10-31-2021

An automated lifeboat, manifesting embarkation system (ALMES): the utilization of RFID/NFC in passenger manifestation during ship evacuation

Antonios Andreadakis

Tabor Sloane

WORLD MARITIME UNIVERSITY
Malmö, Sweden

AN AUTOMATED LIFEBOAT MANIFESTING EMBARKATION SYSTEM (ALMES): THE UTILIZATION OF RFID/NFC IN PASSENGER MANIFESTATION DURING SHIP EVACUATION

ANTONIOS ANDREADAKIS & TABOR SLOANE
Greece & United States of America

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the reward of the degree of

MASTER OF SCIENCE
in
MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2021

Declaration

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

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

(Signature): 

....

(Date): September 3, 2021

(Signature): 

....

(Date): September 3, 2021

Supervised by: **Dr. Dimitrios Dalaklis**

Supervisor's affiliation**: Associate Professor, MSEA Specialization**

Acknowledgements

As the finish line of this Master's Degree approaches, some verses of a poem of Constantine P. Cavafy come to my mind, that express my feelings and thoughts towards the end of this exciting journey:

Keep Ithaca always in your mind.
Arriving there is what you're destined for.
But don't hurry the journey at all.
Better if it lasts for years,
so you're old by the time you reach the island,
wealthy with all you've gained on the way,
not expecting Ithaca to make you rich.

Ithaca gave you the marvelous journey.
Without her you wouldn't have set out.
She has nothing left to give you now.

And if you find her poor, Ithaca won't have fooled you.
Wise as you will have become, so full of experience,
you'll have understood by then what these Ithacas mean.

-Ithaca, Constantine P. Cavafy

The biggest gratitude goes to my parents Athanasios Andreadakis & Vasiliki Skroumpelou for giving me the opportunity, the financial and ethical support for my MSc at WMU. Additionally, I would like to thank from the bottom of my heart my sister Eleni and my best friend Eirini that were both always available to give me their support and unconditional love whenever I needed it. I would also like to thank my friend and "big support mechanism" Maria Moschou for guiding me through difficult moments and providing me always with thoughtful and useful advice. Furthermore, I would like to express my gratitude and appreciation to my sincere friend and dissertation partner Tabor Sloane, who has been great and very helpful throughout this whole challenging learning process.

A great, special and honest thank you to our supervisor Professor Dimitrios Dalaklis for providing us with many useful advices and opportunities along the way of completion of this dissertation; for restlessly helping us with every challenge and obstacle we faced in the way and for the encouragement to take our work one step further. Moreover, I want to thank all my Professors and all the WMU faculty members for all their help and support. Also, I would like to express my extreme thankfulness to my incredible friend Laura Noelia Sanchez for her kindness and precious support, that without her my life in Sweden would not have been the same. Last but not least I would like to thank my friends Adriana Quesada and Paschalia Divari for always been available for me and supporting through difficult moments.
-Antonios Andreadakis

Acknowledgements

First, I would like to thank our supervisor Dr. Dimitrios Dalaklis for his help and guidance in addition with helping facilitate the publications we were able to provide simultaneously with this dissertation.

In addition, I would like to thank my parents, Debra and Jonathan Sloane for their support and well wishes throughout this challenging process. Furthermore, I would like to give my gratitude to my dissertation partner and friend Antonios Andreadakis, for working so thoroughly through the many difficult times that we faced together. Moreover, would like to express my gratitude towards Katarina Veličković, for her incredible support and useful advice throughout my studies. Thank you to all the captains and crew I have sailed with previously, allowing me to realize my potential outside working onboard sailing vessels.

We must free ourselves from the hope that the sea will ever rest. We must learn to sail in high winds.

-Aristotle Onassis

Finally, I would like to thank the American Bureau of Shipping for their research grant which they provided, facilitating the growth of ALMES. I also cannot forget the lifelong friendships that have been made along the way during my time at WMU, and the encouragements which came with them.

-Tabor Forrester Sloane

Abstract

An Automated Lifeboat Manifesting Embarkation System (ALMES)*: Optimising Evacuation and Passenger Manifestation Via RFID/NFC
Degree: **MSc in Maritime Affairs**

The influence of the International Convention for the Safety of Life at Sea (SOLAS) and its related regulatory intervention becoming indispensable in improving the level of safety at sea since its introduction. Nevertheless, the manifestation of passengers during abandonment procedures are still following the anachronistic methods of the early 1900s. Prompting the conception of the Automated Lifeboat Manifestation Embarkation System (ALMES) approach in vessel evacuation. Exploring the hypothetical implementation of Radio Frequency Identification (RFID) and Near Field Communication (NFC) sensors, irremovable bracelets, and the removal of traditional muster stations to facilitate passenger and crew during vessel abandonment. ALMES further employs the concept of the automated satellite transmission of manifestation results, upon Life Saving Appliance (LSA) launch, to the closest Maritime Rescue Coordination Centers (MRCC). Through their installation onboard lifeboats, life-slides, and disembarkation points, it is hypothesized that better coordination and a faster response times can be achieved. Through technological intervention during lifeboat embarkation ALMES may potentially reduce human error and ineptitude, in relation to fear, panic, and confusion, enhancing crowd management procedures during abandonment. Developed through the examination of previous maritime incidents and disasters and the quantitative analysis of human response trends, current voids, and probable solutions to the realized issues involved in passenger vessel abandonment. With the creation of ALMES and its utilization throughout the cruise and passenger vessel industry, ALMES will allow for the streamlining, the elevation of safety levels, and passenger localization during lifeboat embarkation.

KEYWORDS: SOLAS (Safety of Life at Sea), LSA (Life Saving Appliance), RFID (Radio Frequency Identification Device), NFC (Near Field Communications), Tags, Readers, ALMES (Automated Lifeboat Embarkation System), Lifeboat, Evacuation, Abandon

Table of Contents

List of Figures

List of Abbreviations

AIS - Automatic Identification System
ALMES - Automatic Lifeboat Manifestation Embarkation System
ARPA - Advanced Research Projects Agency
DOS - Denial of Service
DoD - Department of Defense
ECDIS - Electronic Chart Display and Information System
EPIRB - Emergency Position Indicating Radio Beacons
GALILEO - European GSNS
GCFD - Gross Cost of Averting a Fatality
GLONASS - Globalnaya Navigazionnaya Sputnikovaya Sistema
GSNS - Global Satellite Navigation System
GMDSS - Global Maritime Distress and Safety System
GPS - Global Positioning System
HEP - Human Error Probability
HEPI - Human Error Probability Index
HF - High Frequency
IC - Integrated Circuit
IFF - Identify- Friend of Foe
IMO - International Maritime Organization
IMSO - International Mobile Satellite Organization
INEA - Innovation and Networks Executive Agency
IOT- Internet of Things
IR - Infrared
ISO - International Standards Organization
ISPS - International Ship and Port Facility Security Code
JAIC - Joint Accident Investigation Committee
LEO - Low-Earth Orbit
LF - Low Frequency
LRIT - Long-Range Identification and Tracking
LSA - Life Saving Appliance
MHz - Megahertz
MF - Medium Frequency
MRCC - Maritime Rescue Coordination Center
MS - Mail Ship
MSC - Maritime Safety Committee
MV - Motor Vessel
NCFD - Net Cost of Averting a Fatality
NFC - Near Field Communications
OCI - Ocean Container Industry
OLF - Norweigen Oil and Gas Association
OOW - Officer On Watch
OPTS - Onboard Personnel Tracking System

PIN - Personal Identification Number
RAM - Random Access Memory
RCI - Royal Caribbean International
RF - Radio Frequency
RFID - Radio Frequency Identification Device
RMM - Risk Mitigation Measure
RMS - Royal Mail Ship
ROM - Read-only Memory
SART - Search and Rescue Transponder
SLIM - Success Likelihood Index Model
SOLAS - Safety of Life at Sea
SSAS - Ship Security Alert System
UHF - Ultra-High Frequency
VDR - Voyage Data Recorder
VHF - Very High Frequency
VMS - Vessel Management System

Chapter 1: Introduction

Chapter 1.1: **Background**

Over the course of time, numerous accidents at sea have resulted in an abandon-ship situation. The impact of a certain number of them was quite influential (Kobylinski, 1997), such as the Titanic disaster that has paved the way for the introduction of the SOLAS convention (Dalaklis, 2017) and the MS Estonia in 1994 that highlighted the need for more effective life-raft designs and improvements of relevant regulations (LSA Code), as well as adjustments to the associated training requirements under SOLAS. Of particular interest is also the case of Costa Concordia. Even though that specific vessel was adequately outfitted with all the equipment and systems prescribed in the LSA Code, it is clear that lessons in relation to an abandon-ship situation have yet to be learned and effectively implemented (with gaps in “soft skills” like leadership clearly standing out), despite the technological progress recorded in recent years (Wang et al., 2020). Accidents and associated lessons learned, such as those mentioned above, have changed the perception of safety on-board vessels and have contributed to great progress within the field (Joseph & Dalaklis, 2021).

Technology applications supporting the shipping industry are numerous; probably, the most significant progress has been made in the field of systems supporting the contact of navigation. In a modern bridge, there are various systems assisting the navigator, such as ARPA Radars (which have the ability to detect accurately and automatically plot targets), satellite-based navigation systems like GPS, GLONASS and GALILEO, various communication means, and more importantly: the ECDIS that is working in unison with the AIS and allows for an improved situational awareness and an optimized understanding of what exactly is happening around the vessel at sea (Pallikaris et al., 2016). Thus increasing safety and vigilance levels amongst vessels and their operators.

In the realm of Life Saving Appliances research has contributed to many advancements, such as self-deploying life-rafts, EPIRBs, and SARTs (IMO 2018). These devices and systems have truly advanced the level of safety at sea. Nevertheless, even though there has been immense growth and breakthroughs in technology applications, especially those related to the LSA field, procedures around evacuation of vessels have not progressed at a similar pace. It is true that lifeboats have significantly improved in terms of construction standards, propulsion systems, communications, and self-launching systems. Additionally, great effort has been placed in order to develop the davit based launching proponents that are effectively being used in all types of vessels (e.g. Gravity Davits, Fixed Davits, Miranda Davits, Free Fall Davits), with the aim to reduce the time of the lifeboats launching and make the procedure of evacuation safer; unfortunately, the methods of evacuation have not followed the same path of improvement. Today, in most passenger and cruise vessels in case of an evacuation, passengers are being manifested verbally before they embark on a lifeboat, something that makes the evacuation procedure extremely time-consuming and arduous.

Chapter 1.2: **Problem Statement**

As aforementioned, the maritime industry over the course of time has shown great interest and has put considerable effort into developing and advancing systems that are improving the quality and safety of everyday navigation. However, analogous focus has not been put on developing further the procedures and evacuation methods which are followed on vessels carrying large numbers of people in case of an abandon-ship situation, as displayed through the vessel evacuations of the *Costa Concordia* and *Viking Sky* and the sheer amount of time and unaccountability involved throughout. The problem which is visible on cruise/ passenger vessels, carrying thousands of individuals that during the unfortunate event of the abandonment are almost impossible to be handled safely and effectively, fulfilling the requirements of SOLAS. It is very important to highlight that during these life-threatening moments onboard vessels of a considerable size, people trained or not, cannot act or think completely rationally; complicating even further the mustering and lifeboat-embarkation processes. That was clearly evident during the disaster of *Costa Concordia* in 2012, where the evacuation lasted more than six hours causing the loss of life to 32 people (Giustiniano et al, 2016). It is alarming that antiquated evacuation procedures are still being followed to this day in such large scale vessels, while huge technological steps have been made that could potentially upgrade the abandonment operation, thus saving more lives. The problem is obvious and requires an imminent solution.

Chapter 1.3: **Research Objectives**

Due to the fact that cruise and passenger vessels are designed to transport large numbers of individuals from point A to B, the majority of these passengers are unaware of and untrained for the current evacuation procedural outline. This irrevocably promotes an environment of panicked reactions, miscommunications, which are inevitable. As per SOLAS requirements, the time from the order of evacuation until the boat is in the water is thirty (30) minutes for passenger/cruise vessels (IMO Annex 6.2.2.2), something that is only achievable in ideal conditions and situations, as was evident during the rather recent evacuation of M/V Viking Sky (Schroder-Hinrichset al., 2012). Unfortunately, in reality such figures are unobtainable during a disembarkation procedure; panic, self-preservation instinct, fear, and insecurities take control over both crew and passengers, making the evacuation procedure more protracted in time (Vassalos et al., 2002). As is evident from the historical accounts of maritime casualties, the fatalities in most of the cases (with Scandinavian Star and Costa Concordia specifically) can be attributed largely to human error and poor decision-making before, or after the accident and not to the accident itself (Akyuz & Celik, 2014).

In efforts to hasten evacuation times, the impact of the human element and the issues encompassed within must be removed from the equation. To effectively deal with these complications, the proposed solution could be an automation of passenger manifestation during lifeboat embarkation. The proposed method of achieving a more efficient evacuation process involves the utilization of RFID/ NFC technology currently implemented within the cruise industry (Ortega-Piris et al., 2020). RFID systems consist of a reader with an antenna, and a transponder (tag). There are two different RFID tags available (active and passive). The active has its own power supply, while the passive does not have a power source and has to be supplied with energy given by an electromagnetic field produced by the reader.

Passive transponders or tags are available in three different RFID frequency ranges: LF, HF and UHF. The reading range of LF and HF systems is usually only a few centimeters. UHF tags, however, are often readable over distances of more than one meter. NFC is also based on the RFID protocols. The main difference to RFID is that a NFC device can act not only as a reader, but also as a tag (card emulation mode). In peer-to-peer mode, it is also possible to transfer information between two NFC devices. NFC systems operate on the same frequency as HF RFID (13.56 MHz) systems. Therefore, there are only short read range limitations.

Recently, cruise lines have been adopting the use of the aforementioned technologies through on-board transactions, as well as an access method to several spaces within the vessel. This newly introduced piece of technology contains the personal information of individual passengers on a multitude of vessels; most recently Royal Caribbean has implemented a network which enables the tracking of the passengers throughout the vessel by means of a system of RFID transponders (Oasis of the Seas - Royal Caribbean) (Schroder-Hinrichs et al., 2012).

Chapter 1.4: **Research Questions**

The research questions examined throughout this dissertation are:

1. What are the current evacuation procedures followed on cruise and passenger vessels and what are the deficiencies during this process?
2. How will the implementation of modern technologies improve passenger and crew manifestation, MRCC response, and reduce evacuation times?
3. Why do the technological characteristics involved in the ALMES approach solve these issues and how shall it be developed?

While these research questions cover a vast amount of information, the answers provided are purely theoretical, due to the lack of sufficient funding required for the development and creation of a working prototype.

