within the scope of SOLAS and the information sharing frequency of Class B AIS devices which are not under SOLAS are different.

In addition, if traffic density is high in an area, the system gives priority to the information broadcasted by Class A AIS transponders.

Broadcast frequency is dependent also on AIS message categories (static, dynamic, etc.) (Url-5).

2.9.1 Class A AIS transponder information broadcasting frequency

Class A AIS device information broadcasting frequency according to categories is as follows:

- **dynamic information:** depends on the alteration of speed and course;
- **static and voyage-related data:** every 6 minutes or on request from shore AIS stations.

2.9.1.1 Dynamic information

Dynamic data transmission intervals depends on the dynamics such as alteration of course and speed of the Class A AIS device-fitted ship, as given in Table 2.2.

Table 2.2 : Class A shipborne equipment dynamic data reporting intervals (Compiled by author from various sources).

Navigational status and speed of ship	General reporting interval
Ship at anchor or moored and not moving faster than 3 knots	180 s
Ship at anchor or moored and moving faster than 3 knots	10 s
Ship with a speed of between 0 - 14 knots	10 s
Ship with a speed of between 0 - 14 knots and changing course	3 1/3 s
Ship with a speed of between 14 - 23 knots	6 s
Ship with a speed of between 14 - 23 knots and changing course	2 s
Ship with a speed of greater than 23 knots	2 s
Ship with a speed of greater than 23 knots and changing course	2 s

2.9.1.2 Static and voyage-related data

- **Static data:** Static data is normally broadcast once every 6 minutes by each ship. Dynamic data is more frequent when it is compared to static data. However, static data transmission could be done more frequently on the request of shore stations by polling mechanism.
- **Voyage-related data:** Voyage-related data should be input manually by the OOW before departure and whenever changes occur. Voyage-related data is normally broadcast once every 6 minutes by each. However, the data transmission could be done more frequently on the request of shore stations by polling mechanism.

2.9.2 Class B AIS transponder information broadcasting frequency

Class B AIS transponders broadcast static data at every six minutes similar to Class A AIS transponders. However, Class B AIS transponders' dynamic broadcast intervals are different from Class A AIS transponders.

Non-SOLAS crafts' broadcasting frequencies can be found in Table 2.3:

Table 2.3 : Class B shipborne equipment reporting intervals (Url-1).

Crafts not subject to SOLAS	Nominal reporting interval
Class B "SO" shipborne equipment not moving faster than 2 knots	3 min
Class B "SO" shipborne equipment moving 2-14 knots	30 s
Class B "SO" shipborne equipment moving 14-23 knots	15 s
Class B "SO" shipborne equipment moving > 23 knots	5 s
Class B "CS" shipborne equipment not moving faster than 2 knots	3 min
Class B "CS" shipborne equipment moving faster than 2 knots	30 s

As can be seen from Table 2.3; Class B AIS devices' reporting frequency is lower than Class A devices.

3. INTRODUCTION TO SATELLITE AUTOMATIC IDENTIFICATION SYSTEM (S-AIS)

The basics of the satellite based Automatic Identification System is introduced in this section through a brief description of S-AIS, them time of its introduction and its architecture.

3.1 A Brief Description to Satellite Automatic Identification System (S-AIS)

Satellite based AIS (S-AIS) is the space based version of standard (terrestrial) AIS. The S-AIS technology enables the use of land based AIS technology for global maritime traffic monitoring by extending the system to space for global coverage. It makes monitoring of vessels that are out of the terrestrial AIS base stations' range, possible.

Satellite-based AIS (S-AIS) is a technology that enables satellites to receive land-based AIS signals from the space by mounting AIS receivers and antennas on the small low earth orbit satellites and then relay them to the ground station (Chen, 2016).

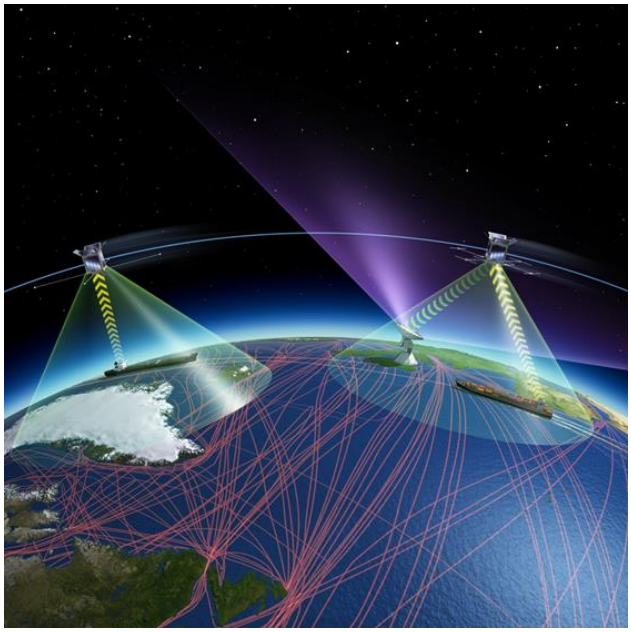

Figure 3.1 : Illustration of the operation of S-AIS (Url-6).

S-AIS is particularly useful in sea regions that are distant from shore-based AIS stations. S-AIS technology provides the information of where ships are and where they are going even if they are in the most remote places. Briefly, it is basically a ship detecting and tracking system provides intelligence data. S-AIS helps to monitor ship traffic over large areas of ocean because it has a much bigger vantage point from space than land-based systems do. By using S-AIS technology, range limits are disappeared as below:

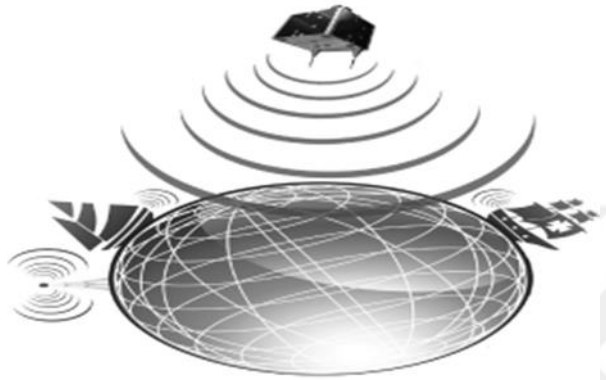

Figure 3.2 : S-AIS breaks the range limits (Ball, 2012).

Thanks to the satellites' ability to see a large area from the above, breaking terrestrial AIS range by S-AIS is satellites is possible.

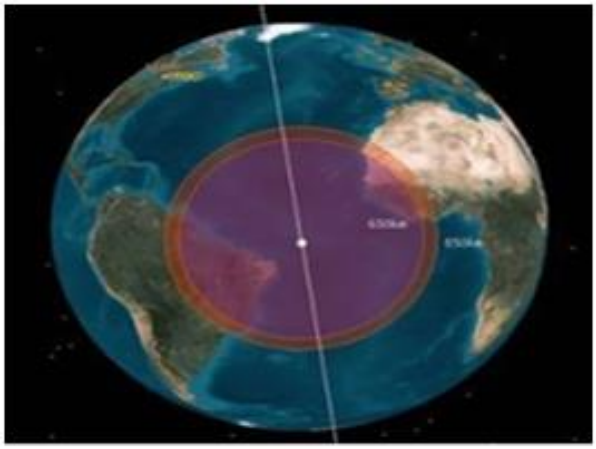

Figure 3.3 : AIS satellites see a larger area from the above

Thanks to S-AIS technology, we can see AIS-fitted vessels around the world on a computer screen and many information about them are available by only one mouse click.

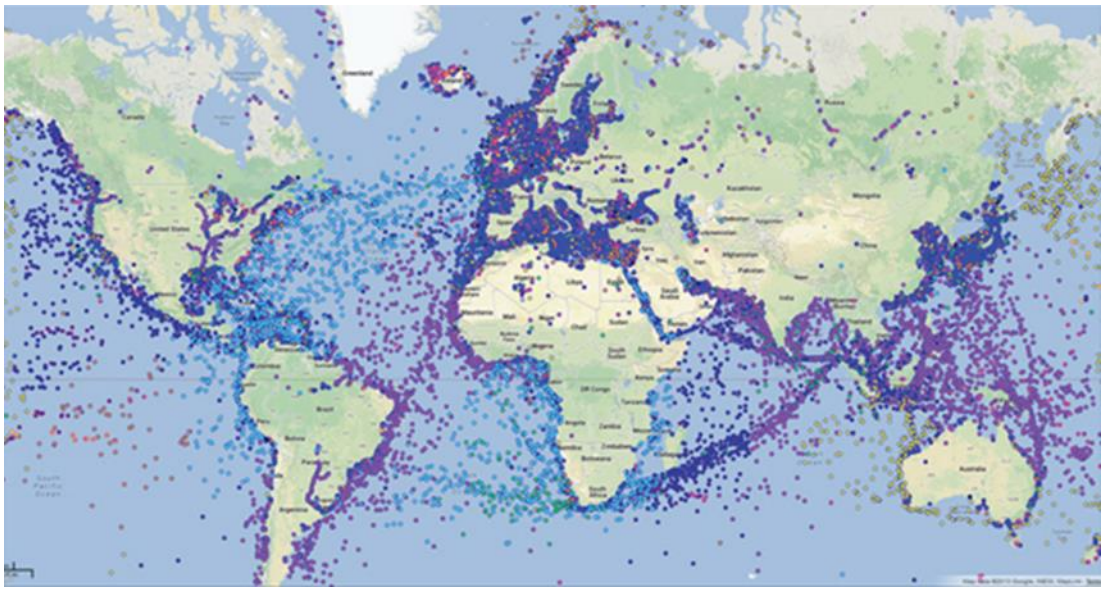

Figure 3.4 : Global ship positions map (Url-7).

Thus, the awareness of governments and commercial organizations about the maritime situation enhanced by getting data from S-AIS whether they're tracking a single vessel or monitoring vast areas of ocean.

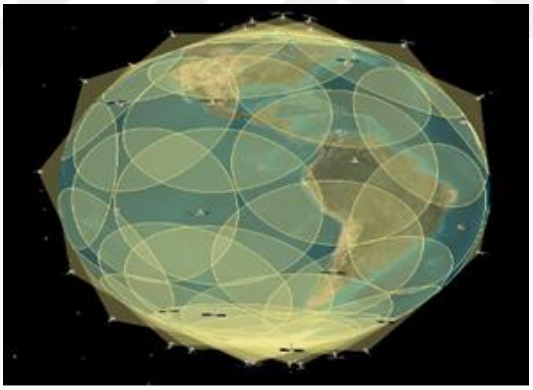

Figure 3.5 : S-AIS provides global coverage in real time

3.2 The introduction time of S-AIS

The idea of collecting AIS signals from space was first presented by Norwegian Defence Research Establishment (FFI) at the "4th IAA Symposium on Small Satellites for Earth Observation" in 2003.

The US Air Force Research Laboratory (AFL) launched the first AIS satellite of TacSat-2 in order to evaluate the concept of the S-AIS in 2007.

3.3 S-AIS architecture

Satellite-based AIS architecture can be illustrated as below:

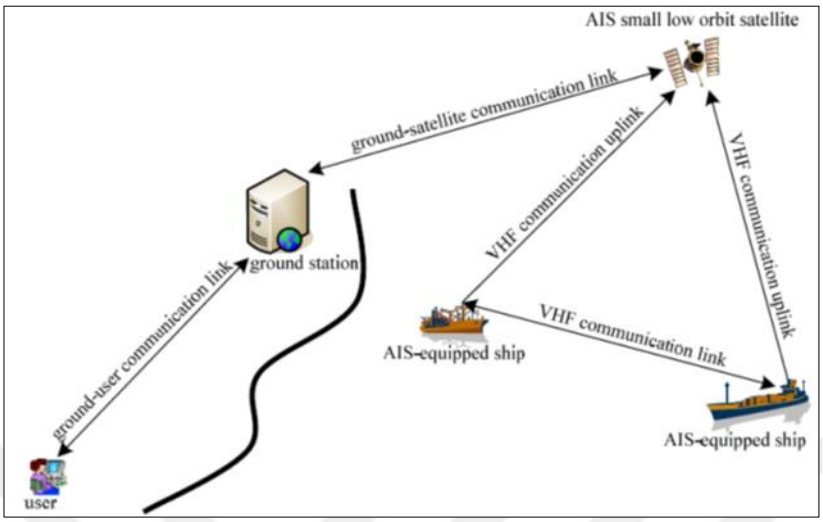

Figure 3.6 : Satellite-based AIS architecture (Cheng, 2014).

The conncetion between the ship to the satellite is uni-directional that is the S-AIS is a monitoring system but it is not a communication system (Cheng, 2014). An AIS satellite is not able to send any signal to any shipborne AIS transponder within its footprint.

4. BENEFITS OF AIS AND S-AIS

The benefits of the AIS and the benefits of S-AIS are intertwined because S-AIS technology provides the benefits provided by AIS, but increases the number and scope of these benefits and provides some additional benefits. Since S-AIS technology allows more data to be obtained from more regions than terrestrial AIS, the results are more valuable and accurate and statistical results can be obtained about the complete maritime picture. Most of the benefits of the S-AIS are based on the fact that continuous monitoring of all vessels on the world is possible through S-AIS technology. Therefore, this section discusses the benefits of AIS and S-AIS together.

There are many benefits directly and indirectly provided by AIS technology. While AIS already provides a wide range of important benefits, it is promising to provide even more benefits. AIS is required domestically on non SOLAS vessels by some administrations. It is inevitable for AIS to become more widespread because maritime traffic elements are a part of the AIS network and have vital importance for navigational safety. AIS is a versatile tool and, as experience is gained in the implementation and use of the various AIS stations, enhancements and other uses are being identified (Url-1).

Fournier et al. (2018) reviewed 204 papers and reports related to the uses and applications of the AIS and they stated that the uses and applications of the AIS can be grouped into four as technical, safety, security and environmental. Their review deliberately omitted some topics such as air pollution/emissions, shipping economics, computer science, and signal processing. They reviewed the techniques applied to processing AIS data, which can have applications and benefits over a large range of fields. After literature review carrierd out between 2004-2016, they compiled papers and reports as can be seen in Table 4.1:

Table 4.1 : Results of the literature review about AIS applications (Fournier et al. 2018).

Main category	Topics	Number of publications reviewed
The value of AIS data from a marine environment viewpoint	**Fishing management:** - AIS as a monitoring data source vs. VMS - Automatic detection of fishing areas/craft - Mapping fishing effort - Need for integrated framework - Illegal fishing assisting distressed vessels	11
	Oil spill monitoring: AIS as a data source for: - Risk analysis - Traffic simulation - Illegal discharge	7
	Ship noise pollution: - Mapping of ship sound - Harm to mammals - Estimation of noise level - Propagation of vessel noise - Ground-truthing capabilities - AIS as an aid to discretizing vessel noise	31
	Species at risk: - Strike risk - AIS as a warning system for whale sightings areas	21
	Other biological impacts: - AIS for MPA (marine protected area) compliance observance - Ballast water and invasive species - Anchor scour - Plastic and marine debris	25
Marine safety	Collision and grounding risks assessment Traffic simulation Small craft issue	40
Security	Maritime domain awareness National security AIS analysis for counter-piracy operations	12
	Satellites for AIS	5
Techniques	Data fusion	11
	Marine traffic pattern analysis, prediction, anomaly detection	27
	Data quality	20
Total papers reviewed		204

The other study, which is similar to this study, was published by exactEarth named "Satellite AIS for Dummies" (Ball, 2012), one of the three largest S-AIS data providers in the world. In this study, the introduction, benefits and applications of S-AIS technology are emphasized. S-AIS applications and benefits in this book are grouped as in the Table 4.2 below:

Table 4.2 : Application Areas of AIS, Edited by the author from (Ball, 2012).

Monitoring vessels and the waters they navigate (Vessel Tracking)	Enhancing search and rescue operations (SAR)	Ensuring the security of people, business interests, and borders (Security and Surveillance)	Protecting the environment (Environmental)
Safer ship routing	Tracking and assisting distressed vessels	Piracy monitoring	Pollution control
Enabling VTMIS (Vessel Traffic Monitoring and Information Systems)	Casualty alerting	Smuggling prevention	Environmental preservation
Ship reporting	Natural disaster relief	Mitigating infectious disease	Fisheries protection
Remote region monitoring		Increasing vessel safety in hostile waters	
Validation of ship declarations		Vessel identification with radar and digital imagery	
Efficient vessel traffic services (VTS)			
Arrival management		Monitoring aids to navigation operations	
Effective vessel traffic analysis			

In this study, the commercial benefits of AIS and S-AIS technologies are also included. The benefits of AIS and S-AIS are grouped under 5 main headings by evaluating current and potential benefits. In cases where a subject applies a technique falling directly in one of the five main topics, it is decided to keep the subject in the respective section. However, if a subject applies a technique falling in more than one of the five main topics, it is decided to keep the subject in the techniques section.