Chapter 1.5: **Methodology and Research Justification**

Development for this research dissertation was conducted primarily through the utilization of the qualitative method. The qualitative analysis mainly focuses on the current absence, throughout the market and in extension the safety industry spectrum, of a method capable of speeding up the evacuation procedure, manifesting effectively, and efficiently the passengers and crew of a cruise/ passenger vessel and transmitting the manifestation catalog without any delay to the responsible MRCC. Furthermore, extensive research was conducted on previous accidents and disasters within the maritime industry resulting in mass loss of human life, in order to identify the main human errors and causes that contributed to delayed actions on behalf of the crew that ended in casualties. Additionally, a comparative analysis between the current methods of evacuation is given, in order to demonstrate the current practices followed in the maritime sector in a more comprehensive and understandable way to the readers. By comparing these methods, this dissertation identifies the items and procedures that can be improved during the abandonment process and offers potential solutions to the issues examined, that include modern technological applications emphasizing renewed passenger and crew management theories resulting in more accurate practices and accountability during ship evacuation. As the idea of this dissertation was established before joining this MSc program, discussions with professionals in the area of the cruise industry were made prior to the commencement of our studies, in order to gain a better understanding of the currently followed evacuation practices and to gain an insight perspective on the areas that can be improved.

Moreover, a comprehensive research and analysis of the technological systems implemented for the creation of ALMES, such as RFID, NFC technology and the

Iridium system, is presented for providing a better understanding to the operation and capabilities of the chosen technological solutions. Furthermore, certain facets of sociological and psychological research were examined regarding human response and reaction in the realm of the human element, during moments of severe panic and pressure due to external factors, in order to isolate the human factor and to comprehensively understand its reactions when unprecedented, unexpected and stressful conditions are faced; and also to create a pattern where ALMES can reduce as much as possible the complications caused by the human element.

Chapter 1.6: **Scope of Research**

This study aims to facilitate the creation of a passenger and crew manifestation system based on RFID/ NFC technologies, that during the last years have been widely expanded on cruise vessels as payment methods or cabin access keys. Also, this MSc dissertation targets to locate the reactions and responses of humans when faced with life-threatening situations and how the proposed system approach can contribute to limiting chaos, speeding up the mustering and life-boat embarkation procedures, and upgrading the safety of people onboard cruise/ passenger vessels. Finally, this research will examine the possibility of a prototype creation feasibility.

Chapter 1.7: **Limitations**

- Development budget: As this is a very fresh idea and approach towards the people manifestation onboard vessels, and as it is still under development, it might be challenging to find potential investors or funding willing to support the proposed approach.
- Device deployment: The creation of a device that conforms with all SOLAS regulations and is ready to be retrofitted on all the existing lifeboat types, can be considered one of the biggest challenges of this research.

- Personnel Training: Training the existing crew on a system that has not been previously used might be a time consuming procedure, involving unanticipated questions and feedback from the users.
- Adoption by Cruise/ Passenger Lines and MRCCs: In order for the proposed approach to be effective the introduction of it shall be made by both parts of the equation; which is something that could take years.
- Software Development: IT specialists involved in the maritime sector, shall also be involved, in order for a software able to handle large masses of people to be developed and tested thoroughly, which is a costly and time-consuming process.
- Hardware Procurement: Specific rigid electronic equipment shall be used that can endure rough weather and environmental conditions and at the same time is cost-efficient, and safety approved.

Chapter 1.8: **Dissertation Structure**

The following dissertation is divided into six main chapters. The preliminary explanatory background information, objectives, methodology and research justification are introduced in the first chapter. The second chapter provides a comprehensive literature review around the problems, risks, dangers and issues involved during the current evacuation procedures, as well as with a presentation of severe maritime disasters and technologies used currently by the cruise industry. Chapter three provides a clear insight of the RFID, NFC and Iridium satellite technology and its evolution through the years and also refers to the selection of the technology implemented in ALMES and the reasons behind it. Chapter four describes the application and retrofitting of ALMES in the lifeboats and how it can be utilized in all types of lifeboats, life rafts and life slides. Chapter five presents the cost-analysis of the project and a price estimation of the required components. Chapter six provides the summary, conclusion and recommendations for the effective application of the ALMES and future developments.

Chapter 1.9: **Expected Results**

- To ensure efficiency, safety, accurate record keeping of passenger location during the disembarkation process in an evacuation scenario.
- ALMES will allow for the accurate transmission of data to MRCCs in regards to missing passengers and crew in an accelerated time frame.
- To reinforce the sense of safety and welfare of crew and passengers.
- To reduce the required embarkation time on lifeboats.
- With the current use of RFID and NFC technology within the Cruise Industry, ALMES will allow for a cost effective addition to current and future ships in the realm of life saving apparatus on board.

Chapter 2: Literature Review

The scope of the following literature review is to track the mustering and lifeboat-embarkation methods in use, examine the deficiencies currently experienced during the existing evacuation procedures and to track the causes behind them. Furthermore, extensive research will be made on the human error factor and the behavioral patterns that are present in passenger and crew during abandonment; and their influence on the outcome. Moreover, maritime disasters that brought changes to procedures followed in the shipping industry will be reviewed, as well as the RFID/ NFC technology which is presently implemented on cruise/ passenger vessels.

Chapter 2.1: **Lack of Proper Passenger Management and Human Error**

As the regulations of the IMO dictate, all seafarers and especially the Officers joining a vessel must have undergone multiple training courses, seminars and personnel management programs in order to ensure safe, efficient, and smooth coordination of crew and passengers during emergency events. While the STCW prescribes the background training in order to obtain certificates and licenses mandatory for the employment onboard commercial vessels, drill conduct and management varies widely between vessels. Whereas the IMO imposes guidelines on drill frequency, there are few requirements on the standardization of these drills except for SOLAS Reg. III/19.3, along with provisions from SOLAS II-1/24 and II-2/15, entail monthly frequency, personnel professional conduct, and safety. While these drills emphasize crew, ship, and passenger safety, they rarely account for the mental stress that are involved within ship abandonment and especially the reaction of passengers during the event. Additionally, in most cases of maritime casualties those trained and well-experienced individuals have been unable to cope with the panic, emotionally, and mentally challenging conditions resulting in the loss of multiple human lives.

The tragic event of *"Costa Concordia"* can be considered as one of the most recent and prominent examples of human error and inability of crew to display leadership in an abandoned ship situation that led to the loss of 32 lives, sentencing not only the Master but also several crew members to prison (Tikkanen, 2021). In data presented by researchers (Lee et al., 2003), it is apparent that unlike the mustering process, human organization is far less regulated in the embarkation process, due to panic and uncertainty on behalf of the passengers. A further example of human error on behalf of the passengers and crew can be seen in the 1995 abandoning ship of the *St. Malo*. Which took one hour and eight minutes in fair weather and sea conditions, while under drill circumstances the crew was recorded at eight minutes. Onboard the *St. Malo,* which struck a rock off the Jersey coast carrying a mere 300 passengers, individuals describe the sheer level of confusion, lack of guidance and advice in relation to the evacuation process, describing that many crew members were issuing conflicting orders (Lee et al., 2003).

Additionally, the sinking of the RoPax Ferry *MV Estonia* which occurred on the early morning of 28th of September 1994, after leaving Tallin, Estonia in route for Stockholm, Sweden. While the conditions where rough, were not out of the ordinary for the Baltic during that time of the year. After hearing a loud series of bangs, the ship began to take on uncontrollable volume of water. This was due to official reports by the JIAC stating that the bow locks failed on the visor style bow, resulting in an opening while underway, sinking the vessel in less than an hour at 0150. This disaster resulted in the fatalities of 852 passengers and crew, with only 137 surviving individuals (Kehren, 2009).

While the investigation and disaster triggered changes within SOLAS regarding life raft launching from listing vessels in rough weather and the legislation lobbying for the implementation of VDR systems. It importantly brought the extension of STCW training onboard all passenger vessels in the realm of human behavior and crisis management, in efforts to mitigate the unavoidable panic during such an event. This crisis response amongst both passengers and crew can be seen as one of the major contributing factors to such a high death toll onboard vessels. A vessel evacuation can be categorically distinguished into a series of human response, being initial situational interpretation, adoption of abandonment protocol, and the actual ship abandonment, all of which requiring controlled behavior within the human element (Cornwell et al., 2001).

Understandably, if panic and hysteria were to occur during a ship evacuation, without the maintenance of social order by properly trained crew members, a breakdown in in situational control is inevitable. In efforts to counteract such a breakdown, the concept of “simpler is better” should be applied, to reduce confusion and mental strain upon both passengers and crew, with less steps a higher survival rate can be expected. Especially applicable onboard the *MV Estonia*, due to the sheer temporal strain applied upon the passengers, with the general alarm not being sounded until thirty minutes before the vessel disappeared completely below the surface (Kehren, 2009). In the approach presented by ALMES, the removal of muster stations is seen as an appropriate response to such a dilemma, with passengers proceeding directly to the lifeboat embarkation stations, with an automated passenger count occurring during the lifeboat embarkation process. This change in evacuation protocol can first of all reduce evacuation times, but additionally relieve panic due to system simplicity and increase passenger localization, due to its interconnected nature. Lastly, with the removal of muster stations, we could see a decrease of congestion within the interior of a vessel, therefor further removing the negative aspects associated with the human element during an emergency.

A multitude of human error assessments have been conducted in the realm of ship abandonment and evacuation, these studies have ascertained that HEP is one of the leading causes in ineffective lifeboat embarkation. HEP can be described as an individual's inability to properly perform a certain task due to external pressures or their respective failures. Human error can be seen as responsible for the majority of accidents occurring offshore and underway, researchers (Kahn et al., 2005) maintain that offshore operations are particularly vulnerable to these human error influences. Asserting that the application of the HEPI which was refined from the SLIM can be used to mitigate the outcome of these mismanagements through changes in safety systems, training, and procedure, “resulting in a more error tolerant design and operation” (Kahn et al., 2005). Their study indicates human error increases during the mustering and egress process and that with the higher complexity of a mustering procedure the likelihood for error to develop increases immensely. Through these studies it has become evident that the implementation of RFID and NFC assisted embarkation and egress would be classified as RMMs, which are produced through the application of HEPI. These RMMs which are culminating in changes to current safety systems, management, and equipment. These facilitate the development of an enhanced and further efficient mustering and embarkation process, in efforts to alleviate the problems including confusion, panic, and inability of action during an evacuation.

Additionally, passenger data tracking systems as demonstrated by experts (Ortega et al., 2020) indicate a “substantial reduction in the number of incidents that pose a security risk, as well as a more efficient management of resources”, through the implementation of RMMs and RFID systems tracking passengers and crew throughout the vessel. These findings can be further substantiated by researchers (Galea et al., 2013; Wang et al., 2020) with their experimental validation and predicted passenger behavior models, which record the evacuation routes, choices, and demeanor of passengers while being monitored through an IR field. Based on their model they support that during an evacuation event many passengers due to frustration, panic, and inefficient knowledge of the vessel might feel disoriented and unable to find the exit to muster stations. The crew viewing on a closed circuit RFID/NFC system could effectively detect the exact position of individuals throughout the spaces of the vessel and guide them to their Muster Stations, knowing also their personal data being age and pre-existing conditions. These studies have undoubtedly indicated that these RMMs being proper passenger management, factor/step reduction, and system advancement through the potential application of RFID assisted mustering/ lifeboat embarkation can reduce the current issues associated with human error during an emergency situation.

Chapter 2.2: **Embarkation Efficiency and Issues**

As mentioned previously above RFID technologies have been successfully deployed onboard vessels, displaying their ability to track the location of passengers and crew onboard and provide essential information to the master on the bridge. Furthermore, these technologies have been emplaced on cruise ships and passenger vessels in efforts to ease passenger movement and onboard transactions. Ship architect Alexey Parnyakov discusses these applications and how they are being implemented to raise the levels of comfort experienced by passengers (Parnyakov, 2015). Currently, Royal Caribbean International, is one of the most innovative and technologically unique lines within the industry. Onboard many of their vessels RCI has been employing RFID interfacing, from the mundane utilizations including onboard purchasing and cabin access, to two more contemporary projects. First being, the tracking of family members within the vessel, in efforts to calm parental related stresses and secondly, being passengers' abilities to track the movement of their baggage from its embarkation in port to its arrival at their cabins, and vice versa upon their return to port. Displaying how the applications of RFID throughout vessels can be deployed in a numerous number of applications. Nevertheless, until the proposition of the ALMES approach an automatic electronic system with the ability to manifest the passengers and crew while boarding the lifeboats has not been developed.

Presently, a few cruise lines have implemented an electronic manifestation system that counts passengers by scanning their cabin cards containing their information while assembled at muster stations before boarding the lifeboats. This is performed by designated crew members holding portable scanners going through every passenger at the Muster Station (Andreadakis & Sloane, 2020). This process is commonly executed through the use of the ResCO Front Desk Software by means of their emergency control center’s application eSouls. Assistant Cruise Director Pauline Steudten described that, although this technology has accelerated and eased facets of the lifeboat embarkation process, it has not minimized considerably the frustration and confusion taking place during those moments as there are still large concentrations of people in one place, thus causing unwanted confusion and panic in both crew members and passengers (Sloane & Andreadakis, 2020). This would be due to a number of factors, firstly the electronic devices used during the muster roll call are stored within the bridge, causing for lifeboat/ muster station commanders to go far out of their way to retrieve them before proceeding to the muster points.

Secondly, would be the panic and confusion that occurs during an evacuation in even the most idyllic of situations, many times passengers and crew have failed to conduct a successful muster process during an emergency. Thirdly, during evacuation proceedings on many occasions passenger and crew are unable to make it to their prescribed muster stations, either due to age (lack of mobility), egress passages being obstructed, and lack of situational awareness and disorientation. Finally, is the passenger transit from the assigned muster stations to the lifeboat embarkation zones, during which many passengers have found themselves lost or separated from their muster groups due to crowding, panic, extreme apprehension, and turbulence causing for the accounted passenger to once again be unaccounted for. These obstacles involved within the mustering and embarkation process have resulted in a myriad of complications, which can result in the loss of numerous lives during ship abandonment.

Chapter 2.3: **Risks and Time Involved in Ship Abandonment**

It is commonly known throughout the maritime industry that during an emergency the boarding of the lifeboat is the last course of action, with the ship being the safest place to remain, offering the highest probability of survival. Though this is not always possible, seafarers must proceed with the next best option being ship evacuation, nevertheless this process also entails its own inherent risks. These risks can be brought on through a multitude of external influences, from severe weather conditions including high winds and rough seas, to developing vessel list, fire blocking egress, and additional emergency conditions onboard. Furthermore, human factors contribute markedly to the implicit risk involved, lifeboat operations experts assert that an individual's ability relies heavily on the resources available to them during a critical situation (Ross, 2006). Describing that in an emergency situation persons find themselves in a deep-seated state of crisis, resulting in their problem solving abilities being diminished due to these extremities.