The benefits of S-AIS technology are not limited to what we have identified today. As technology advances, the performance of S-AIS will increase, the benefits that are not yet in our mind will emerge, and the usage areas created by new needs and technologies will increase and the number of benefit areas will increase. In addition, the benefits of S-AIS technology will increase as investments in S-AIS technology increase. AIS continues to be employed for an increasing number of applications.

Table 4.3 : Topics and sub-topics of this study.

Safety	Security	Environmental	Technique	Commercial
Collision and Grounding Avoidance	Maritime Domain Situational Awareness	Sea Pollution	Analysis	Route and trade pattern analysis
Search and Rescue (SAR) Operations	Fighting Against Piracy	Marine mammal strike risk	Multidisciplinarity (Data fusion)	Trade share by vessel size
Mitigating infectious disease	Increasing vessel safety in hostile waters	Anchor scour	Independence from environmental conditions	Utilisation Rate
Training	Smuggling prevention	Air Pollution (Emissions)	Compliance observance	Arrival Management
	Terrorism	Guarding environmentally special areas	Facilitation of the jurisdiction	Cargo Tracking
		Fishing management		Determination of statistical commercial facts
				Proactivity in commercial activities
				Enables more prudent chartering decisions
				Getting intelligence about competitors

4.1 Safety Benefits Of AIS And S-AIS

AIS contributes to the safety of life at sea by making shipping a safer business in the many aspects so in this section, it will be explained how AIS do it.

4.1.1 Collision and grounding avoidance

AIS device is an assistance for anti-collision (Url-2). The initial idea for AIS was to prevent collisions between ships. The AIS make it easy for ships to identify and tracking the other ships in their vicinity as a complement to the radar. Thanks to the AIS data exchange between vessels, they can avoid collision and navigate safely even when they can't see each other. That is, OOW doesn't need to physically see

where other vessels are located in order to avoid them. When other ships and maritime traffic services know the vessels' details such as position, course, speed etc., they can use them to ensure ships are following a safe course and to prevent collisions. Therefore AIS reduce the risk of collision and grounding and it contributes to safety of navigation (Allianz, 2012). However, in order to prevent collision, OOW should not rely solely on AIS and should benefit from other facilities together with AIS.

Because of the main benefits of AIS is the enhancement of safety at sea by reducing the possiblity of vessel collision, there are many academic AIS studies related with collision.

Based on AIS data examined, Zaman et. al (2015) found that tankers comprise the biggest proportion of vessels that are passing Strait of Malacca reaching approximately 50% every day and tankers have a high degree of probability of an accident in this area. The value of the Closest Point Approach (CPA) and Time to Closest Point Approach (TCPA) obtained from AIS is used to perform collision risk analysis by generating the value of the risk. It is concluded that human factors highly contributes to the collusions. They expressed that, when the risks are determined it is possible to take the necessary measures to prevent its occurence (Zaman et. al 2015).

Goerlandt & Kujala (2011) proposed a route-based traffic model by utilizing number of vessels, sailing speed, vessel dimensions, routes and departure time information in the AIS data from the period January to December 2006 (Goerlandt & Kujala, 2011).

Tsou (2010) shows that AIS improves navigation management (Tsou, 2010).

Felski & Jaskólski (2013) studied about rate of turn and heading based on AIS data between 2006–2012 from the Gulf of Gdansk (Felski & Jaskólski, 2013).

Asmara et al. (2015) modelled the probability of grounding and collision (Asmara et al. 2015).

Stitt (2004) studied on the impact of the AIS on the Convention on the International Regulations for Preventing the Collusions (COLREG) (Stitt, 2004).

As understood from the all these studies, the AIS has a vital role in the enhancing safety by reducing vessel collisions.

4.1.2 Search and rescue (SAR) operations

The AIS provides increased situational awareness for authorities which enables effective response to incidents, accidents, or dangerous situations. It assists in the search and rescue operations by providing information of the vessels in distress and the vessels in the vicinity to the executers of the search and rescue (SAR) operations.

The AIS can be used as a supplement and alternative to LRIT data in the SAR operations. The AIS data contributes to tracking and assisting distressed vessels. Often, vessels send the distress signal at the last moment when it's too late, or not at all. That leaves little time to the authorities for coordinating search and rescue operations. Search and rescue operators need a current image of all vessels in the vicinity in order to use resources efficiently and send help quickly. If the crew abandoned the vessel without finding a chance to send distress alarm, the authorities that realize the vessel data anomaly through S-AIS technology will understand the problem and take the necessary action. If the vessel is sunk, search and rescue operations can be started by looking at the last position report by using the vessel's S-AIS data history.

The AIS transponder can be used for the distress veya urgency communications in addition to the Global Maritime Distress Safety System (GMDSS) equipment. By this way, the AIS facilitates assistance to the distressed vessels. The ships in the distress situation can broadcast information via AIS message transmission for emergency assistance. S-AIS can track a drifting vessel from the location of a distress call through considering its last known position. S-AIS can also quickly identify which vessels are in the vicinity of a distress call, so that help can arrive as soon as possible (Ball, 2012).

In addition, ship and shore AIS stations can send safety messages. So a ship that is adrift can broadcast an "adrift with no engine" warning, stations can issue storm warnings to vessels. The operator should ensure that the incoming AIS safety-related messages are displayed and considered and should send safety-related messages as required (Url-2).

S-AIS satellites can also help saving lives by detecting signals from AIS-SART which is a low-powered (transmission power is 1 watt) search and rescue transponders (Ball, 2012). AIS SART is a search and rescue transponder (SART) that

uses AIS technology to find distressed vessels' location. It intermittently sends a position report and safety text message. When there is no any AIS fitted ship and shore stations in the range of the AIS-SART device which is transmitting the position of the survivors based on latitude and longitude, loss of lives occur because of nobody is aware of the distress situation. However, thanks to S-AIS technology, AIS-SART signals can be detected by sattelites even if there is no any AIS fitted ship and shore stations in the range of the AIS-SART device. Thus, it becomes possible to save lives in such situations.

On some ships, AIS transponders enable to input crew number information as an extra feature. Therefore, information about the number of persons on these ships can be captured by S-AIS data and search and rescue operation executers can find out how many persons should be saved in case of an accident.

The information provided by S-AIS technology allows authorities to create behavior patterns of ships, and they can use this information to better plan daily search and rescue patrols in a proactive manner (Ball, 2012).

S-AIS contributes also for natural disaster relief. After natural disasters such as tsunami that caused many ships to sink, authorities can refine search areas by the use of S-AIS when looking for people and vessels in distress, and compare a traffic image before and after a dangerous weather event to find survivors in the area (Ball, 2012).

4.1.3 Mitigating infectious disease

Ships that working internationally are at risk of passing on human or animal disease to crew and to anyone who comes in contact with the them. Some kinds of cargo are prone to infestation.

4.1.4 Training

Actual ship positions and traffic patterns data provided by AIS made it possible to design simulations closer to reality. Last et al. (2017) studied on how real objects can be integrated by the use of a live feed of AIS data into the simulators for crew training to increase its closeness to real-world scenarios (Last et al. 2017).

4.2 Security Benefits of AIS and S-AIS

The benefits of the AIS and S-AIS in the aspect of security can be grouped into:

- Maritime Domain Situational Awareness
- Fighting Against Piracy
- Increasing vessel safety in hostile waters
- Smuggling prevention
- Terrorism

4.2.1 Maritime domain situational awareness

Authorities are against to acts of piracy, armed sea robbery, environmental degradation, illegal fishing, and the trafficking of drugs, humans, and arms etc. These illegal activities which are happening in both national and international maritime waters are a threat to governments and businesses (Ball, 2012). Therefore, coastal authorities such as naval forces, port authorities, coast guards, and other marine authorities require an up-to-date and in-advance information of where all ships are, where they are coming from, when they will arrival, where they are going, what type of cargoes they carry and who they are in order to prevent and respond incidents which threaten the security of its citizens and their business interests. However, it is crucial for authorities to identify suspicious vessels not only in their harbour or jurisdiction but globally.

When a vessel's S-AIS data history is investigated, it becomes possible to find out if it is stopped in a distant and isolated position which is out of the destination port's territorial waters for a suspicious reason or not. Line-of-sight range limitation of land-based AIS stations prevent maritime authorities from getting a complete picture of maritime traffic outside of their borders and on a wider scale. Authorities want to be able to know as much as they can about vessel traffic over the widest area possible to get the complete picture of current maritime situation. So they can get beyond the land-based AIS range limitations by using S-AIS. Thus the use of S-AIS data improves awareness about comprehensive picture of what's happening at sea of the stakeholders such as industry, governments, maritime authorities, and businesses.

Satellite AIS enables authorities to monitor massive protection zones which they are responsible for.

Tun et al. (2007) introduced a computational method that promises improved maritime security in a cost effective manner by using AIS. Their algorithm is capable of detecting abnormal vessel activities for a range of different port profiles. They explored the use of spatial data accumulated from AIS information to model activities of vessels in a Port. A number of machine learning techniques are presented to detect abnormal vessel behaviour (Tun et al. 2007).

4.2.2 Fighting against piracy

Maritime awareness that is the knowledge of where the ships are on the sea is one of the essential component of counter-piracy activities in addition to intervention capability. Besides real-time situational maritime awareness, also patterns of normality and risk (incidents) should be known (Posada et al. 2011). The S-AIS data provides vessel tracking data history that allows for detailed analysis of vessels' behavior patterns to make a deduction, so authorities figure out that when a vessel may be at risk. The changes in a vessel's speed can be detected by using S-AIS data and any disparities between its course over ground (COG) and the heading may indicate that this vessel is drifting or was pirated (Ball, 2012). When the vessels are under a pirate attack, they manoeuvre hard a port and hard a starboard consecutively in order to prevent pirates to get onboard. A ship seized by pirates could stop immediately or alter its course to an unplanned route. Therefore, when these kind of anomalies detected by the authorities, they find a chance to realize the situation once it is happened and to respond immediately even if there is no any broadcast or alarm such as SSAS alarm activated by the OOW. This makes the pirates surprising and enables authorities to catch tham napping.

It is possible to identify and analyze traffic patterns in piracy hotspots through data extraction from S-AIS data to allow authorities determine more secure shipping routes. The AIS data assists in forming convoys and guiding vessels through a protected route. When the vessels form convoys, it deters pirate attacks (Ball, 2012).

In addition, because of the pirates know that the S-AIS enables the coverage of a wider area, it deters possible future pirate attacks.

The exactEarth Limited Company, one of the largest commercial S-AIS data provider, plays a key role in anti-piracy operations and making easier to preventing piracy by currently supplying data to the North Atlantic Treaty Organization (NATO) Shipping Centre in conjunction with Operation Ocean Shield, a counter-piracy initiative headed up by NATO to improve the effectiveness of joint operations (Ball, 2012). As it is understood, significant organisations such as NATO take advantage of S-AIS data.

4.2.3 Increasing vessel safety in hostile waters

Conflicts between countries can cause hostile military forces to threat the safe passage of ships close to their shores and result disruption of global shipping. S-AIS data helps authorities to plan safe escorts and manage convoys to keep ships, cargo, and crews safer when in unfriendly waters. During voice communication, there is a risk of routing information leakage to the wrong people. S-AIS data is more secure than voice communication because of its encrypted nature (Ball, 2012).

4.2.4 Smuggling prevention

Ports are entry points for smuggled weapons (Sinai, 2004). Handoff of illegal drugs and maritime smuggling often happens out of the range of regular coastal AIS, so it goes undetected. But S-AIS can track vessels and note where they may stop or slow down unexpectedly, providing an indication of when a drug handoff may be taking place (Ball, 2012). Suspicious behaviour detection for the vessels which are involved in maritime smuggling can be done by S-AIS considering distance to nearest vessel, time of day (day or night), risk of departure port and AIS off time.

The last port of calls of a vessel is quite significant in the aspect of human trafficking, stowaway and teror risks. Historical vessel positions and port of calls data provided by AIS and S-AIS technologies enable to validate ship declarations.

4.2.5 Terrorism

A terrorist attack can disrupt the trade by causing shut down of a port or block a critical sea-lane (Chalk, 2008).

An Organisation for Economic Co-operation and Development (OECD) report named “Maritime Security Measures to Amplify Cost for Shipping,” states that

much of this maritime infrastructure is vulnerable to terrorist attacks or misuse (Sinai, 2004). Therefore ports are at terror risk also. AIS and S-AIS data can be used for port security purposes. Eriksen et al. (2010) presented experience gained with the S-AIS systems and comment on possible contributions to port security (Eriksen et al. 2010).

Much of the Northern European continental shelf is covered by oil or gas platforms. There is a great risk of sabotage or a major disaster in one of the oil or gas platforms caused by acts of terrorism (Rowbotham, 2013).

It is possible to detect anomalies and suspicious vessels by using AIS and S-AIS data together with the other means of vessel detection Technologies such as Synthetic-aperture radar (SAR) imagery, to prevent terorist activities.

4.3 Environmental Benefits of AIS and S-AIS

The AIS and S-AIS assist to control, preserve, and protect the world's natural resources. This assistance can be grouped into four:

- Sea Pollution
- Marine mammal strike risk
- Anchor scour
- Air Pollution (Emissions)
- Guarding environmentally special areas
- Fishing management

4.3.1 Sea pollution

Sea pollution is a threat for not only marine species but also for human kind indirectly in the health, economic and cultural aspects. Sea pollution can be categorised into four as:

- Spill
- Marine debris
- Noise Pollution

4.3.1.1 Spill

Schwehr & McGillivary (2007) described that oil spill analysis can benefit from AIS and S-AIS data in detection and identification of vessels responsible from illegal oil discharges, ship accident risk areas analysis and reducing response time by means of processing information on traffic flows and location of oil spill incidents to inform related parties (Schwehr & McGillivary, 2007).

Spill monitoring and detection: Reducing response time to oil spills by means of processing information on traffic flows and location of oil spill incidents is vital to prevent the deterioration of the negative situation. In some of the distress situations such as abandon, floundering, fire, capsizing etc., crew of a tanker could not find a chance to send a distress call so authorities could not realize and respond the situation in time. However, using S-AIS gives the opportunity of realizing the situation through anomaly detection and reducing response time to react immediately after the spill to the responsible authorities. Moreover, S-AIS can assist to the authorities for being proactive by the way of warning them about the vessels which present anomaly.

Illegal discharges: International Convention for the Prevention of Pollution from Ship (MARPOL) prohibits ships from discharging harmful or dangerous substances such as oil and noxious liquids into the ocean. It is possible to detect illegal discharges by getting ocean surface image from the SAR satellites. The responsible authorities need to detect the polluter vessels for prosecution.

Satellite images from CleanSeaNet is integrated AIS information via the European Maritime Safety Agency (EMSA) managed SafeSeaNet system. The wide picture of vessel traffic which is obtained by this way, substantially improve the system for detecting illegal oil discharges and identifying those responsible (Url-8).

Maritime authorities can cross-check the positions and locations of ships recorded in the onboard logbooks with the S-AIS data and find if there is any discrepancies in reporting or not. Suspicious activities that may be related to pollution can be detected with the help of data collected with S-AIS. Deviation from the preset course may indicate that the ship is trying to hide prohibited discharge (Ball, 2012).

4.3.1.2 Marine debris

Marine debris caused by marine traffic is a threat for marine ecology and is an international concern. Mapping vessel traffic patterns based on AIS and S-AIS data is used to estimate the potential marine debris quantities by some researchers.

4.3.1.3 Noise pollution

Vessel-originated noise, which is a contributor to ocean noise, has chronic negative impacts on aquatic mammals.

4.3.2 Marine mammal strike risk

The ship traffic taking place in marine mammal habitat area can be identified by AIS ship positions data (van der Hoop et al. 2012).

Marine mammal strikes can be reduced when whale sightings are communicated directly to the vessels.