As prescribed in SOLAS Chapter III Regulation 21.1.4 instructs that all survival crafts including lifeboats, life rafts, and life slides shall be capable of being launched within thirty minutes after the orders are put forth by the master. Nevertheless, IMO regulation specifies that this thirty-minute period only begins after the muster proceedings have been completed and life jackets have been donned. Furthermore, the time between the muster signal, the completion of this process, and the migration to the lifeboat boarding stations can be immense. As aforementioned, during this period a numerous factors can transpire, leading to the loss of passengers and crew. The recommended maximum time for a full passenger ship evacuation is to be sixty to eighty minutes as stipulated in the IMO's *Guidelines for a Simplified Analysis for New and Existing Passenger Ships* published in MSC Circ 1033 and 1238; recommending that vessels with three or less vertical zones to be fully evacuated in sixty minutes and three or more to be fully evacuated within eighty minutes. Though it is understandable that these recommendations by the IMO are difficult to obtain and are unenforceable, leaving it up to the governments and industries to enforce.

It has been asserted by researchers that complete passenger evacuation time can be split into four categories:

1. Awareness time; stated to be five to ten minutes, being the amount of time expended from the alerting of an emergency, to the times it takes for passengers and crew to fully apprehend the situation and begin movement towards the muster locations.
2. Travel Time; stated to be the time elapsed from the initial alerting of an emergency to the assembly at the muster station, then including the final travel time to the lifeboat stations.
3. Embarkation Time; stated to be the time it takes for passengers and crew to board the lifeboat or life raft.

4. Launch Time; stated to be the time for the lifeboat to disembark the abandoned vessel and make their way to water level (Kim et al, 2003).

This current evacuation process displayed within Figure (1), demonstrates it to be an intense and laborious multistep process, involving many instances for which error can occur. Allowing for delayed emergency response and evacuation times, with the additional possibility for the loss on passengers throughout the procedure.

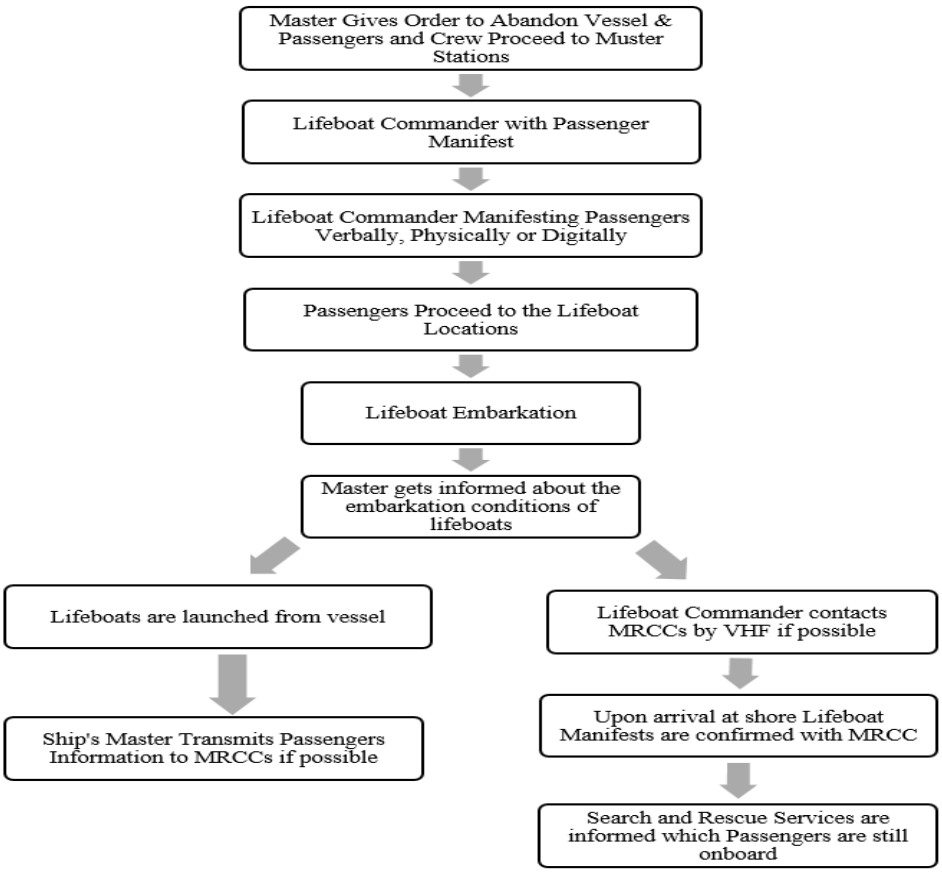

Figure (1). Evacuation and Manifesting Under Traditional Methods (Created by Authors)

As defined by the IMO above, the total of these times are recommended to be no more than sixty to eighty minutes, which can be found highly difficult to execute due to external delays during the travel time and the embarkation times. These delays can be brought about through the time it takes to travel up and down stairs and through corridors. Especially depending greatly upon the amount of individuals and conditions within those environments, all affecting the walking speed of the passengers and crew.

Additionally, injuries during the abandonment process have also found themselves prevalent onboard lifeboats. These injuries and deaths suffered during lifeboat operation and evacuation are not solely limited to emergency situations. Though the intention of lifeboats is to save lives, it is all too common for passengers and crew to be severely injured during drilling, periodic maintenance yearly, and embarkation/ disembarkation. With a further efficient and less panicked and complicated abandonment process brought upon by the implementation of ALMES, a reduction in embarkation/ disembarkation injuries could be possible.

Chapter 2.4: **Ship Evacuations Models**

Throughout the years, accidents occurring on passenger and cruise vessels have taken the lives of passengers and personnel. Although, many of the fatalities can be attributed to the nature of the accident, being the speed of the vessel's sinking (MV Doña Paz, St Thomas Aquinas), the weather conditions and the various aspects of the human error. There are some unbalanced factors, such as the time between the order of the evacuation till the final lifeboat launching (known as response time), in conjunction with the unpredicted human behavior and the moving conditions of the vessels, can seriously affect the outcome of a safe evacuation and costing the lives of numerous people.

Taking that into consideration, MSC of IMO, at its 71st session on May 1999, noted that under SOLAS regulation II-2/28-1.3, Ro-Ro passenger ships constructed on or after 1 July 1999 are required to undergo an evacuation analysis at an early stage of design. Until that time there was insufficient or no information relating to passenger response times in maritime environments. Much of the presented data inside the maritime industry was derived from land based building measurements and as it could be understood there is a considerable number of operational differences for passenger ship evacuations. The committee recognized that there was a need for data and information to help further validate and develop the conditions during an evacuation. The purpose of those guidelines would be to create a useful analysis that would identify, indicate, and decrease the congestion during the response time of the evacuation, in order to create a safer environment for the passengers and crew.

Additionally, it was found that the construction and the structural complexity of a vessel also played an important role in the realms of the evacuation times as it can generate problems with the movement of people. It was observed that the more stairs and doorways existing, the more congestion, confusion exist. Taking this into consideration as well as the complexity, unpredictability and versatility of human behavior under immense pressure. Professionals from the maritime community target to create safer and more efficient ways of abandonment in efforts start constructing and implementing advanced evacuation models.

Evacuation models have been implemented throughout the safety industry in efforts for marine architects to design safer and more evacuation efficient vessels. In 2009, the European Union developed Project FP7 SAFEGUARD, currently a closed project concluded in 2012, who's directive was to collect full scale human performance data during ship evacuation. This evacuation dataset was collected through a series of five trials of 2500 passengers and 842 crew. Conducted onboard three different types of passenger vessel including a Royal Caribbean International ship, in a semi-unannounced trial; while passengers knew the exercise would be conducted, they were uninformed of the time. This data was collected through the employment of IR sensors located on each individual and IR beacons throughout the vessel. In efforts to collect passenger movement data, video cameras were also installed to ensure the accuracy of the sensors. Datasets from the cruise ship trials consisted of passenger starting locations, response time, end locations, and the time of arrival at the prescribed muster stations. As a result, an acceptance criteria and a validation protocol were applied to the resulting data, which displayed the variations between the predicted and the experimental results. Finally, these results were applied to the ship evacuation software Maritime Exodus, allowing for it to successfully predict the outcome of future datasets. These results have allowed for the IMO to utilize and adopt the prediction results in future vessel design, ship evacuation enhancements, and developments, in the prospect to use computer simulation to predict the application of new safety devices onboard passenger vessels (Galea et al, 2014).

Chapter 2.5: **Relevant Incidents and Accidents**

In the past century the maritime industry has been witness to a multitude of incidents and disasters that have resulted in the loss of human life and property. Though in particular five incidents and accidents began in the realm of human error and lifeboat embarkation mismanagement. On the 15th of April, the "*RMS Titanic"* sank in the waters of Nova Scotia, as a result of poor passenger safety and management 1,514 souls making up sixty-eight percent of human lives onboard were lost that day, leading to the introduction of SOLAS in 1914.

Secondly, we have seen similar circumstances in conduct onboard during evacuation events, in 1990 "*MS Scandinavian Star"* incident. Which caught fire killing one hundred and fifty-nine people, due to the inability of the crew to cope and conduct themselves and their passengers during the crisis (Kristiansen, 2013). While these disasters seem to be a relic of the past, they are still occurring today. More recently, we have witnessed two events while on opposite ends of the spectrum both exhibit quintessential examples of crew and passenger panic, as well as improper passenger manifestation and embarkation of lifeboats and the abandonment of ships. In 2012, the world bore witness to the grounding and capsizing of the "*Costa Concordia"* off of Isola del Giglio, which resulted in the deaths of thirty-two individuals. Many of these deaths can be attributed to the incompetence of proper leadership onboard the vessel, leaving passengers trapped and stranded without guidance from crew members. This failure on behalf of the crew can be traced back to inadequate passenger management and lack of professionalism, making the embarkation of lifeboats extremely time consuming (Stefanidis et al., 2019).

Not all accidents in regards to poor lifeboat embarkation management involve solely cruise vessels, in 2010 the drilling rig "*Deepwater Horizons"* caught fire and sank in the Gulf of Mexico, resulting in the deaths of 11 individuals. Many professionals attribute some of the fatalities to "the late activation of a general alarm, personnel's ability to act being compromised by the hazards, incompetent management of lifeboats and life rafts, lack of command and control, as well as communication problems", leading to changes within MODU. It was later surmised that many of the crew members were unable to perform headcounts or register individual names aboard lifeboats due the extreme and intense conditions that they were subject to (Norazahar et al., 2014). It can be easily inferred that if ALMES was installed onboard the lifeboats, that the issue involving crew numbering would have been easily accounted for leading to a more rapid, efficient, and less complex abandonment of the rig and previous vessels mentioned.

Chapter 2.6: **Survivor Statements During Ship Evacuation**

Chapter 2.6.1: **Costa Concordia**

After the grounding the and eventual capsize of the Costa Concordia on the 13th of January 2012, which resulted in the deaths of 32 of the 3229 passengers and 1023 crew onboard. In post-incident statements taken after the event, cognitive specialists identified numerous behaviors that may have likely contributed to the deaths of said individuals. These behaviors included, competitive behavior, insecurity and hesitation, freezing (cognitive paralysis), and confusion; which are seen to be a result of the stress induced panic and misunderstanding that are brought on as a result of the accident (Kvamme, 2017). In additional statements taken, multiple operational and abandonment procedural errors were identified resulting in further delay and confusion. As discussed by Victor Kvamme, these include:

a) The absence of communication between passengers and crew due to multiple barriers, which comprised of contradicting orders and language obstacles, leading to further misunderstanding between personnel and passengers. Passenger Nancy Cacopardo stated, “The crew were all Asian and it was very hard to communicate with them. They were trying to help us and working hard to get us off, but there was so much confusion.”

b) The lack of safety briefings for 696 passengers due to the safety procedures and drilling being scheduled for the following day. Passenger Monique Maurek stated, “There was a panic and my husband pushed me into a lifeboat to make sure I got on. Other people fell on top of me and I was screaming. People were falling out of the lifeboat in front of us down into the water.”

c) The lack of appropriate training measures amongst a multitude of crew members, leading to lack of confidence amongst passengers. Passenger Fernando Tofanelli stated, “Some of the crew didn’t seem to even know how to release the lifeboats or even start the lifeboat engines once they were down on the water. The crewman in charge of our lifeboat was absolutely ashen-faced, he just didn’t know what to do.”

d) The postponement of mustering and lifeboat embarkation leading to the loss of time and the extending and loss of an effective ship abandonment. Passenger Fernando Tofanelli stated, “The crew left it until the very last moment to begin boarding people onto lifeboats. As a result, precious time was lost, and in the panic people began jumping into the water.” (Telegraph, 2012)

Chapter 2.6.2: **Scandinavian Star**

Of the 439 passengers and 268 crew members, 156 Norwegian and 3 Swedish individuals were lost on the evening of April 7, 1990, as a result of a disastrous fire onboard the vessel. While the initial investigation by the Oslo police turned towards arson, by truck driver Erik Mørk Andersen. An unofficial 2013 investigation by Stiftelsen Etterforskning Av Mordbrannen Scandinavian Star (Foundation for Arson Investigation Scandinavian Star), asserted that this was not the case, stating that multiple deliberate fires were set throughout the vessel making it impossible for one individual. In 2018, the Norwegian parliament declared that the disaster was not the result of foul play, though many investigators and personnel still remain skeptical at such claims (CTIF, 2018). As a result of the fire and panic brought about many attempts at evacuation were highly ineffective. In statements taken from passengers, crew, and investigators it is asserted that:

a) Individuals could not find their way due to a thick smoke that shrouded evacuation routes, this smoke was produced by burning melamine panels generated poisonous carbon monoxide and hydrogen cyanide leading to unconsciousness and death.

b) The crew composed greatly of Portuguese personnel did not speak English, Danish, Norwegian, or Swedish, which resulted in a lack of communication between passengers and crew.

c) Many of the crew members were new to the vessel, causing for them to be insufficiently trained in fire and evacuation response onboard leaving them unfamiliar with the ship.

d) Numerous individuals both passengers and crew were unable to hear the alarms due to cabin distance from the alarms, and the high levels of mechanical noise produced by the vessel.

e) Confusing and illogical vessel layout on Deck 5, lead to multiple dead ends, causing a majority of deaths and disassociation amongst the passengers (CTIF, 2018).

As it appears the lack of training and the confusion and panic induced by the disaster lead to unnecessary loss of passengers and crew. If these individuals were potentially properly briefed and the crew sufficiently trained beforehand, that would have allowed for them to proceed directly to the lifeboats and disembark the ship as prescribed by ALMES. Which could have led to a conceivable increase of safety of life onboard the Scandinavian Star.

Chapter 2.7: **RFID/NFC Technology in Shipping Industry**

Technology aboard passenger vessels has been expanding at an exponential rate over the past decade. We have seen the implementation of many systems in regards to passenger and crew comfort and systemization throughout vessels, allowing for individuals to have a more care-free experience onboard. With these new technologies, the cruise industry has recently deployed the use of low-power radio assisted devices such as NFC and RFID bracelets amongst their passengers. So far these technologies have enabled the passengers and crew with the ability to vessel boarding logging, cabin access, non-contact forms of payment, and access to a variety of onboard amenities. Vessel lines including Royal Caribbean Lines have taken advantage of these features on their newly launched ships, with *Oasis of the Seas* being at the forefront of the industry and its potential capabilities. In a study conducted by vessel researchers onboard Brazilian cruise lines have recently been utilizing RFID technologies in the hospitality sector focusing on the tracking of passenger and crew behaviors in tourism and cruise management studies (Dias et al., 2016). In this application crews were able to track passengers' likes and dislikes within multiple scenarios from scheduling to entertainment, through their movement onboard the vessel and the localization of individuals onboard. Thus displaying the further potential possibilities on the applications of RFID outside basic functions. Furthermore, researchers have stated that with this new implementation cruise ships will be able to track passengers and crew operations throughout the vessel with the RFID/ NFC sensors installed throughout (Ortega-Piris et al., 2015).