4.3.3 Anchor scour

Position data extraction of anchored vessels from AIS and S-AIS makes anchor scour analysis process possible to estimate anchor drag (Fournier et al. 2018). Historical AIS and S-AIS data provide vessel anchoring manoeuvre tracks which enable to estimate "anchor drop" position and anchor drag approximately.

4.3.4 Air pollution (Emissions)

The AIS and S-AIS data provide voyage distance and speed data for all type of vessels fitted with AIS transponder which enable to calculate emissions caused by ships when this data combined with data such as fuel consumption, engine power etc. from another data sources.

Vessel sailing speed is one of the key variables governing ship-to-air emissions. Therefore, vessels' speed data obtained from AIS and S-AIS is useful not only for technical and commercial interests but calculating vessel emissions in the environmental aspect (Adland & Jia, 2016).

While comparing the global carbon footprint for transport modes the cargo quantity transported, in tonnes, is needed. For instance, while evaluating CO2 emissions in transportation, efficiency is measured as grams of CO2 per tonne-km. Therefore,

estimation of cargo volumes transported by different vessel types and routes at the micro level by means of vessel draught information obtained from AIS messages is key for studies about environmental impact of maritime transportation (Jia et al. 2019).

4.3.5 Guarding environmentally special areas

Oceans and coasts have some of the most productive eco-systems in the world, providing food and livelihoods to millions of people, sustaining local and national economies, and supporting cultural services to humanity. Marine ecosystems and resources are vulnerable and becoming increasingly degraded because of pollution and over-exploiting. To fight these problems and protect the oceans by improving the situation, some areas that are vulnerable to damage by international maritime activities are given special statue because of some reasons such as ecological, socio-economic, scientific, historical/archaeological, cultural and safety reasons. Access to these areas is strictly limited or forbidden to protect them.

4.3.6 Fishing management

Regularly, the fishing vessels that are fishing illegally use large reefer ships as mother ship which anchor outside of Exclusive Economic Zone (EEZ) coverage and act as a collection point for smaller fishing vessels. S-AIS uncovers this scheme via detecting the vessel movement patterns such as in the case that many fishing vessels stay generally in a zone and make any transshipment to a reefer ship. If the reefer ship turns off its AIS and small vessels keep returning to the reefer ship, probably this is a sign of an illegal, unreported, or unregulated (IUU) activity. If the fishing vessels turn off their AIS, it can be determined that IUU fishing is taking place because we can see a large reefer vessel at anchor in the middle of the ocean (Ball, 2012). Also, when the fishing vessels turn off their AIS devices, they become targets for investigation simply because they aren’t using AIS. Thus, the coastal state can detect these suspicious vessels that do not send the AIS signal due to data from various other sources, such as SAR imagery.

4.4 Technical Benefits of AIS and S-AIS

Some technical advantages come exist with the use of AIS and S-AIS. We can deal with these advantages in five groups:

- Analysis
- Multidisciplinarity (Data fusion)
- Independence from environmental conditions
- Compliance observance
- Facilitation of the jurisdiction

4.4.1 Analysis

Analysis of some of the maritime activities is possible through handling of AIS data.

4.4.1.1 Traffic pattern analysis

Etienne et al. (2012) aimed to perform a data mining on vessels' positions using AIS data in order to deduce their behaviour. They stated that by comparing ships' positions with the patterns, ships' behaviours can be defined and unusual situations can be detected (Etienne et al. 2012).

4.4.1.2 Remote traffic analysis

S-AIS technology allows to make traffic analysis in remote coastal and offshore areas and even in the most remote areas of the planet, where it couldn't be done before (Ball, 2012).

4.4.1.3 Anomaly detection

Anomaly defined as unusual vessel behavior that may pose a potential threat (Fournier et al. 2018). Any unusual changes in AIS signals may be an indication of suspicious activities (Andersson & Johansson, 2010).

4.4.1.4 Automated reasoning tools (Proactive efforts/Casualty alerting)

Maritime automated reasoning tools are part of intelligent maritime transportation systems that warns authorities before a disaster strikes by giving alerts or alarms on risky situations that necessitate an early and preventive intervention after collecting,

processing and interpreting the data they receive. Thanks to continuous vessel tracking and getting a complete set of vessel information capability, AIS and S-AIS properly assess when a vessel is in danger, so authorities know the best way to assist. S-AIS enables casualty alerting facility and makes it possible to be proactive rather than reactive for maritime authorities. Maritime authorities can prevent maritime casualties including damaged vessels, loss of cargo, loss of human life and damaged marine environment and ecosystem by casualty alerting system that warns vessels which are about to collide, going off course, going into a tropical cyclone etc. The S-AIS can automatically monitor a defined area or predetermined route which is out of the range of radar or coast-based AIS systems, and warn maritime authorities if a vessel appears to be going off course. That is, S-AIS also allows authorities to take action for the potential problems that may be caused by the negligence of the OOW, shipowners or those who operate the ship before an incident or accident happens. The AIS and S-AIS can detect if a vessel is steaming too fast for the prevailing conditions, that causes risk of structural failures, by combining vessel speed data with the data about weather and sea conditions. The S-AIS can also use this data fusion to warn vessels routeing into a bad weather such as tropical storm and direct them to a safe course. Moreover, all of these preventive actions can be organized by the system itself automatically and thus reduce human involvement and the human fault risk.

4.4.1.5 Calculation of the real voyage distances

There is some difference between the actual (in-practice) distances between ports and the distance table's theoric distance information. With the examination of S-AIS history of ships, actual distances on each voyage can be calculated easily and accurately.

4.4.2 Multidisciplinarity (Data fusion)

Multi-sensor integration is a requirement for developing the most accurate maritime picture. Multidisciplinary usability of the AIS and S-AIS data allows many parties to improve their operational capabilities. Data Fusion is the integration of AIS or S-AIS data with the information from other data sources such as synthetic-aperture radar (SAR), electro-optical imagery, long-range identification and tracking (LRIT) data, vessel monitoring system (VMS), radar etc. Data fusion increases the benefits of

both S-AIS and the systems fused with S-AIS. When evaluating the potential benefits of S-AIS technology, it should be taken into account that this technology becomes much more useful if it is used with radar photography and other remote sensing technologies. It should not be overlooked that the potential of S-AIS technology is much more than expected.

4.4.3 Independence from environmental conditions

AIS signals can be sent and received even in very poor weather conditions, such as in nighttime heavy rain, in fog, or during snow squalls and provides continuous coverage, unlike coastal stations, even in the case of natural disasters such as tsunami which bring massive destruction to coastlines and land and disrupt signals of traditional coastal surveillance systems (Ball, 2012).

4.4.4 Compliance observance

A breach may be associated with multiple aspects such as safety, security and environment and thats why this subject is handled under this section rather than keeping it in the respective sections.

Authorities can make sure that ships are following maritime regulations, recommendations, and safe practices with the assistance of AIS and S-AIS data for the enforcement purposes such as collision regulation (COLREG) conformance, ship declarations validation, sensitive sea area trespass detection, spill detection and illegal activity detection such as illegal fishing, contraband and human and drug trafficking.

Without S-AIS, maritime authorities need to rely on other, less efficient methods, such as periodic aircraft patrols for monitoring a vessel’s compliance with declaration protocol. Using S-AIS, maritime authorities can check whether a ship made a required deviation in course, or not (Ball, 2012). Through examining a ship’s S-AIS data history, it is possible to see its past ports of call and find out if it is called a blacklisted or sanctioned port. In addition, validation of ship declarations can be carried out by this way. If the OOW tries to conceal his/her ship’s position via turning-off its AIS transponder, there will be a missing parts in this vessel’s S-AIS data history so authorities will become alerted and suspect this vessel.

4.4.5 Facilitation of the jurisdiction

In the case of a dispute, historical S-AIS data of a ship can be used as an information and a proof in the court, mediation or arbitration. Enabling to record all AIS-fitted vessels' history, S-AIS provide benefit for jurisdiction process. For instance, past S-AIS data of a vessel can be used to check whether the ship meets the warranted contractual performance or not. A charterer can make a claim in the case of the vessel's speed & consumption warranties have not met.

4.5 Potential Commercial Benefits of AIS and S-AIS

It is possible for many seaborne trade stakeholders to make use of AIS and S-AIS directly or indirectly for commercial purposes. In spite of this, there is a relatively less study about potential commercial benefits of AIS and S-AIS technologies.

The main potential commercial/economic contributions of AIS and S-AIS Technologies can be collected into 9 groups:

- Route and trade pattern analysis
- Trade share by vessel size
- Utilisation Rate
- Arrival Management
- Cargo Tracking
- Determination of statistical commercial facts
- Proactivity in commercial activities
- Enables more prudent chartering decisions
- Getting intelligence about competitors

4.5.1 Route and trade pattern analysis

Main potential commercial benefit provided by AIS and S-AIS is that it allows for the monitoring of ship movements and therefore cargo movements. With S-AIS technology, it is possible to determine the global seaborne trade routes and volumes. For the determination of routes, it is sufficient to examine current and historical S-

AIS ship positions data. West et al. (2010) used AIS data to map the traffic density, patterns according to the type of ship, speed, destination, etc (West et al. 2010).

Position data of the vessels gathered by AIS or S-AIS can be displayed on a computer screen and every ship type are depicted with a different colour scheme. Thus, ship chartering patterns and ship operators' decision patterns can be determined with examining which ship types and tonnage groups are directed on which routes after discharge.

Figure 4.1 : Global Shipping Density Map (Url-9).

For the determination of the global seaborne trade volumes, it should be found out that which ships sailing with how much cargo onboard. The AIS also indirectly provides us with the knowledge that a ship is empty (ballast condition), partially loaded or fully loaded. The draft, type, size and dwt information of the ship must be obtained in order to estimate the cargo quantity onboard. Draft and vessel dimensions information can be obtained from AIS messages directly. However, the raw AIS data do not contain the ship characteristics such as ship type and ship size. These ship characteristics can be extracted from other sources such as a ship database by means of the corresponding MMSI (Maritime Mobile Service Identity) number (Chai et al. 2017). MMSI number is a nine-digit number unique to all vessels, contained within all AIS messages which enable the retrieval of the vessel name and IMO number, which in turn can allow us to find out the vessel type and its dead weight tonnage (dwt). It is also possible to obtain information from the various marine sources, including the dwt capacity of each ship and the information of how many tonnes of cargo they can carry on which draft level. That is, when we find out a vessel's

identity (MMSI number) by means of AIS messages, the opportunity to find much more details about this vessel quickly and easily will be arise. Therefore, calculation of approximate onboard cargo quantity can be done with the help of an algorithm that combines AIS data with the information obtained from various other sources. This can also help in determining the estimated value of products onboard (Url-10).

Jia et al. (2015) argue that the prediction of approximate onboard cargo quantity can be done with a standard deviation of 7–9% based on AIS draught information contained in cargo vessels' AIS messages (Jia et al. 2015).

A state's international trade statistics include type, time, and quantity information about imports and exports. With the use of S-AIS, it becomes possible to know countries' international trade statistics in real-time, unlike customs and statistics institutions' delayed published reports. However, AIS does not provide the individual cargo details such as title (name) of the cargo. AIS only provides if the cargo onboard is dangerous or not. On the other hand, it is possible to derive trade statistics for homogeneous commodity groups by AIS data. However, onboard specific cargo type can be estimated for some ships by looking at its ports of call and the type and size of it. For instance, if a ship calls a port that handles only one type of cargo, it is obvious that this ship carries that cargo. If we get the type and dimension information of a ship, we can determine potential cargoes groups that can be carried by this ship because every tonnage groups (ship tonnage classes) are focused on carrying certain cargoes. One of the reasons is every type of cargo has its own Parcel Size Distribution (PSD) function. A 'parcel' is an individual consignment of cargo for shipment. The PSD function describes the range of parcel sizes in which a commodity is transported. Each commodities shipped by sea has its own PSD function. For instance, iron ore is almost all shipped in vessels over 100,000 dwt, with the largest cluster of cargoes around 150,000 dwt, whilst bulk sugar, a much smaller trade, clusters around 25,000 tons (Stopford, 2009). Thanks to AIS, it becomes possible to determine commodities' PSD functions and trade shares by vessel sizes. Adland et al. (2017) fullfilled a breakdown of the crude oil export trade by vessel size over time in the selected countries (Adland et. al 2017).

AIS data outperform in terms of availability, scope and timeliness compared to the other data sources such as port agent reports or Bill of Lading data. The scope of AIS can potentially allow to cover all ports for various types of vessels including smaller

ports where other third-party data is not easily accessible or not at all (Jia et al. 2019).

Sekkesaeter (2017) aimed to compare AIS data supplied by the Norwegian Coastal Administration with the customs data published by Norway's national provider of statistics, SSB (Statistics Norway). In the study, AIS data belongs to ships which call the iron ore terminal of the port of Narvik between 2012-2016 are analyzed by a model and it is found that AIS data is 8.8% lower than SSB's official figures for iron ore exports. While iron ore export quantity computed as 86,086,429 tonnes based on AIS data, it was 94,313,141 tonnes based on SSB data. The model named "Simple AIS model" has a noteworthy proximity to the official export figures so with the further optimisations and enhancements, more accurate results can be obtained (Sekkesaeter, 2017). In addition to the tonnage estimations, trend analysis can be done with the help of the AIS data to support decision-making process of the shipping players like charterers and ship owners.

4.5.1.1 Port throughput estimation

Analyzing the vessels' historical AIS and S-AIS data at port to measure the difference in draught compared to the overall capacity enables calculating the cargo payload (cargo quantity onboard) of a merchant vessel and the quantity of the commodity handled. Thus, inflow and outflow of cargo in this port can be determined (Url-10). That is, with the estimation of total onboard cargo sizes based on AIS draught data, one can have real-time market information on cargo flows. Jia et al. (2019) utilised vessel draught information reported by AIS messages to estimate vessel payloads (Jia et al. 2019).

S-AIS technology provides detailed real-time intelligence about all states' homogenious seaborne cargo import and export quantities and the information about the ports that these imports and exports are taking place.

4.5.1.2 Seasonality

Thanks to AIS data, it is possible to derive seasonal fluctuations from the AIS enabled trade data. In the case of monitoring a port constantly by AIS or S-AIS, a historical dataset become accumulated. Analyzing historical dataset, it can be detected whether there is a significant fluctuation on handled cargo quantity. If there

is a fluctuation in some periods, it is also possible to determine in which months cargo handling fluctuates and in which direction? Through monitoring of cargo inflow and outflow quantities in a port during a year and, after statistical analyzing, combination of this information with the other sources such as the expert knowledge enables to determine seasonalities. The ability to visualize changes in seasonal or regional trading patterns enables economists and policy makers to monitor changes at a macro level (Jia et al. 2017).

4.5.1.3 Market analysis and forecasting

Through examining port throughput changes, trends can be determined and real-time market analysis and forecasting become possible.

As a result of the real-time monitoring of port throughput, it would be easier to estimate the time it takes freight rates to react to cargo volume fluctuations.

AIS and S-AIS data are useful tools to predict future international trade environment.

Næss (2018) investigated the use of AIS data for multivariate machine learning forecasting methods to predict short-term freight rates in Liquefied Petroleum Gas (LPG) market. In this study, it is stated that AIS data adds predictive value in forecasting short-term spot price fluctuations (Næss, 2018).

4.5.1.4 Shipping demand

Port throughput data is one of the ship demand forecasting parameters. Thanks to AIS data, in addition to global shipping demand derivation, it is possible to derive shipping demand of a terminal, port, region and country from the AIS enabled trade data. Shipping demand of a port can be estimated by the integration of past port throughput data with the information from other data sources such as national growth rates etc.

S-AIS data allows for prediction of seaborne trade which is crucial in the estimation of shipping demand by enabling access to past track of vessels (cargoes) on a tonne-mile basis.

4.5.1.5 Repositioning

Because of demand for shipping is low in some routes, it is very important to make correct ship positioning (Rowbotham, 2013). Profitability and competitiveness are

directly related with the ship positioning. Correct repositioning that is giving correct chartering and routing decisions that causes ships to be a suitable position for finding cargo on the next voyage is dependent on port throughput and the vessel density in an area. Both of port throughput and the vessel density can be determined by AIS and S-AIS data to give correct repositioning decisions by ship operators. If the discharge is completed in an area that there is no any cargo nearby to load for the next voyage, the ship has to navigate in ballast condition (empty) to a loading port which means sailing without any earning.