Moreover, the potential of RFID tracking capabilities is beginning to be explored within the shipping sector of commercial maritime and naval ships, through its use in personnel location monitoring. Displaying the effectiveness of incident response team monitoring from the bridge, through the tracking of crew location and the optimization of efficiency during onboard procedures (Kim et al., 2020). This display accurately describes the possibilities of RFID implementation within the realm of maritime security and casualty location in the event of an emergency, from the shipping sector and the cruise sector, to the military additionally. These technologies display the benefits of a potential efficient passenger location system in the event of a crisis. Asserting that the use of RFID/NFC technology will allow for proper management of individuals and cargo onboard vessels, allowing for more thorough manifesting and organization of crew and passenger movement (Mišković et al., 2016). It has been stated that the advantages of such technologies will provide greater logistical flow throughout, allowing for the accommodation of more efficient operations across crew working environments (Veronneau & Roy 2008).

RFID technologies are not solely limited to the tracking of personnel, additionally maritime logistics have been utilizing RFID tracking in container and port management. In recent years the application of RFID based tracking platforms have been proposed to substantially improve port based logistics. Shi et al., (2011) indicate that RFID and the IOT technologies are expected to play a vital role within seaports and container terminals in regards to the operations within these facilities and the monitoring of cargo passing through. Playing an essential role within the industry, allowing for further control of cargo and procedure. Furthermore, it has been maintained that the OCI is plagued with a multitude of security, safety, and environmental protection flaws (Tsilingiris et al., 2007). Discussing that container identification by means of RFID will soon be implemented within ISPS Code and the Custom Conventions of Containers allowing for the automatic identification of canisters without any external human intervention. Resulting in the securing of port terminals, the identification of errant containers, and streamlining of operations, through removal of human interaction in seal checking, contents understanding, and damage inspection.

Currently many ports have begun the implementation of these technologies, along with AIS, ECDIS, Big Data Analytics, and GPS technologies in efforts to interplay within the maritime supply chain. Supporting many operators relaying a more complete and secure understanding of the traffic and data flowing through the ports and onboard vessels. These diverse applications of RFID technologies within the Maritime Industry display the potential of its utilization in a multitude of facets. From individual tracking and manifestation to the recording of port traffic, ranging from large scale environments to ship based application.

RFID/ NFC technologies during the last decades have been widely introduced in many aspects of the modern merchant shipping industry. The transshipment and tracking of containers and commodities has been revolutionized, transforming a time and effort consuming procedure into a fast and standardized process. Furthermore, the recent establishment of the aforementioned technologies into the cruise industry, show optimistic evidence around the safety tracking of crew and passengers resulting in wider development to be expected in the future. As RFID/ NFC technologies have already established their grounds through the shipping industry; it is safe to say that ALMES would be a useful and achievable addition to the sector, enhancing further the safety of passenger and personnel lives onboard modern cruise/ passenger ships.

Chapter 3: Bridging the Technological Disparities

Chapter 3.1: **RFID Technology Explained**

Although RFID technology has been in use since the 1970s and largely in commercial use for the last 30 years, it can be considered as a relatively old technology. It was first introduced in its premature form in 1948 by the Swedish radio engineer Harry Edmond Sigfrid Stockman while he was working as the head of communications technology division of the US Army Air Forces in Cambridge Field. He developed a system called "Number Identification System", that was implementing radar technology in order to pass easier and more efficiently signals without the need of using repeater stations in order to pass information, through a number of retroreflectors (Roberts, 2006). Of course, that version of RFID does not have any commonalities with the RFID as it is considered today, nevertheless Harry Stockman is considered by the international community as the father of the RFID technology as he was the one that made an effort to expand the usage of the radio frequencies. Similar technologies were used also during WWII by the allies. The British developed a system named IFF transponder, that was based on the passive radar reflector technology. The IFF was tuned to the frequencies of the chain home radar stations and was presented on the radar screen the friendly aircrafts in a bright color compared to the enemy aircrafts, thus giving to the operator’s warnings.

Through the following decades RFID technology moved beyond the strict limits of military use and was introduced as means of identification in many different commercial industries. RFID today, is classified as a type of wireless communication through the implementation of electromagnetic or electrostatic fields in the radio frequency area of the electromagnetic field, used as means of identification for a wide variety of commodities (pallets, containers, spare parts, construction materials, cars, every day goods), livestock and humans. RFID is a term used to describe any device with the ability to receive information from a distance acquired by radio frequencies, such data can be retrieved, even if there are small or larger scale obstructions in between. The function of an RFID system is based on three basic components: RFID tag (or transponder), the RFID reader, and a database (Want, 2006). The RFID tags consist of an IC, an antenna, and a substrate. They also contain microchips that have the ability to store the individual information of each object or subject in a serial number form, something similar to an "upgraded" barcode. RFID tags can incorporate different memory chip types that are permanent or changeable (rewritable) depending on the scope of use of each product. ROM edition tags which contain permanently stored data cannot be changed without being reprogrammed electronically, while rewritable circuits such as volatile read/ write RAM tags are able to be reprogrammed without any limitation by using the reader (Ahsan et al., 2010). As RFID tags are used for many different purposes e.g. credit cards, healthcare, retail sales, vehicle tracking, livestock tracking, etc., their size and shape differs depending on the occasion.

Furthermore, currently in the market there are three types of RFID tag types in use: active, semi-active and passive. Active tags, which are also called transponders due to their ability to transmit to the reader under their own power, are usually larger, more expensive and require a power source, which is either electricity or more often a battery (advanced modern technology gives a battery life of approximately 10 years in some cases, but that co-depends also to the number of reading operations performed). As they have their own power source, it is natural that their read range is generally larger than the passive and semi-active tags, and they are usually being used as identification means on aircrafts or as locating means in vehicles. Due to their bigger size, higher price and limited life-cycle they are considered non-viable for the larger retail market. Passive tags have been used on a wider scale, as they don't require any maintenance making their operational life indefinite, they are cheaper and their size is more practical. A passive RFID tag consists of an antenna, a semiconductor chip attached to the antenna, and a form of encapsulation. Since it is not operating with the use of batteries, it is powered by the tag reader, which is also responsible for communicating with the tag (Ahsan et al., 2010).

There are two different ways for transferring power from the reader to the tag: electromagnetic wave capture and magnetic induction; both methods use the Electromagnetic field's properties through the process of inductive coupling. Inductive coupling usually requires a relevant proximity to the reader in order to power the tag. The only drawbacks that can be addressed to the passive readers are their limited storage capacity, the shorter range that they operate and their declining performance in high electromagnetic "noise" environments (Roberts, 2006). Semi-passive tags are less popular than the other aforementioned tags and they combine properties of both, as they use the battery to run the chip's circuit, yet the communication between the tag and the reader is conducted by acquiring power from the reader.

The reader's strength, especially in the RFID systems using passive tags is of critical importance, as it is responsible for the generation of magnetic fields that will enable the RFID system to communicate with the tags in range. Moreover, the reader is responsible for generating the electromagnetic energy and query signal that triggers the passive tags to reply, thus creating an effective communication between the two devices. In other words, the reader is an electronic device which produces, transmits and accepts radio signals triggering a response from the tag. Additionally, most of the time antennas and readers are integrated into one and are operating simultaneously.

In order for the reader and the tag(transponder) to communicate and operate efficiently in an RFID system, a certain radiofrequency should be chosen and established. The selection of the frequency and consequently the selection of the tag depends on the purpose of the use of the system, as the range of operation of the RFID tasks relies on their frequency. As RFID technology is growing at a rapid pace year by year and steadily taking over a large majority of the market, replacing in many cases barcoding, as a more secure, fast and capable solution. There has been a need of establishing international standards and protocols addressing quality and operational standards. This step will facilitate easier global trade on products coming from different countries currently using different RFID frequencies in order to mark their goods; for example, in Europe the UHF of 868 MHz is used, while USA uses 915 MHz, that is not restricted to those geographical regions as similar frequency differences are noticed at a global scale (Roberts, 2006). EPCglobal, as well as the ISO, are working towards the development of standards for RFID technologies in the UHF band, that will upgrade even further the status of the existing RFID technologies. Creating a common “language” of communication globally, but still it should be noted that still that is an ongoing process with the two organizations working towards resolving these compatibility issues. Furthermore, it shall be mentioned that the frequency selection dictates the performance of the whole RFID system, in conjunction with the resistance to outer interferences.

Presently there are four types of operating RFID frequency systems:

a) Low Frequency RFID systems: The usual operating frequency is 125 kHz and has a reading range of approximately half meter, although the operating frequencies can differ anywhere between 30 kHz to 500 kHz with a reading range of a few centimeters to two meters accordingly.
b) High Frequency RFID systems: The usual operating frequency is 13.56 MHz and has a reading range of less than one meter, although the operating frequencies can differ anywhere between 3 MHz to 30 MHz with a reading range of few centimeters (usually determined around 10 centimeters) to one and a half meters accordingly. High Frequency RFID tags are inexpensive and are commonly found in smart payment cards, cataloging and other proximity-activated devices.
c) Ultra High Frequency RFID systems: The typical operating frequency is 433 MHz and has a reading range of approximately 3 meters, although the operating frequencies can differ anywhere between 300 MHz to 1 GHz with a reading range of a few centimeters to 15 meters accordingly. Although UHF systems have a very large operating range and have a data transfer speed faster than the High Frequency systems, they are susceptible to external interference.

d) Microwave RFID systems: The operating frequency of that RFID type is 2.45 GHz or 5.8 GHz and has a reading range that can reach up to 90 meters if an active RFID tag is being used. Moreover, the Microwave RFID systems present a better reading rate than the UHF RFID systems, although presenting some limitations when found close to water and metal surfaces, without that meaning that they cannot operate correctly, they will just present a slower reading rate. They are usually being used in vehicle tracking, or in activities requiring long-range tracking capabilities (Ahsan et al., 2010; Amsler & Shea, 2021).

Types of RFID Systems	Frequencies Used	Range of the Systems
Low Frequency RFID systems	30-500 kHz, typically 125 kHz	Up to 2 meters
High Frequency RFID systems	3-30 MHz, typically 13.56 MHz	Up to 1,5 meters
Ultra High Frequency RFID systems	300 MHz-1 GHz, typically 433 MHz	Up to 15 meters
Microwave RFID systems	2.45 GHz or 5.8 GHz	Up to 90 meters

Figure (2). RFID Frequencies and Characteristics (Created by the Authors)

Chapter 3.2: **NFC Technology Explained**

Another cutting edge technology that also uses magnetic fields and frequencies to initiate communications between two devices is the NFC technology. Unlike RFID that was initially developed more that seventy years ago, NFC technology is relatively new as it was a product of the collaboration between Sony and Philips in the late 2002, targeting to facilitate easier and safer contactless communications. NFC technology is another method of wireless data transfer and is based on the principles of the RFID technology as it sends radio waves to communicate with electronic devices in close proximity. It operates at 13.56 MHz, while having a data transfer speed of maximum 424 kbps per second.

Furthermore, the range which that technological system operates is quite limited as it is practically not more than 5cm, even if in theory some sources claim that it can reach up to 20cm; that limitation of course enhances the security of the whole system as by its nature prevents any possible interference of other device. NFC technology is based on the inductive coupling principle between transmitting and receiving devices. In order to be conducted two acting parts are required: the initiator and the target. The initiator is the power-supplied (active) device that is responsible for starting the communication and also regulating the information exchange process between the two devices. The target device can be active or passive responding to the request made by the initiator and providing it with the relevant information. When both devices operate on the active mode, they use their own power supply to create the required radio-field for the transmission of data; but when the target is passive, the initiator creates the radio-field with the target device using the energy that is produced by the active initiator.

It is interesting to mention that as NFC technology was brought into the commercial market after the breakthrough and the wide-spread use of mobile phones, it was targeted to act complementary on the operation of the cell-phones as a means of data transfers through a personal wireless network between two or selected multiple devices; something similar to Bluetooth technology. So it can be understood that the initial operation of a NFC system was to be conducted between two active devices (initiator, target). As that technology gained more popularity based on its simplicity, low cost, effectiveness, security and ability to communicate with RFID tags and sometimes to working in combination with Bluetooth, further development came across.

Today NFC technology has experienced an immense growth with passive NFC tags gaining more and more popularity and especially NFC tags and NFC sticker tags being widely implemented. Their use has been part of everyone's everyday life especially over the last decade. Contactless credit or debit cards, automotive industry, electronic keys, health monitoring systems, logistics, file transfer are some of the many fields that NFC technological systems have been used in lately.

Currently there are three operating modes of NFC technological systems: the reader/ writer, peer-to-peer and card emulation. These operating modes are established to cover the specific needs of all user, as every one of them carries different technical infrastructure and advantages.

a) Reader/ Writer Mode: In that mode the NFC initiator works as a reader or a writer for passive NFC tags by detecting a passive tag located in a close vicinity from it, such as contactless smart cards or even RFID tags. The NFC active device is equipped with a program capable of reading or writing information on the detected tag by implementing the read/ write mode operations. When the system is operating in the reader mode, the initiator starts the communication between the two devices by creating a 13.56MHz magnetic field requesting the data that they are located in the NFC passive tag. The NFC passive tag contains the information requested by the initiator and also a program that is responsible for delivering that data back to the initiator. When the system is operating in writer mode, the active NFC device(initiator) is responsible for writing information on the passive tag. If the tag already contains saved information, the initiator will delete them and write the new data. There have been developed also algorithms capable of updating already existing information, when connection with the initiator is established. Some common applications of the reader/ writer mode are the smart posters, social and networking, location based services, and remote shopping.
b) Peer-to-Peer mode: This mode of NFC technology operation is conducted between two active NFC devices, that are usually mobile phone devices that are located in close proximity. On that operational mode, data is being transmitted over a bidirectional half duplex channel, which means that when one device is transmitting, the receiving device has to listen and initiate its transmission upon the completion of the transmission of the first. The applications of the peer-to-peer mode vary largely and can be found focusing

mostly around the transfer of data and other services provided by modern mobile phone devices. Peer-to-peer mode is considered ideal for device pairing services, networking, and the exchange of information and files; such as assisting in Bluetooth connection between devices, social network services and quick personal information sharing among two NFC operating devices. As NFC in that mode of operation requires a maximum distance of a few centimeters, a safe and secure transfer of important information between two compatible devices can be guaranteed. The peer-to-peer NFC mode is considered to add extra market and functionality value to a mobile phone carrying it, as it creates additional ways of sharing securely data and is also compatible with Bluetooth or Wi-Fi. The most frequent uses of that mode are:

i. Social Networking
ii. Money Transfer: If the devices are equipped with electronic wallets, two users can swap money, tickets, coupons and gifts between them.
iii. Data Exchange: By implementing the new mobile phone technology in combination with the peer-to-peer NFC technology, users can store on their devices useful and personal data. Additionally, the exchange between themselves with the security that this application mode is providing, as external interference by other devices is at a larger range is nearly impossible for that to occur.

c) Card Emulation mode: This mode of NFC application has been largely gaining popularity during the last years and can be seen in many different aspects of our everyday life. Card emulation enables mobile phones with embedded NFC technology to act as a contactless smart cards. As people carry their mobile phones everywhere they go and as the technology is rapidly progressing, in the future that NFC mode will provide them with even more capabilities at hand with the press of a button. Currently, mobile devices have the capability of storing multiple different types of digital contactless cards such as debit cards, credit cards, identity, transport or access cards. It is believed that in the future people will be able to use their mobile devices in many different ways facilitating in everyday life. It is interesting to mention that in this operational mode the mobile phone does not create the RF field, in others words it is not the initiator but the target device; the initiator which establishes the communication between the devices and creates the RF field is the NFC reader.

The card Emulation Mode is applied mainly on:

i. Payment: Today almost all smartphone devices are capable of supporting electronic payment applications using the NFC features of the devices, replacing credit or debit cards. At the same time reward points, vouchers or coupons can be stored in the mobile device without any further action; making this application one of the most common and popular.
ii. Ticket services: Theater, airplane and public transportation tickets can be obtained through mobile phone applications. With monthly subscription or instant purchase, via the use of the card emulation NFC mode can be used to enter the aforementioned places or means of transportation.
iii. Identity Services: Mobile phones are capable of storing the relevant identification information of the user and provide them to the relevant reader when asked by using this mode of NFC application, and thus acting as identification means.
iv. Access Control: Card Emulation mode integrated in mobile devices, can be securely as an access key to hotel rooms, building entrances, limited access areas and most recently to cars supporting said technology.

Comparison between RFID and NFC technology		
	RFID	**NFC**
Working Properties	Radio Frequency	Electromagnetic Field
Components	Antenna, Transceiver, Transponder	NFC tags, Reader
Communication	One Way Communication	Peer-to-peer, two-way communication
Range	Medium and Long Range	Short Range
Characteristics	Multiple tags can be scanned at a time	One tag can be scanned at a time
Protocols	ISO & EPC Global	Simple NDEF Exchange format NFC (LLCP)

Figure (3). Elemental Comparison of RFID and NFC (Created by the Authors)

Chapter 3.3: **Instances of RFID Implementation in Maritime Safety**

As of recent, research and developers have been further looking into the use of RFID within the maritime safety industry, in different approaches than ALMES. Previously, funded by the European Union and now undertaken by Waterborne, the Lynceus2Market project has been focusing on the implementation of RFID technologies through onboard localization systems. Focusing on the tracking and localization of passengers during an emergency such as fire, man overboard, and ship abandonment. Through their utilization of RFID tagging systems affixed to life jackets, cabin keycards, and ship launched aerial drones to support search and rescue during diverse conditions and events. These include the use of fire/ smoke, flooding, sensors and transponders for the scaling and monitoring of events in real-time. Being partially funded through the European Union's Innovation and Networks Executive Agency (INEA) at a total cost of € 10,155,002.50, Lynceus2Market was a highly innovative project focusing on the location of passengers and crew during an emergency situation through the usage of monitoring sensors and software throughout the vessel.

While being a particularly well compounded project, Lynceus2Market does appear to have several concerns. First of which, is the use of key cards within passenger localization, as aforementioned during an emergency scenario individuals are further inclined to make mistakes, such as the inability to retain key cards on their person.

Secondly, would be the lack of accurate manifestation systems regarding the personal information of passengers, and the overall complexity of the implementation and installation of the system on existing vessels. With such a high degree of complexity it appears the system is eminently reliant on onboard vessel electrical systems, denoting that in the event of a vessel blackout due to fire, flooding, or malfunction it would result in system collapse and failure. Thirdly, would be the overall cost of system installation and development of these systems onboard vessels and the overall degree of the training that will be required for competent operation by personnel and MRCCs. While Lynceus2Market is an innovative and thought-provoking concept it appears to have a number of difficulties to be viable.

Currently on the market, INDENTEC SOLUTION's Crew Companion is a RFID localization, monitoring, and modular system. Employed throughout the maritime and shore based industries, Crew Companion was developed on the Norwegian Oil and Gas Association's Guidelines, allowing for it to be a highly innovative system. Consisting of RFID tags, bracelets, and identification cards this handheld tablet based system displays real-time monitoring information and location of personnel throughout scalable areas of operation. The additional features of Crew Companion include automated and mobile mustering systems, personnel identification, and an achievable price point allowing for it to be further attainable for small scale operators. While Crew Companion is a noteworthy and encompassing system offering solutions to many issues regarding emergency management, it does have a minor number of flaws which would be solved by the ALMES approach.

Firstly, being a tablet based system, the location of the Crew Companion system can be easily compromised through the inability of access to the storage location, much as we are currently faced onboard cruising vessels. Secondly, would be that all RFID scanning must be undertaken by the tablet administrator making quick disembarkation at the muster points a time consuming process.

Additionally, which cannot be entirely seen as a flaw, Crew Companion was developed for its application primarily on offshore platforms, making it unsuitable for its deployment onboard passenger vessels, due to differentiating operational standards. Albeit being an impressive addition to safety standards throughout the oil and gas industries. ALMES can acquire lessons and learn from the shortcomings within INDENTEC SOLUTION's approach to the implementation of RFID evacuation and safety techniques within the maritime industry. Allowing for ALMES to become a more comprehensive approach to the disembarkation and abandonment of passenger vessels.

Furthermore, much like Crew Companion and Lynceus2Market a wide arrangement of personnel and crew tracking platforms are based off the application of RFID. Though many of these systems have been developed and employed for the tracking of individuals during their working hours, to ensure productivity levels and activity monitoring. These systems include INTRASYS' Vessel Personnel Tracking System, MARTEC's OPTS, and Salcon Petroleum Services' Offshore Personnel Tracking System, including numerous shore-based RFID tracking systems within commercial and professional facilities. These maritime based RFID systems whose prerogatives are largely similar in their application and their framework being comparable, due to sensor and transponder format, localization abilities, and data transmission capabilities.

The differences within the systems come as a result due to their installation environments. In reference to INTRASYS' design it is meant for its employment onboard passenger vessels for the tracking of crew throughout the vessel and the zones in which they are operating within in efforts to improve working efficiency and accountability through data collection.

Separately, MARTEC's OPTS was designed for its utilization onboard naval vessels, in efforts to ensure crew safety through their tracking of personnel in danger zones during the event of naval exercises. In efforts to negate the confusion and loss of crew as a result of hull breach and fire. Lastly, Salcon Petroleum Services' Offshore Personnel Tracking System was designed for its use throughout offshore wind farms, integrated into VMS through the exploitation of a vessel's AIS. This system tracks the personnel's disembarkation from support vessels recording their entry and exit on wind turbines and their re-embarkation onto the support vessels. Allowing for operations managers to document the location of employees and the turbines which they are working on. Along with securing their location and activities in the event of an emergency situation.

While these above-mentioned projects and services vary in their particular ways due to application and environment. Many of their base operations remain the same, being the manifestation and recording of personnel or crew movement and practice by means of RFID transponders and sensors through their working habitat. Much can be learned and implemented from these systems and methods, within the realm of ALMES, from their faults to their practicalities. Though it is evident that currently within the cruise industry, there are multiple situations. It is apparent that the implementation of ALMES protect against these downfalls amongst these current systems, allowing for the further enhancement of the safety of passengers and crew during evacuation procedures.

Chapter 3.4: **Selection of Technology**

As it can be understood from the aforementioned data both RFID and NFC technologies have made great steps towards further progress during the last decades. Services that would be unimaginable 50 years ago, such as electronic payments, identification, space access, money transfers, tracking of people, vehicles and products are possible to be accomplished today within seconds with a touch of a button. Clearly there are many arguments that could be brought in favor or against of both technological spectrums as both systems have in many instances, a similar price range and each one of them offer advantages that the other lacks. For instance, although NFC technology provides a better data security protection, its operating range is very limited, while in RFID technology although security might face some potential threats from time to time its operating range is very vast ranging widely depending on the application.

So far the Maritime Industry as mentioned has taken steps in order to establish new procedures in efforts to increase the safety onboard vessels or other floating objects, through the implementation of modern technologies like RFID. Lynceus2Market and Crew Companion are two programs that are in use and still developing that target to safeguard passengers and crew by locating them via RFID tags and sensors. ALMES being an approach that aims to safeguard crew and passengers during the evacuation procedures and to provide easy, quick, and efficient an up-to-date electronic manifestation in real time will also follow the RFID path. After extensive research, it was found that the advantages of the RFID technology on that particular application, outweigh the assets of the NFC technology. As it was mentioned above, NFC technology by implementing the electromagnetic field properties operate on the frequency of 13.56MHz. Allowing for the transfer of information only in a very close proximity of a few centimeters, thus making it impossible to operate effectively and efficiently on ALMES.

Bearing in mind, the basic targets of the ALMES approach which are the quick, accurate, safe and efficient embarkation of people in lifeboats. It is understood that it would be infeasible for every person to stop while entering in order to scan his/ her bracelet and would create congestion and further panic. In order for that to be prevented and the people's embarkation can flow through all times without any concern, the selection of RFID technology is the correct one for the current occasion. As RFID is able to work in a variety of frequencies that can be decided upon the given occasion and the structure of every lifeboat. Limited proximity is not required for the system to be effectively operational; and in combination with the fact that it has already been successfully tested in the maritime industry. Proving its value in the previously mentioned applications, it is clear that the selection of that technology will bring many benefits and facilitate ALMES better.

Chapter 3.5: **RFID System Limitations**

In reference to the potential limitations that can be associated with the development and implementation of ALMES, display themselves in a varied amount of ways and situations that the system is subject to. Foremost, are the technological limits that are associated with RFID technologies.

- **Tag Collision**

As established by RFID programmers, tag collision occurs when a transponder attempts to read multiple RFID tags instantaneously, resulting in signal collision and potential data loss. In efforts to counteract this, the utilization anti-collision algorithms can reduce this complication. Additionally, as RFID technology advances, these issues have become less problematic, along with transponder placement and proper embarkation procedures can help reduce this possibility (Kaur et al., 2011).

- **Defective Tag Detection/ Accidental RFID Jamming**

Further asserted, defective tag detection can occur for various reasons. Tag damage can occur when RFID tags are employed in adverse conditions resulting in read failure (Kaur et al., 2011). Defective detection may also occur when transponders are installed in an improper environment leading to the deflection, absorption, and ambient reflection of the RFID along with disruption from external signals. Lastly, faulty detection may arise due to faulty transponder readings which are difficult to predict and counteract. Backup measures must be implemented to negate these factors; being the addition of readers associated with the ALMES, placed in the tablet along with the bulkhead/ entryway placed reader/ transponder. ALMES will need additional backup procedures to ensure the accuracy of RFID manifesting.

Chapter 3.5.1: **Non-RFID Related System Limitations**

- **Adoption of New Mustering Protocol**

Amidst the introduction of ALMES and its newly proposed evacuation approach, being the elimination of common mustering procedures. Thus allowing for passengers and crew to directly assemble at the lifeboat embarkation areas. A potential limitation of such a method could be the industry acceptance of this approach, leading to the retraining of crew members and the rewriting of evacuation procedures.

- **Potential Indirectly Induced Panic**

With the proposed abolition of standard mustering protocols with the introduction of ALMES, thus allowing for individuals to muster directly at the lifeboat embarkation stations. In a time of panic and confusion, there is the potential for the mass incursion of passengers attempting to board the lifeboat through the entryway. These circumstances could lead to slip, fall, and trample related injuries. In efforts to inhibit these possibilities, competent passenger management techniques should be enacted to counteract, much as boarding procedures are accomplished today. Additionally, this mass influx of passengers within the lifeboat could conceivably lead to the aforementioned tag collision. To preclude such complications, the S4A UHF 105 RFID reader has the capabilities of reading up to forty RFID tags per second.

Chapter 3.6: **Security Issues Associated with RFID Technologies**

Security and privacy threats incurred with the use of RFID technologies differ drastically from those of a traditional wireless network and these issues continue to plague industries exploiting these technologies.

- **Spoofing**

Pertaining to an attack on the transmission between an RFID tag and reader/ transponder, spoofing occurs through the impersonation of an RFID tag by ways of exploiting authentication tools and protocols (information in which must be obtained previously) by use of an RFID emulating device (Spruit & Wester, 2013). When an RFID is spoofed the exploiter has access to all information sent and received by the tag and sensor/ transponder.

- **Tag Cloning and Data Interception**

Similar to spoofing, RFID tag cloning can be accomplished through the reverse engineering of RFID tags and signals (Ahuja & Potti, 2010). Allowing for the data to be embedded on a new tag, resulting in an identically operating tag as the original in the possession of the security threat. The ability to counteract cloning and interception is difficult due to the tags active data transmission. Additionally, with the ease of attainability and availability of RFID readers and cloning machines on the market and due to the fact that the attacker does not need to have physical access to the tag during the attack.

- **Eavesdropping**

Taking two forms eavesdropping being the reading of data and the reading of the occurring transmission. Occurring during the reading of data, also known as skimming, it is the unwarranted interception of communication data between the sensor/ transponder and the tag (Spruit & Wester, 2013). Allowing for the tag information to be recorded on radio receiving equipment, which in the case of ALMES bracelets this data would consist of passenger/ cabin information and potential financial and credit card information.

- **Denial of Service**

Targeting the disruption of communications between the sensor/ transponder and the tag, a DOS attack achieves this through the use of multiple RFID tags designed to disrupt the operational abilities of the RFID system. A DOS attack is designed to make the RFID system such a ALMES inoperative and effectively useless (Spruit & Wester, 2013).

- **Desynchronization**

RFID desynchronization occurs when an RFID tag information and key protocols which are stored within the systems back-end database differentiate. Losing their typical identical status from that contained within the physical tag, which in turn disrupts the communications between the reader/ transponder and the tag, rendering the tag or in the case of ALMES the RFID bracelets useless (Bilal, 2015).

- **Kill Command**

Kill command attacks involve the permanent disruption of communications between the tag and the reader. While this feature was originally implemented by the manufacturer as a privacy feature, attackers have found ways to manipulate these commands for malicious intents (Mitrokotsa et al., 2010).

- **Jamming**

Classified as both passive and active, jamming can occur by either an attacker or through the product of their working environment. As aforementioned in regards to RFID jamming due to conditions, jamming can also occur under malevolent circumstances. An attacker can manipulate electromagnetic signals in efforts to jam and prevent communications between tags and the readers/ transponders (Mitrokotsa et al., 2010).