4.5.2 Trade share by vessel size

AIS and S-AIS data allow for the acquisition of a comprehensive data set on the distribution of vessel sizes by load country, commodity type and across time. Adland et. al (2017) illustrated seaborne crude oil export share by vessel size for selected countires as in the Table 4.4 below:

Table 4.4 : Seaborne crude oil export share by vessel size (Adland et. al 2017).

Country	Vessel Size	2013	2014	2015	2016a
Saudi Arabia	VLCC	87.6%	87.8%	88.1%	87.2%
	Suezmax	8.0%	8.2%	8.0%	8.5%
	Aframax	4.0%	3.5%	3.5%	3.6%
	LR1	0.4%	0.4%	0.3%	0.7%
	ULCC	0.0%	0.1%	0.0%	0.0%
	MR	0.0%	0.0%	0.0%	0.0%
Angola	VLCC	65.2%	61.8%	58.3%	64.7%
	Suezmax	34.5%	37.7%	41.5%	35.3%
	Aframax	0.1%	0.2%	0.2%	0.0%
	LR1	0.1%	0.2%	0.0%	0.0%
	MR	0.0%	0.0%	0.0%	0.0%
Norway	Suezmax	41.1%	49.4%	55.6%	58.7%
	Aframax	57.4%	50.4%	44.2%	41.3%
	LR1	1.2%	0.2%	0.0%	0.0%
	MR	0.4%	0.0%	0.2%	0.0%
Russia	Aframax	79.3%	77.6%	78.3%	77.1%
	Suezmax	19.3%	19.6%	17.4%	17.8%

	LR1	0.9%	2.3%	4.0%	4.5%
	MR	0.5%	0.4%	0.4%	0.6%
Venezuela	Aframax	43.7%	47.8%	46.4%	42.1%
	VLCC	34.6%	30.6%	34.9%	39.5%
	Suezmax	15.5%	16.8%	15.2%	14.9%
	LR1	6.1%	4.7%	3.5%	3.4%
	MR	0.0%	0.0%	0.0%	0.0%

aYear-to-mid-March only.

4.5.3 Utilisation rate

Information about cargo payload of a merchant vessel is usually not publicly available. However, cargo payload information is essential in assessing vessel utilisation, fleet productivity, and subsequently the real-time market based on seaborne cargo transportation supply and demand conditions (Jia et al. 2019). Fortunately, voyage related AIS messages contain ship draught information which is used to reliably estimate a vessel's payload. With the processing of vessel draught information from AIS and/or S-AIS for a period, vessel utilisation rates for each type and tonnage class of ships and routes can be revealed. If laden (loaded) sailing distance percentage of a ship is low that means this vessels' utilisation rate is low. Thanks to the S-AIS technology, we can find out which ships on the world are empty so it is possible to reveal the rate of utilization of every AIS-fitted ship by calculating its laden sailing ratio in a certain period. By detecting which ships are sailing in ballast condition (empty), it is also possible to reveal statistically that if the ship operators prefer to load cargo for their next voyage from a port which is close to the discharge port or to sail to a port that offers higher freight rates in ballast condition.

4.5.4 Arrival management

Captain of a ship is obliged to give authorities a notice of arrival about 24 to 72 hours prior to arriving at port. Some stakeholders such as ship's agent, VTS, customs and immigration, charterer's agent and harbormaster use this information for scheduling their activities. S-AIS can monitor ships that are far out to sea, so the authorities and stakeholders can better plan ships' arrival and be prepared for it to schedule administrative requirements well in advance, improving wait times for vessels (Ball,

2012). If the time the ships spend in the port is shortened, port and ship efficiency is increased and competitive advantage is ensured.

With S-AIS data users can ensure minimal delay at port with better planning and efficient use of resources as ETAs are identified early on. S-AIS track all route deviations, stoppages as well as monitor the ETA for better use of resources at port calls (Url-10).

4.5.5 Cargo tracking

AIS and S-AIS can be used by shipping lines and cargo operators to track the movements and locations of vessels and the cargoes carried by them. In other words, the ability of tracking ships enables also to track the cargo onboard in the meantime. The AIS and S-AIS data enable the shipper to plan shipping movements and cargo deliveries in order to plan production scheduling and order fulfilment. The AIS device enables shipping lines to accurately track any of their vessels enroute, and to guarantee vessel departures and arrivals to their customers (Rowbotham, 2013).

4.5.6 Determination of statistical commercial facts

Trade data obtained by AIS and S-AIS enable historical and statistical analysis and empirical modelling of international trade.

With the use of S-AIS, as the past position data of the vessels can be recorded, it can be predicted how long the ships will wait for each channel and strait pass. Thus, during voyage estimation, it is possible to make a more accurate estimation of the length of time a vessel will wait to pass through a channel or strait. As an example of waiting times, Panayides (2016) stated that the average waiting time in Suez Canal was 11 hours before “New Suez Canal” project (Panayides, 2016).

4.5.7 Proactivity in commercial activities

Thanks to AIS and S-AIS; fuel suppliers identifying ships that will soon arrive in their service area will be able to identify potential customers by estimating where that ship could have last supplied fuel by looking at its historical AIS and S-AIS data. If a ship has not called any of the ports where it is possible to supply fuel, a bunkering supplier can realize that this ship needs bunkering and he/she may contact with the operator of the ship to offer bunker supply as a proactive seller.

4.5.8 Enables more prudent chartering decisions

With analyzing a ship's past position and speed data, S-AIS enables charterers to check the vessel's performance history and decide whether that ship is able to meet charter party warranties or not. Thus, charterer will find a chance to make correct chartering decision in a more prudent manner. Also, it can be checked by charterer whether the vessel is really in its reported position or not.

4.5.9 Getting intelligence about competitors

The history of vessel movements can be obtained by S-AIS. Kaluza et al. (2010) used information about the itineraries of 16 363 cargo ships based on AIS data during the year 2007 to understand patterns of global ship movements and global trade. They found that bulk dry carriers, container ships and oil tankers differ in their mobility patterns and networks. Arrival and departure records for each vessel is presented in the study (Kaluza et al. 2010). By means of monitoring vessel movements, the business connection between ship operator and charterer can be revealed and it becomes possible to determine which markets the competitors are heading towards. It can be found out which ship drydocked at which shipyard. Moreover, the competitors' technical and commercial management abilities can be assessed via monitoring their ships.

5. FEEDBACK FROM THE EXPERTS

In this study, the potential benefits of S-AIS technology were determined by adding new ideas to the benefits obtained through literature review. The extent to which the benefits that could directly or indirectly affect commercial stakeholders could contribute in practice was tested through feedback from chartering experts.

There are three type of shipbrokers in ship chartering: owner's broker, charterer's broker and competitive broker (Gorton et al. 2009). In order to receive multidimensional feedback on the benefits of this technology, face-to-face interviews were conducted with the top executive persons of all type of brokerage companies. Experience, recognition, reliability and business volume are taken into consideration when selecting companies.

The form in Appendix-A was used to get feedback from experts. The form consists of 20 different benefits and these benefits are rated by the experts in the 1-5 scale.

The details of the meetings and important notes are presented in below sub-sections. Detailed records may be obtained upon request from the author of this thesis.

5.1 Interview with the Experts

Through using a survey template, face-to-face interviews were conducted with the senior managers of brokerage companies which every one of them represents one of the brokerage types.

5.1.1 Charterer broker

The GMD marine company, which provides services in a wide variety of brokerage types, evaluated the answers given during the interview from the perspective of the charterer broker. This company is the exclusive broker of some of charterers. The expert gave the most importance to the benefits of "route and trade pattern analysis", "getting intelligence about competitors", "facilitation of the jurisdiction", "trade share by vessel size", "SAR operations". They are followed by "repositioning",

“shipping demand determination”, “market analysis and forecasting”, “arrival management”, “cargo tracking”, “calculation of the real voyage distances” and “figthing against piracy” benefits. The expert considers the benefits of “port throughput estimation”, “Seasonality determination”, “Determination of statistical commercial facts”, “Proactivity in commercial activities”, “Enabling more prudent chartering decisions”, “Automated reasoning tools (Proactive efforts/Casualty alerting)”, and “Increasing vessel safety in hostile waters” as relatively less important.