Many countermeasures have been implemented in order to defend against these series of attacks and difficulties brought about during the exploitation of RFID information. In efforts to counteract such attacks either intentional or unintentional, the use of anti-interfering materials in and around the readers and transponders may be employed. Furthermore, to ensure the safety of information on the tag, encryption can be involved in which the wearer of the tag can assign a PIN at the time or embarkation in efforts to safeguard their personal information.

Additionally, through data collection and enhanced security/ network protocols, tag identification is possible regarding the recognition of cloned and spoofed RFID tags, combating potentially exploited RFID tags (Mitrokotsa et al., 2010). With the working environment of an RFID being enclosed in the case of ALMES and its reason for concept and implementation, security threats are some of the last concerns involved within its development, being a life-saving device and not being one whose primary function is fiscal. While these threats must not be forgotten, the defense against such attacks is highly enforceable and achievable within the closed environment of a passenger/ cruising vessel.

Chapter 3.7: **Iridium and Satellite Communications**

During the last 30 years, satellite communications have advanced in several ways in many different aspects. Maritime communications and GMDSS equipment on vessels is a field that has been improving exponentially. Providing almost total global coverage to vessels depending on the sea areas of operation, thus providing enhanced safety to crew and passengers. Furthermore, the function and usability of the new technology has been such, that today there is no need for the vessels to have an onboard an officer providing radio-communication as their sole duty. Through daily, weekly and monthly checks GMDSS certified navigation officers are capable of verifying the proper functionality of the systems carried onboard, as well as receiving information crucial about the safety of navigation on the current passage of the ship. Navigational Warnings, Meteorological Warnings, and Security Alerts are some of the many provided services that in combination with the progress experienced in the GNSS fields, have upgraded the safety and security of vessels, personnel, and passengers to an unprecedented capacity.

One of the most advanced and revolutionary systems that has been developed through the previous decades is the Iridium Satellite System that has been in use since 1998. The Iridium Satellite Constellation consists of 66 LEO satellites. The LEO region is defined as the area of space with a maximum altitude of 2,000 kilometers. Satellites within this region are cross-linked and placed at a height of approximately 780 kilometers above Earth with an inclination of 86,4 degrees, providing world-wide coverage including the polar regions (Sekiguchi, 2016). Iridium is capable of providing voice and data satellite communication services in a reliable, inexpensive, and effective way. It is worth mentioning that till now Iridium is the only satellite network system that provides coverage of all Sea Areas (A1-A4) with a sufficiently lower subscription fee than other competitor satellite communication providing companies and with devices much smaller in space and cost. Currently, Iridium provides services and products that are used in Aviation, Maritime industry, as well as by individuals travelling to isolated global regions; but also by the United States DoD in various operations including air, sea, and land missions (Iridium, 2021).

Moreover, the IMO's MSC in November 2014 appointed to IMSO, which is an intergovernmental organization having as its primary purpose to inspect the quality and efficiency of certain public safety and security communication services provided by mobile satellite communication systems (Ahmed, 2019). Forming a team of industry experts to provide through an extensive operational and technical assessment report on Iridium inspecting if it is capable of being considered as a GMDSS provider (Sekiguchi, 2016). In December 2019, a Letter of Compliance was signed by the IMSO affirming that Iridium successfully fulfils all the expected quality checks around the operational and technical requirements. Authorizing Iridium as a provider of GMDSS satellite services, bringing official GMDSS global coverage to all the interested parties. This may be viewed as a revelation in the GMDSS services of the maritime industry, especially today that more and more vessels operate close to the Arctic and Antarctica (Sea Area A4) (Iridium, 2021), being an area of low coverage. As claimed by Iridium the new terminals will be able to facilitate the key three GMDSS services - distress alert, distress voice and Maritime Safety Information – all in one truly global compact terminal. These terminals can provide both normal and emergency communications, including SSAS, Anti-Piracy/Citadel Communications, and LRIT.

ALMES which utilizes Iridium technologies, aims to be a system that will implement the existing RFID technology in order to make the embarkation and manifestation of passengers easier, faster and more efficient, by reducing the required for these actions time and thus saving more lives. The digital manifestation of crew and passengers will be displayed by the tablets connected to each lifeboats and after the launching the final passenger and crew manifest will be transmitted via the selected Iridium Roger ITAS Satellite Modem to the closest MRCC, in order for the search and salvage procedures to be coordinated more easily and effectively.

The Iridium satellite system was selected as it is an overall affordable system, through the years it has proven its reliability, durability, and quality through many different circumstances making it ideal for a lifeboat use. Furthermore, as ALMES will be an LSA, employed on passenger and cruise vessels, the best given coverage is mandatory to secure the safety of life at sea. During the last decades, cruises in the Arctic and Antarctic regions have gained great popularity and is expected for them to continue to gain prevalence within the cruise industry. Consequently, in the unfortunate event of an evacuation at these regions ALMES shall be capable of transmitting to the nearest MRCC the required passenger information. The model Iridium Roger ITAS Satellite Modem was selected as it is an inexpensive very small, ready-to-use satellite transceiver, that will be able to be retrofitted with minimal or no alterations (e.g. use of a holding magnet) to the lifeboat. Not requiring any additional approval of the classification societies removing excess complication and the time consuming the installation procedure. Additionally, it is able to operate in between –40°C and +85°C, and at 75% Relative Humidity, making it appropriate for vessels operating on most waterways (Iridium, 2021).

Chapter 4: Implementation and Expected Outcomes:

Chapter 4.1: **ALMES Implementation**

As it has been mentioned previously RFID technologies have been proven as an accurate and cost-effective localization technology. With the ability to seamlessly track and count individual data of hundreds of passengers who pass through the sensors. They have been successfully implemented not only in the cruise industry but also as a useful tool within logistics tracking. It can thus be said that the RFID technology has already passed its first crash test throughout the cruise industry. Effectively contributing to the safety of the passengers and crew under normal circumstances. It is understandable that it is now time for this technology to be applied in "extraordinary" circumstances that will aid and reinforce the safety of passengers and crew in real-life threatening situations like the emergency evacuation of vessels. The development of this project and manufacturing of the proposed device will enable for the automatic manifestation of passengers while embarking the lifeboat through low-range RFID technologies. The components of ALMES are expected to be:

a) UHF RFID bracelets containing passenger's information (Name, Family, Cabin Number, Body Weight).

b) RFID Sensors with a range of 1 meter installed on the entranceway or internally within the lifeboat on the bulkhead (installation position will be determined based on the design of each lifeboat, aiming for an efficient and accurate manifestation).

c) A Rugged Tablet connected by cable with the RFID sensors and stored in a waterproof compartment inside the lifeboat (the waterproof and humidity resistant nature of the tablet in combination with the storage compartment aim to prevent any damage to the electrical equipment that could be caused due to the different and adverse climates a vessel sails through).

d) An Iridium Roger ITAS Satellite Modem installed on each lifeboat for the transmission of the manifestation data upon the launching.
e) Data transfer capabilities to a monitor on Bridge via onboard wireless network.
f) Backup of manifestation data on vessel’s VDR and on solid state units carried on the lifeboats.

ALMES bracelets will be given to the passengers upon their embarkation on the vessel and their construction will be such that it will be impossible for the passengers to remove them without breaking them till their disembarkation at their final destination. That measure is taken in order to reassure that the bracelets will accompany the passengers throughout their time onboard and no error will occur in case of an emergency evacuation. The sensors that will be placed on the entrances/ bulkheads of lifeboats will be able to keep real time track of the passengers and crew entering the lifeboats. Presenting the information of each passenger to the commander of the lifeboat that will be holding the tablet and overseeing the embarkation of the lifeboat. The tablet will be equipped with an application interconnected with the tablets of the other lifeboats. Allowing information to be present and removed from the passenger and crew list who have already embarked on a lifeboat, not only making the mustering of crew and passengers unnecessary, but additionally speeding up the abandonment process significantly.

Furthermore, the data will be presented not only to the lifeboat commander via the designated tablet device for each lifeboat, but also on a monitor located on the Bridge. Allowing the Master to have a full overview of the evacuation procedure in real-time, without having to ask the boat commanders and add extra pressure to the existing intense situation they face (Roy & Veronneau, 2009).

Moreover, the ALMES approach will be capable of creating a backup of the passenger manifest carried in every lifeboat. Storing them not only in a solid state drive kept aboard the lifeboat, but also store the data in the vessel's VDR and also transmiting them to the nearest MRCC. In this way the MRCCs will have a clear overview of the possible remaining passengers onboard and will have to solely focus their efforts on salvaging them from an early time. Without having to search blindly or waiting until they have an accurate countdown of the passengers that have abandoned the vessel.

Furthermore, the evacuation of vessels will become easier and more time efficient as the passengers will need just to enter the lifeboat without having to assemble at the Muster Stations. Avoiding passenger manifesting prior embarkation, thus valuable and vital time will be spared, also the crew and the passengers will feel more safe and at ease knowing that a system containing all the necessary information regarding them exists onboard and the only thing that should be done is to board the lifeboats and launch them. With the proposed evacuation procedure being displayed in Figure (4), exhibiting the potential simplicity brought about the adoption of ALMES. We are expecting ALMES to bring a breath of fresh air in the nearly outdated evacuation procedure of cruise ships, while concurrently promoting safety of crew and passengers to an unprecedented level.

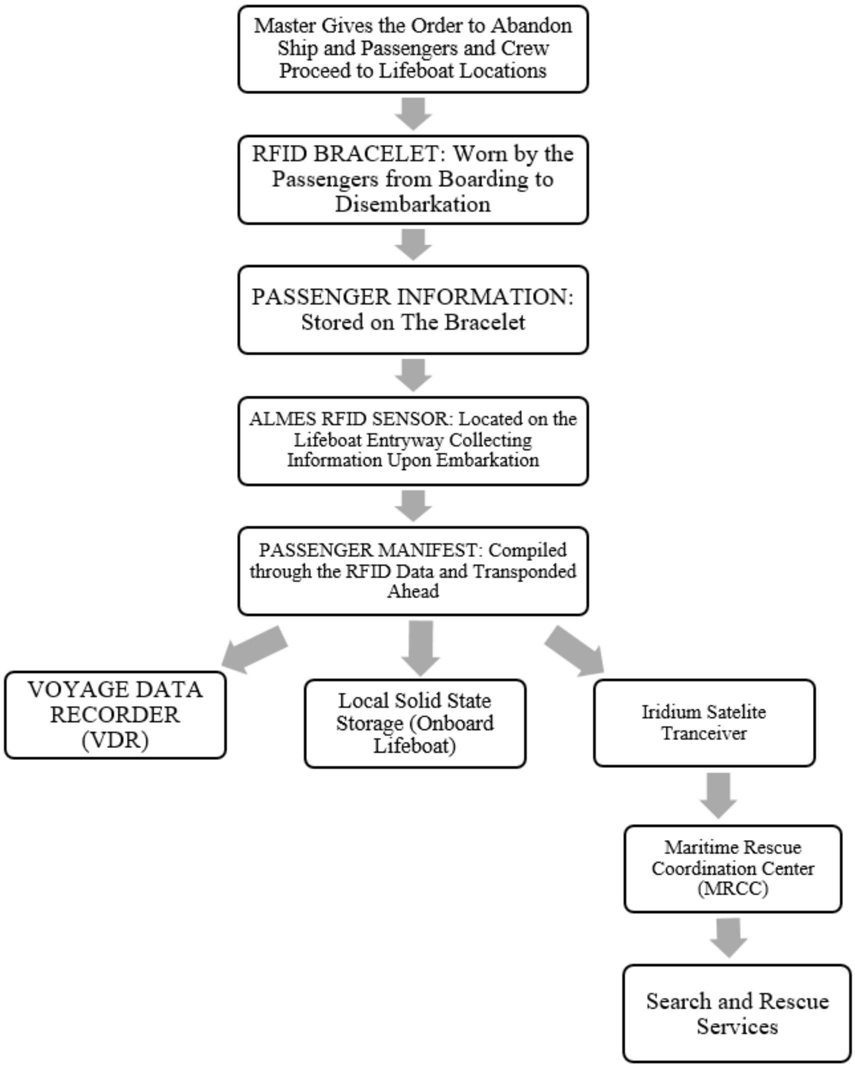

Figure (4). Ship Evacuation and Lifeboat Embarkation Under the ALMES Approach (Created by the Authors)

Chapter 4.2: **Application on Various LSA Models**

Chapter 4.2.1: **Slide Systems (Chute/ Mini-Chute, Slide/ Mini-Slide System)**

The utilization of ALMES can also occur on non-rigid lifeboats, being the operation regarding slide systems, connecting to life rafts at the water level. At the entryway of the life slide, an RFID reader may be installed as done within the lifeboat approach. In a different approach, there would be the scanning of evacuees via the UHF RFID equipped tablet that the crew member assisting with the disembarkation by life slide will be attending to. An issue relating to the installation of ALMES on slide system entryways is the equipping of satellite modems at every-point, though this can be overcome due to the interconnected operation of ALMES between all manifests, allowing for the slide system manifest to piggyback on lifeboat connectivity.

Additionally, the installation of a second RFID sensor at the exit of the slide systems could potentially be installed to ensure the slide is clear for the next passenger. Allowing for the avoidance of passenger obstruction during an evacuation event onboard a Carnival Cruise Line *Arcadia* in January 2018, resulting in the injuring of five passengers.

Chapter 4.2.2: **Application of ALMES on different types of lifeboats**

The following figures demonstrate graphically the potential installation practices of ALMES that can be followed, in order to retrofit the essential devices onboard lifeboats currently in operation throughout the cruise/ passenger vessel industry. It shall be noted that the presented graphs do not provide data and evidence confirmed by electrical engineers or professionals of the sector, but ideas of the authors around the most optimal possible installation of the system on the lifeboats; they are subject to change.

Enclosed Lifeboats

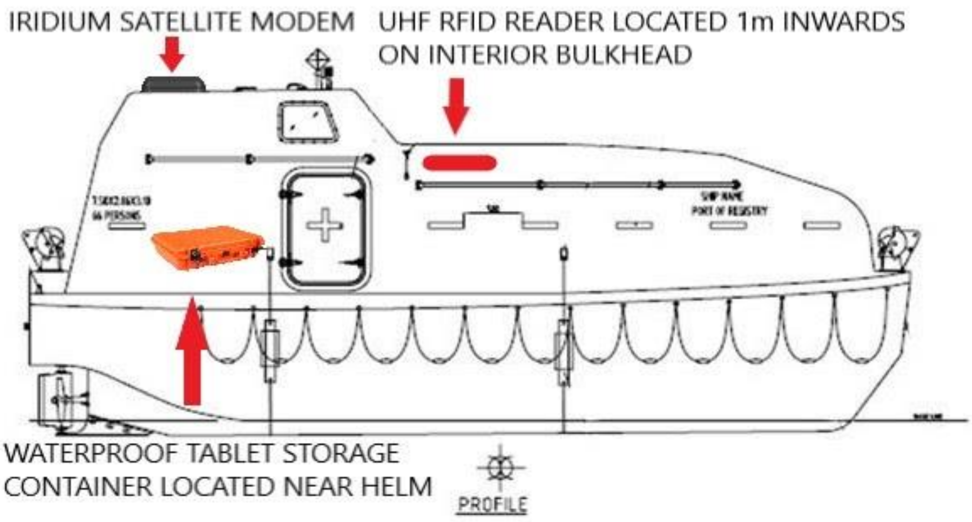

Figure (5). Installation Onboard Enclosed Lifeboats (Created by the Authors)

Partially-enclosed Lifeboats

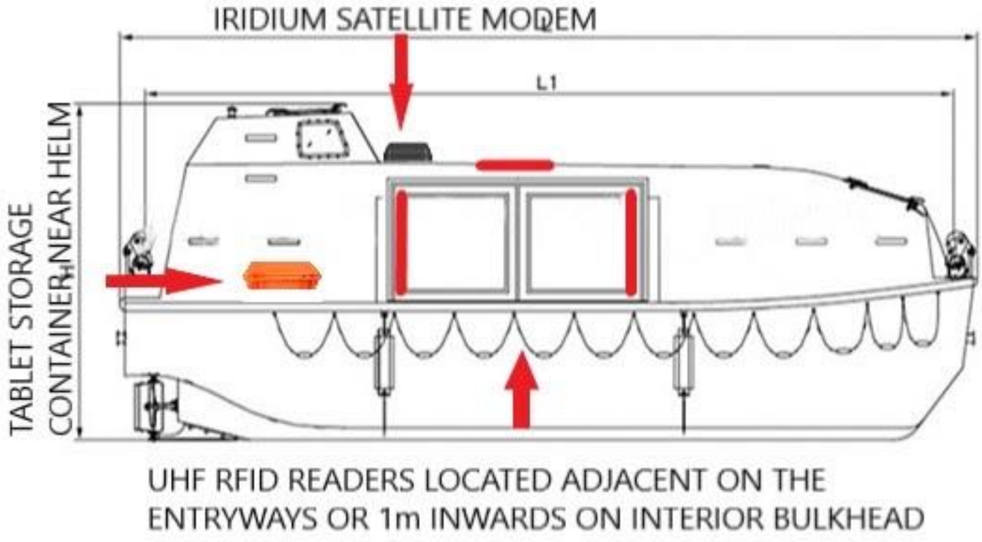

Figure (6). Installation Onboard Partially Enclosed Lifeboats (Created by the Authors)

Lifeboat Tenders

Figure (7) Installation Onboard Lifeboat Tenders (Created by the Authors)

Chapter 4.3: **Applications Other Than Cruising Vessels**

The application of ALMES can further be seen achievable in environments external to those of cruising vessels. Due to the dangers associated with operations onboard offshore platforms, being oil, gas, and wind platforms. ALMES could further help facilitated crew localization and manifestation during platform abandonment, with its implementation similar to that of passenger vessels, being that ALMES would be installed onboard both lifeboats and life slides. As mentioned previously in regards to INDETEC SOLUTION's Crew Companion which undertakes the tracking of personnel throughout the entire platform, ALMES can conceivably be regarded as a lightweight version in comparison. Being that installation onboard existing platforms would be less budget and technologically intensive, while still allowing for the improved safety standards throughout offshore platforms.

Chapter 5: Developmental and Installation Cost Analysis

Chapter 5.1: **Previous RFID Utilization Cost Analysis**

In the past decade researchers have been experimenting with the application of RFID passenger tracking systems, though from an initial cost standpoint it appears to be a hefty investment, in installing ship wide sensors and receivers outside the areas being those of cabin entry, contactless payment, and amenities. The first example of these sensors were trialed onboard "*Oasis of the Seas*" in 2009, while it was first fully implemented in 2014 onboard "*Quantum of the Seas*". This application determined that even with their initial high investment price, the managerial and efficient based properties cut costs and elevated ship operations in the long term (Mišković et al., 2016). With ship-wide installation ranging in 700,000 to 6,200,000 USD, with estimated 900,00 USD in maintenance fees every four years, to this the cost to risk ratio must be analyzed as well, in terms of GCFD and NCFD, being that ship-wide systems may in fact reduce these overall accident related values with the implementation of a system that can reduce the risk to life (Vanem & Ellis, 2010). Contrary, smaller scale installations being those implemented solely on lifeboat entrances, would be a small fraction in comparison of cost to ship-wide systems. Further allowing for accurate accountability and manifesting of passengers and crew when they embark the lifeboats, being either installed in addition to ship-wide systems or on their own as additional LSA enhancements.

Chapter 5.2: **ALMES Cost Estimation**

Estimated Cost Per Unit:	
Satellite Modem	Iridium Roger ITAS Modem: £261.00
Tablet Options	➢ UA-80 Ultra Rugged Tablet (Android 8.0): $ 700.00 USD ➢ P80 RFID Tablet (Android 9.0): € 836.50 EUR ➢ RT 308 RuggTek (Windows 10 Pro): € 1096.78 EUR
RFID UHF Reader	S4A 1-5M UHF105 Reader: $75.00 USD
Waterproof Housing	Orange Max 430 Case: £84.85
UHF RFID Bracelets	$1.00-$3.00 USD (Depending on Order Size)
UHF RFID Identification Cards (Crew Only)	$00.25-$5.00 USD (Depending on Order Size)

Figure (8). Estimated Per Unit Costs (Created by the Authors)

Throughout researching, it became apparent that Iridium being the industry leader in satellite communication would make their system be the most appropriate choice for this project. The Iridium Roger ITAS Modem was chosen for various different reason as aforementioned in Chapter 3.7, being ease of installation, compact for factor, rugged operating and transmission conditions capabilities, and relatively inexpensive price point. Furthermore, we have chosen three different potential tablets to be employed within the ALMES process. Initially, two Android tablets were chosen, being the UA-80 Ultra Rugged Tablet and the P80 RFID Tablet. The UA-80 operating on Android 8.0, is rated at IP97 waterproofing and further drop and chemical resistant, allowing for its capable operation within lifeboats. Secondly, the P80 RFID Tablet, which is rated at an IP65, which while doesn't protect from complete water incursion, operates on Android 9.0 allowing for smoother application development in the coming years. Both tablets contain build UHF RFID readers, allowing for the manual scanning on passengers as a preemptive backup measure in the instance system failure. Lastly, the RuggTek RT 308, which while being the most expensive option, appears to be the most appropriate choice. Operating on the Windows 10 platform, it allows for easier application development and integration with existing hardware. Equipped with UHF RFID readers and constructed to IP65 and MIL-STD 810G standards, it also allows for system backup and the rough operating conditions experienced onboard lifeboats.

Additionally, the S4A UHF 105 RFID Reader which has been utilized in asset and personnel tracking was chosen due to its adjustable reading distance, and as previously mentioned in Chapter 3.5.1 has the capability to read up to forty tags per second, allowing for thorough accountability and the reduction of potential tag jamming, and its waterproof and operating condition specification being in temperatures ranging from -40℃ to approximately 65℃. Furthermore, the reader has multiple communication interfaces being Wiegand, Ethernet, Wifi, and Relay allowing for different configuration varieties depending on working environment

The Max 430 Case in Orange was tabbed in regards to its ability to encase the tablet and allow for a complete waterproof housing, removing the potential of humidity incursion, blocking the device from possible damage and ease of location due to safety color. Moreover, UHF bracelets and crew identification cards were selected for their fully waterproof capacity, no need for battery changing, and extremely low price allowing for passengers to dispose of the bracelets upon disembarkation. This selection of technologies allowed for the compilation of an approximate price point, displaying that ALMES can be a potential easily installable and affordable option to increase the thoroughness of passenger manifestation and streamlining of MRCC communications.

Chapter 6: Conclusions

As aforementioned the lives of passengers and seafarers have been at the focal point of technological innovation over the past decades. This is evident through the development of technologies such as ARPA, RNSS for instance GPS, GLONASS, and GALILEO have awarded the operator the ability to record the location with a high degree of accuracy. Additionally, AIS has increased situational capabilities regarding surrounding vessels limiting the probabilities of accidents occurring at sea. To further improve the facilitation of vessel adherence to the charted route and traffic scheme, the introduction of ECDIS has been a key ingredient for the improvement of the navigation procedures followed onboard by combining the information provided by several bridge instruments.

Contrary, the accountability of passenger manifestation on behalf of cruise operators has not followed a corresponding development, leaving evacuation procedures partially unchanged compared to previous eras. Currently within the maritime industry there is a lack of appropriate passenger manifestation during ship evacuation. With such technological abundance onboard vessels at this time, it is apparent that more comprehensive methods are entirely feasible within the abandonment process. In efforts to reduce the impacts of the human element in regards to panic, confusion, and inability to act, further technologically expedient approaches towards passenger management and evacuation proceeding are paramount onboard passenger vessels. Thus allowing for the growth of passenger accountability on behalf of the cruise industry and the improvement on search and rescue response on behalf of MRCCs.

Through the examination of ship evacuation models and studies involving the human response in times of extreme external pressure, it was observed that individuals regardless of their previous experience and levels of training, are susceptible to acute behavioral patterns. Results of these behavioral tendencies emerge through displays of panic, erratic demeanor, elevated stress levels and cognitive deficiencies; accumulating in a breakdown of passenger management and evacuation procedures. As it is understandable, these behaviors have a serious impact on the abandonment processes, as they tend to create further delays and complications throughout the mustering and lifeboat embarkation operations. Taking into consideration that during an abandonment every minute is critical for the survival of passengers and personnel; the sociological factor of this research is of a great importance, in order to identify which elements of the human behavior can be minimized by the proposed approach.

The ALMES approach entailed within this project, involve the implementation of RFID automation during the lifeboat embarkation process and revised mustering protocols. Through the utilization of present RFID systems employed throughout the cruising industry concerning, cabin entry, onboard payment applications, and asset tracking. ALMES will be capitalizing on the use of irremovable RFID bracelet tags, that will be used concurrently with the aforementioned abilities, containing the individual identification information of each passenger and crew member onboard the vessel. Furthermore, every lifeboat shall be retrofitted with RFID readers, installed within the entry way or the interior bulkhead depending on the configuration of the LSA. Linked with the readers, a tablet based system compiling the automated manifest results, and an Iridium based satellite modem system to relay these results to the closest MRCCs. With the additional transmissions via onboard wireless network of results to the Master on the bridge, and its storage on the VDR upon lifeboat launch.

ALMES additionally necessitates the annulment of traditional mustering and role calling procedures during an evacuation. With the application of ALMES, individuals will proceed directly to their assigned lifeboat boarding stations. With passengers proceeding directly onboard the LSA, with ALMES automatically recording the embarkation and sharing it to the accompanying systems throughout the foundering vessel. This process will alleviate the congestion of bodies throughout the interior of the vessels and limit on deck crowding, in turn reducing levels on panic and confusion amongst passengers and crew. Moreover, the interconnectivity of ALMES, will allow for the accounting of passengers boarding errant lifeboats due to the inability to reach their formally assigned stations. In turn, sharing the said information to external lifeboats containing spouse and kin, further reducing the impact of the human externalities.

In efforts to facilitate the prospective creation of ALMES, proper developmental fields must be assessed. Initially, guidance from maritime professional in the field of passenger ship operations and LSA development shall be requested in order to more precisely locate areas requiring further development in ALMES. Furthermore, the involvement of competent marine technologies experts in order to provide guidance towards the correct selection of the required electronic hardware, shall be requested. Additionally, software development engineers shall closely work with these hardware specialists and current personnel within the maritime industry both working onboard and specializing in ship evacuation and the stresses that brought about in the process. Allowing for the creation of a streamlined and intuitive manifestation and relay program, relieving the crew members and lifeboat commanders of further impacts relating to the ship abandonment.

Since the proposed approach is currently under development, even with the future construction of a prototype being plausible, testing the system under real-life conditions and granting approval to be deployed widely throughout vessels is a time consuming and challenging process. Furthermore, even if ALMES is deployed onboard ships, proper training of the personnel in charge is expected to be a gradual procedure in order for them to reach to a competent level of handling. Additionally, as this method in order to be successful requires an overall endorsement between the vessel operators and MRCCs, it is probable that a further delay may occur until the global adoption is achieved.

Moreover, with the lack of funding leading to the inability of prototype development and manufacturing of ALMES, the full potential and capabilities of the approach are not fully determined. Though with the current exploitation of RFID within the maritime industry from port management to personnel tracking, the competence of such a system are boundless. Current systems such as Lynceus2Market and Crew Companion being massively technological and budget comprehensive, ALMES can potentially offer a light-weight solution of proper passenger manifestation and allow for ease of installation and employment synchronously with existing systems upon its eventual development.

Until funding is provided from potential suppliers, allowing for the construction of a functioning prototype. Many of the claims brought out through this project are speculative and undemonstrated. While practical in theory, until the necessary funding is available and further steps are able to be undergone including prototyping and programing. With current plans associated with such construction occurring within the next three years, concrete data and conclusions related towards the approach regarding improved manifesting, mustering, and transmitting will remain unproven, yet plausible.

References

Ahmed, M. (2019). Public services agreement between the International Mobile Satellite Organization and Iridium Satellite LLC. *International Mobile Satellite Organization*. https://imso.org/

Ahsan, K., Shah, H., & Kingston, P. (2010). RFID applications: An introductory and exploratory study. *International Journal of Computer Science Issues, 7*(1). https://arxiv.org/abs/1002.1179

Ahuja, S., & Potti, P. (2010). An introduction to RFID technology. *Communications and Network*, *2*(3), 183-186. https://10.4236/cn.2010.23026

Akyuz, E. (2016). Quantitative human error assessment during abandon ship procedures in maritime transportation. *Ocean Engineering, 120*, 21-29. https://10.1016/j.oceaneng.2016.05.017

Akyuz, E., & Celik, M. (2014). Utilisation of cognitive map in modelling human error in marine accident analysis and prevention. *Safety Science, 70*, 19-28. https://10.1016/j.ssci.2014.05.004

Alpha micro wireless - roger TAS. Iridium. https://www.iridium.com/products/alpha-micro-wireless-roger-itas/

Amsler, S., & Shea, S. (2021). *RFID (radio frequency identification).* Internet of Things Agenda. . https://internetofthingsagenda.techtarget.com/definition/RFID-radio-frequency-identification#:%7E:text=RFID%20(radio%20frequency%20identification)%20is,an%20object%2C%20animal%20or%20person.5

Bartolucci, A., Casareale, C., & Drury, J. (2021). Cooperative and competitive behaviour among passengers during the Costa Concordia disaster. *Safety Science*, *134*, 1-11. https://10.1016/j.ssci.2020.105055

Bilal, Z. (2015). *Addressing security and privacy issues in low-cost RFID systems* [Doctoral thesis, Royal Holloway, University of London]. http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.792307

Casareale, C., Bernardini, G., Bartolucci, A., Marincioni, F., & D'Orazio, M. (2017). Cruise ships like buildings: Wayfinding solutions to improve emergency evacuation. *Building Simulation, 10*(6), 989-1003. https://10.1007/s12273-017-0381-0

Cornwell, B., Harmon, W., Mason, M., Merz, B., & Lampe, M. (2001). Panic or situational constraints? The case of the M/V Estonia. *International Journal of Mass Emergencies and Disasters*, *19*(1), 5-26. https://www.researchgate.net/profile/Benjamin-Cornwell/publication/270568250_Panic_or_Situational_Constraints_The_Case_of_the_MV_Estonia/links/54ad5e1b0cf2213c5fe3d2c4/Panic-or-Situational-Constraints-The-Case-of-the-M-V-Estonia.pdf

Coskun, V., Ozdenizci, B., & Ok, K. (2013). A survey on near field communication (NFC) technology. *Wireless Personal Communications*, *71*(3), 2259-2294. https://10.1007/s11277-012-0935-5

Sawer, P, Duffin, C. (2012, January 21). Consta Concordia: The inside story of the night of Friday, January 13th. *The Telegraph.* https://www.telegraph.co.uk/news/worldnews/europe/italy/9029866/Costa-Concordia-the-inside-story-of-the-night-of-Friday-January-13.html

Costa concordia disaster (2020). Encyclopædia Britannica Inc.