In particular, he noted that the benefit of “facilitation of the jurisdiction” would make a difference in practice and that he was ready to purchase information from companies providing such a service, as it would be possible to avoid the risks that would likely arise in the future when the performance histories of the chartered vessels could be examined by S-AIS.

5.1.2 Owner’s broker

Hanbulk chartering is responsible for chartering of the vessels of KIRAN shipping which operates its own vessels in the dry bulk sector.

The expert gave the most importance to the benefits of “route and trade pattern analysis”, “getting intelligence about competitors”, “SAR operations”, “Automated reasoning tools (Proactive efforts/Casualty alerting)” and “cargo tracking” faydalarına vermiştir. They are followed by the benefits of “Port throughput estimation”, “Utilisation rate”, “Arrival management”, “Determination of statistical commercial facts” and “Proactivity in commercial activities”.

5.1.3 Competitive broker

The Green & Black marine company, which serves a wide range of brokerage types, evaluated the answers given during the interview from the perspective of the competitive broker.

The expert gave the most importance to the benefits of “route and trade pattern analysis”, “arrival management”, “cargo tracking”, “getting intelligence about competitors”, “calculation of the real voyage distances”, “facilitation of the jurisdiction”, “figthing against piracy” and “Automated reasoning tools (Proactive

efforts/Casualty alerting)". They are followed by the benefits of "repositioning", "Market analysis and forecasting", "Seasonality determination", "Increasing vessel safety in hostile waters", "Search and Rescue (SAR) Operations".

He stated that he found it very useful to be able to make projections which allow him to foresee in which regions there will be ship concentration in the world after 10-15 days and sometimes even more time thanks to the ETA data obtained from the ships and emphasized that this projection will provide great benefits to the users in practice.

All the benefits in the form filled out by the experts were considered important by the experts and it was stated that each of them contributed to some of the maritime stakeholders, although their contribution levels were different. However, chartering experts paid particular attention to the benefits of "repositioning", "performance", and "jurisdiction", and stated that these benefits can create competitive advantage in practice.

When all expert opinions are evaluated together, the benefits that are considered to be the most beneficial are as follows:

- Route and trade pattern analysis
- Getting intelligence about competitors
- Arrival management
- Cargo tracking
- Facilitation of the jurisdiction
- Automated reasoning tools (Proactive efforts/Casualty alerting)
- Search and rescue (SAR) operations

5.2 Application Plan

It is planned to place an AIS receiver in the laboratory at the top of the tower at Istanbul Technical University Maritime Faculty in order to gain knowledge and experience in processing the data to be obtained with S-AIS technology. Thus, AIS data obtained from ships navigating around Izmit Bay will be analyzed and statistical

data will be provided for the studies to be used in areas where AIS benefits can be used.

When S-AIS data is obtained from Pirisat and KILICSAT projects, it will be possible to carry out numerical studies on this technology in our country. Therefore, it is planned to carry out further studies during the future doctoral study.

6. CONCLUSION

Comprehension of the benefits of big data is vital for both governmental and commercial parties. Satellite-based Automatic Identification System (S-AIS) can be defined as big data in terms of its data production and data content. The S-AIS technology has current and potential uses in the Intelligent Transport Systems. Since S-AIS technology can benefit many maritime stakeholders, various military institutions, commercial companies and research organizations are working on this issue. If the awareness of the importance of this issue in our country increases, it is possible to create added value by utilizing this technology.

The S-AIS technology provides a wide range of benefits, as mentioned in this study, by expanding the coverage of the AIS system and increasing the benefits achieved through AIS. Among these, Safety, Security, Environmental, Technical and Commercial benefits have been examined and it should not be forgotten that these potential benefits are not limited to the benefits listed in this study. As technology evolves, new uses of AIS and S-AIS technologies will emerge, the existing benefits will be improved, and these two systems will be more useful than they are today.

In this study, after giving basic information about AIS and S-AIS technologies, the multidimensionality of AIS and S-AIS benefits has been addressed and efforts have been made to pave the way for the stakeholders in our country to benefit from these technologies. The importance of digitalization and the phenomenon of big data began to be gradually understood in maritime industry so in this study, it is aimed to give information about what benefits can be achieved by means of S-AIS technology which is a big data resource. As the number of companies, institutions and organizations operating in this field increases, both competition and progress in this field will increase exponentially. Stakeholders in our country should benefit from this technology which has started to be comprehended in recent years and should not be left behind in this field.

Public and private stakeholders in Turkish maritime industry should make use of this system before it is too late. In our country, where AIS device production is available, in order to better understand this technology and make maximum use of it, this study has been tried to create an awareness on this subject. As a matter of fact, this study has achieved its objective before it is completed. With the "Pirisat" and "KILICSAT" Projects, Turkey has started to take steps to benefit from and experience this technology. By expanding such projects in terms of number and scope, it will be possible to produce solutions to the interests of the maritime stakeholders in our country and to ensure that maritime stakeholders in our country can benefit from this technology.

Another benefit of this study is to outline the topics that researchers may want to focus on, and to direct them to conduct more detailed research on these issues.

Turkey is located in the middle of important trade routes and geographically a critical position. Thus, it is vital for Turkey's interests to monitor more about maritime activities taking place in its waters, to increase the situational awareness and regain consciousness necessary to achieve them.

In order to increase our awareness and control power in the surrounding waters of our country, which is located in a region which has a particularly busy ship traffic, it is of great importance to establish our own S-AIS system. It will be useful to further explore the S-AIS technology whose importance is not yet fully understood in our country and many maritime stakeholders are not aware of its existence and to add the AIS receiver and antenna to our satellites that will be sent to space. Systems and technologies in S-AIS require serious expertise. Cooperation should be established in different fields of expertise on how to benefit from S-AIS technology.

Multidimensional feedbacks were obtained from the sector by asking the chartering experts, each representing different chartering parties, to see how much the stakeholders directly or indirectly involved in commercial transactions could benefit from this technology. All the benefits in the form filled out by the experts were considered important by the experts and it was stated that each of them contributed to some of the maritime stakeholders, although their contribution levels were different. However, chartering experts paid particular attention to the benefits of "repositioning", "performance", and "jurisdiction", and stated that these benefits can

make a direct difference in practice. On the other hand, the direct relation of the human lives with the safety and security benefits makes S-AIS technology is of vital importance.

Based on the literature and the ideas presented in this study, it is obvious that AIS and S-AIS Technologies have a vast application areas and benefits. Through this study, it has been tried to pioneer the studies about this technology. In particular, studies on the technical features of this technology will contribute to the inclusion of our country among the countries that benefit from this technology.

The AIS receiver, which is planned to be placed in the laboratory at the top of the tower at Istanbul Technical University Maritime Faculty, will create a university-controlled data source for the studies on AIS and S-AIS, thus enabling more studies on AIS and S-AIS easily and rapidly.

In the event some projects carried out in Turkey such as Pirisat and KILICSAT, it will be possible to carry out numerical studies about S-AIS in our country. With the increase of such studies, the maritime stakeholders in our country will be able to obtain maximum benefit from this technology.

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APPENDICES

APPENDIX A: Survey template used during interviews

PURPOSE: It is aimed to determine which companies operating in the field of Chartering can benefit from S-AIS applications.			
Company/Organization:			
Interview with:			
Date:			
Duration of Interview:			
After a brief introduction presentation about S-AIS system, the following interview items are discussed and appropriately filled:			
BENEFITS OF USING S-AIS FOR YOUR ORGANIZATION	**Is it beneficial for your operations / activities? (Yes, No, or N/A**	**Level of Benefit (1-5, 5: highly beneficial, or N/A)**	**Describe briefly how it may be beneficial in your company work, operations, or activities**
1) Route and trade pattern analysis			
2) Port throughput estimation			
3) Seasonality determination			
4) Shipping demand determination			
5) Market analysis and forecasting			
6) Repositioning			
7) Trade share by vessel size			
8) Utilisation rate			
9) Arrival management			
10) Cargo tracking			
11) Determination of statistical commercial facts			
12) Proactivity in commercial activities			
13) Enables more prudent chartering decisions			
14) Getting intelligence about competitors			
15) Facilitation of the jurisdiction			
16) Calculation of the real voyage distances			
17) Fighting against piracy			
18) Automated reasoning tools (Proactive efforts/Casualty alerting)			
19) Increasing vessel safety in hostile waters			
20) Search and rescue (SAR) operations			

Figure A.1 : Survey template used during interviews.

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