Dalaklis, D. (2017). Safety and security in shipping operations. *Shipping operations management* (pp. 197-213). Springer International Publishing. https://10.1007/978-3-319-62365-8_9

Desai, E., & Shajan, M. G. (2012). A review on the operating modes of near field communication. *International Journal of Engineering and Advanced Technology*, *2*(2) https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.687.2619&rep=rep1&type=pdf

Dias, D., Lima, F., & Dias, E. (2016). Tourism management and automation: RFID applications in Brazilian maritime cruises. *International Journal of Internet of Things and Web Services, 1*, 43-49. https://iaras.org/iaras/filedownloads/ijitws/2016/022-0006.pdf

Eidemiller, P. (2004). *RFID control system* (U.S. Patent No. 20040176872A1). U.S. Patent and Trademark Office. https://patentimages.storage.googleapis.com/a7/ef/04/aff13a56a879ec/US20040176872A1.pdf

El Agroudy, N., Georgiades, G., Joram, N., & Ellinger, F. (2017). RSSI overboard localization system for safe evacuation of large passengers ships. *13th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME)*, 177-180. https://10.1109/PRIME.2017.7974136

Galea, E., Deere, S., Brown, R., & Filippidis, L. (2014). A validation data-set and suggested validation protocol for ship evacuation models. *Fire Safety Science*, *11*, 1115-1128. https://10.3801/IAFSS.FSS.11-1115

Galea, E. R., Deere, S., Brown, R., & Filippidis, L. (2013). An experimental validation of an evacuation model using data sets generated from two large passenger ships. *Journal of Ship Research, 57*(3), 155-170. https://10.5957/JOSR.57.3.120037

Giustiniano, L., Cunha, M. P. e., & Clegg, S. (2016). The dark side of organizational improvisation: Lessons from the sinking of Costa Concordia. *Business Horizons, 59*(2), 223-232. https://10.1016/j.bushor.2015.11.007

Gubian, P., Piccinelli, M., Neri, B., Neri, P., & Giurlanda, F. (2015). The disaster of Costa Concordia cruise ship: An accurate reconstruction based on black box and automation system data. *2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*, 178-185, https://10.1109/ICT-DM.2015.7402049.

Hanchrow, G. (2017). International safety management – safety management systems and the challenges of changing a culture. *TransNav, 11*(1), 125-131. https://10.12716/1001.11.01.15

Harder, F., & Voß, S. (2012). A simple RFID cost model for the container shipping industry. *International Journal of Shipping and Transport Logistics*, *4*(2), 172-181. https://10.1504/IJSTL.2012.046194

Hu, M., Cai, W., & Zhao, H. (2019). Simulation of passenger evacuation process in cruise ships based on a multi-grid model. *Symmetry (Basel), 11*(9), 1166. https://10.3390/sym11091166

International Maritime Organization. (2010). *Life-saving appliances: Including LSA code / international maritime organization*

Joseph, A., & Dalaklis, D. (2021). The international convention for the safety of life at sea: Highlighting interrelations of measures towards effective risk mitigation. *Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5*(1), 1-11. https://10.1080/25725084.2021.1880766

Kang, H., Lee, D., Shin, J., & Park, B. (2011). Location tracking of moving crew members for effective damage control in an emergency. *Defense Science Journal, 61*(1), 57-61. https://10.14429/dsj.61.503

Kaur, M., Sandhu, M., Mohan, N., & Sandhu, P. S. (2011). RFID technology principles, advantages, limitations & its applications. *International Journal of Computer and Electrical Engineering*, 151-157. https://10.7763/IJCEE.2011.V3.306

Kehren, F. (2009). *The sinking sequence of MV Estonia* [Doctoral thesis, Entwerfen von Schiffen und Schiffssicherheit M-6]. https://doi.org/10.15480/882.485

Khan, F. I., Amyotte, P. R., & DiMattia, D. G. (2006). HEPI: A new tool for human error probability calculation for offshore operation. *Safety Science, 44*(4), 313-334. https://10.1016/j.ssci.2005.10.008

Kobylmski, L.K. (1997). Rational approach to ship safety requirements. *WIT Transactions on the Built Environment, 27.* https://10.2495/MTECH970011

Konidala, D., Kim, W., & Kim, K. (2006). Security assessment of EPC global architecture framework. *Auto-ID Labs*, 103-106. http://caislab.icu.ac.kr/

Kristiansen, S. (2005). *Maritime transportation: Safety management and risk analysis*. Routledge. https://10.4324/978080473369

Kvamme, V. (2017). Use of behavioral theories for the interpretation of human behavior in the Costa Concordia disaster [Bachelor's thesis, Lund University]. http://lup.lub.lu.se/student-papers/record/8908712

Kwee-Meier, S. T., Bützler, J. E., & Schlick, C. (2016). Development and validation of a technology acceptance model for safety-enhancing, wearable locating systems. *Behaviour & Information Technology*, *35*(5), 394-409. https://10.1080/0144929X.2016.1141986

Lange Edman, L., & Johansson, L. (2018). Lifeboat launch on passenger-and cruise vessels during a heel exceeding 20. [Bachelor's thesis, Chalmers University]. https://hdl.handle.net/20.500.12380/255041

Lee, D., Kim, H., Park, J., & Park, B. (2003). The current status and future issues in human evacuation from ships. *Safety Science*, *41*(10), 861-876. https://10.1016/S0925-7535(02)00046-2

Lee, D., Park, J., & Kim, H. (2004). A study on experiment of human behavior for evacuation simulation. *Ocean Engineering*, *31*(8), 931-941. https://10.1016/j.oceaneng.2003.12.003

Lee, J., Cho, S., & Kim, S. (2008). A crew location recognition system for a naval ship by applying ubiquitous technologies. *Journal of Ship and Ocean Technology*, *12*(3), 26-35. http://click.ndsl.kr/servlet/LinkingDetailView?cn=JAKO200806942465690&dbt=JAKO&org_code=O481&site_code=SS1481&service_code=01

Lee, J., Park, J., Cho, S., & Lee, D. (2007). An application of ubiquitous technologies for naval ships: Crew location recognition system. *Proceedings of the 2nd International Conference on Marine Research and Transportation, ICMRT'07, 51-59.* http://www.icmrt07.unina.it/Proceedings/Papers/D/30.pdf

Lozowicka, D. (2012). Organization of evacuation from passenger ships–a concept of safety enhancement. *Zeszyty Naukowe / Akademia Morska w Szczecinie*, *32*(104), 110-114.

http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-article-BWM7-0007-0042

May, M., & Jørgensen, H. D. (2002). Human factors management of passenger ship evacuation. *Human Factors in Ship Design Operation, RINA conference*, 145-156. https://www.academia.edu/download/6404766/Human_factors_management_of_passenger_ship_evacuation__RINA__2002_.pdf

Mišković, T., Ristov, P., & Markić, Z. (2016). RFID control system for the embarkation/disembarkation of passengers and vehicles on/from ferries. *Transactions on Maritime Science, 5*(2), 161-171. https://10.7225/toms.v05.n02.007

Mitrokotsa, A., Rieback, M., & Tanenbaum, A. (2010). Classifying RFID attacks and defenses. *Information Systems Frontiers, 12*(5), 491-505. https://10.1007/s10796-009-9210-z

Norazahar, N., Khan, F., Veitch, B., & MacKinnon, S. (2014). Human and organizational factors assessment of the evacuation operation of BP Deepwater Horizon accident. *Safety Science, 70*, 41-49. https://10.1016/j.ssci.2014.05.002

Ortega Piris, A., Diaz Ruiz, E., Pérez Labajos, C., & Navarro Morales, A. (2020). Implementation of a RFID system on ships for passenger and crew location. *8th International Conference on Maritime Transport, 311-329* http://hdl.handle.net/2117/329935

Pallikaris, A., Katsoulis, G., & Dalaklis, D. (2016). Electronic navigation equipment and electronic chart display and information systems. *Eugenides Foundation.* https://www.researchgate.net/publication/296607800_Electronic_Navigation_Equipment_Electronic_Chart_Display_and_Information_Systems_in_Greek

Park, J., Lee, D., Kim, H., & Yang, Y. (2004). Development of evacuation model for human safety in maritime casualty. *Ocean Engineering, 31*(11), 1537-1547. https://10.1016/j.oceaneng.2003.12.011

Parnyakov, A. V. (2014). Innovation and design of cruise ships. *Pacific Science Review, 16*(4), 280-282. https://10.1016/j.pscr.2015.02.001

Rahul, A., Krishnan, G., Krishnan, U., & Rao, S. (2015). Near field communication (NFC) technology: A survey. *International Journal on Cybernetics & Informatics, 4*(2), 133-144. https://10.5121/ijci.2015.4213

Roberts, C. M. (2006). Radio frequency identification (RFID). *Computers & Security, 25*(1), 18-26. https://www.sciencedirect.com/science/article/pii/S016740480500204X

Ross, T. W. (2006). *Ship's lifeboats: Analysis of accident cause and effect and its relationship to seafarers' hazard perception.* http://s214227135.websitehome.co.uk/trevor_w_ross_report.pdf

Schröder-Hinrichs, J., Hollnagel, E., & Baldauf, M. (2012). From Titanic to Costa Concordia— A century of lessons not learned. *WMU Journal of Maritime Affairs, 11*(2), 151-167. https://10.1007/s13437-012-0032-3

Sekiguchi, K. (2016). Iridium contributes to "maritime safety". *2016 Techno-Ocean Conference,* 90-92. https://10.1109/Techno-Ocean.2016.7890625

Shi, X., Tao, D., & Voß, S. (2011). RFID technology and its application to port-based container logistics. *Journal of Organizational Computing and Electronic Commerce, 21*(4), 332-347. https://10.1080/10919392.2011.614202

Sloane, T., & Antonios, A. (2020). *Discussion with assistant cruise director Paulina Steudten*

Andreadakis, A. & Sloane, T., (2020). *Discussion with second officer Ioannis Agathos*

SOLAS: Consolidated edition 2014: Consolidated text of the international convention for the safety of life at sea, 1974, and its protocol of 1988 : Articles, annexes and certificates (2014). (Sixth edition ed.). International Maritime Organization.

Spruit, M., & Wester, W. (2013). *RFID security and privacy: Threats and countermeasures* (Publication No. UU-CS- 2013-001). Department of Information and Computing Sciences, Utrecht University, Utrecht, the Netherlands.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.303.4627&rep=rep1&type=pdf

Stefanidis, F., Boulougouris, E., & Vassalos, D. (2019). Ship evacuation and emergency response trends. *Design & Operation of Passenger Ships 2019.* https://10.3940/rina.pass.2019.01

Stefanidis, F., Boulougouris, E., & Vassalos, D. (2020). Modern trends in ship evacuation. *Sustainable and Safe Passenger Ships.* https://strathprints.strath.ac.uk/72789/

Thanapal, P., Prabhu, J., & Jakhar, M. (2017). A survey on barcode RFID and NFC. *IOP Conference Series. Materials Science and Engineering, 263*(4), 42049. https://10.1088/1757-899X/263/4/042049

Tsilingiris, P. S., Psaraftis, H. N., & Lyridis, D. V. (2007). Radio frequency identification (RFID) technology in ocean container transport. International Association of Maritime Economists conference “Challenges and Trends in Shipping” http://www.martrans.org/docs/publ/REFEREED%20CONFERENCES/IAME%20tsilingiris%20et%20al%202007.pdf

Ulfsson, B. (2018). Norwegian parliament confirms no foul play in the 1990 Scandinavian Star ship fire. *International Association of Fire and Rescue Services*. https://www.ctif.org/news/norwegian-parliament-confirms-no-foul-play-1990-scandinavian-star-ship-fire

Vanem, E., & Ellis, J. (2010). Evaluating the cost-effectiveness of a monitoring system for improved evacuation from passenger ships. *Safety Science*, *48*(6), 788-802. https://10.1016/j.ssci.2010.02.014

Vanem, E., & Skjong, R. (2006). Designing for safety in passenger ships utilizing advanced evacuation analyses—A risk based approach. *Safety Science*, *44*(2), 111-135. https://10.1016/j.ssci.2005.06.007

Vassalos, D., Christiansen, G., Kim, H. S., Bole, M., & Majumder, J. (2002). Evacuability of passenger ships at sea. *Safety at Sea and Marine Equipment Exhibition (SASMEX)*, https://www.researchgate.net/profile/Marcus-Bole/publication/237657474_Evacuability_of_Passenger_Ships_at_Sea_By/links/568bac3508ae051f9afc573e/Evacuability-of-Passenger-Ships-at-Sea-By.pdf

Véronneau, S., & Roy, J. (2009). RFID benefits, costs, and possibilities: The economical analysis of RFID deployment in a cruise corporation global service supply chain. *International Journal of Production Economics, 122*(2), 692-702. https://10.1016/j.ijpe.2009.06.038

Wang, X., Liu, Z., Zhao, Z., Wang, J., Loughney, S., & Wang, H. (2020). Passengers' likely behaviour based on demographic difference during an emergency evacuation in a ro-ro passenger ship. *Safety Science, 129*. https://doi.org/10.1016/j.ssci.2020.104803

Want, R. (2006). An introduction to RFID technology. *IEEE Pervasive Computing*, *5*(1), 25-33. https://10.1109/MPRV.2006.2

Appendices:

Questions asked during the discussions before the commencement of the MsC

Name of the Researchers: A. Andreadakis, T.F. Sloane

1. What is your role during ship evacuation?
2. What is the current method of ship evacuation aboard the cruise vessels on which you operate?
    a. Do you see this method as effective?
    b. What duration of time does this method of evacuation take?
3. What issues do you see as prevalent in the current evacuation methods?
4. What areas of lifeboat embarkation do you observe as needing improvement?
5. What levels of panic and their impact do you see as spreading amongst passengers and crew during evacuation drills?
    a. How do you see these potential levels of panic and impacts rising during an actual evacuation?
6. Do you think the concept of ALMES would improve on evacuation times, and lead to a reduction of stress and panic levels?
7. Do you think ALMES would be desirable towards the cruise line of which you are employed by?