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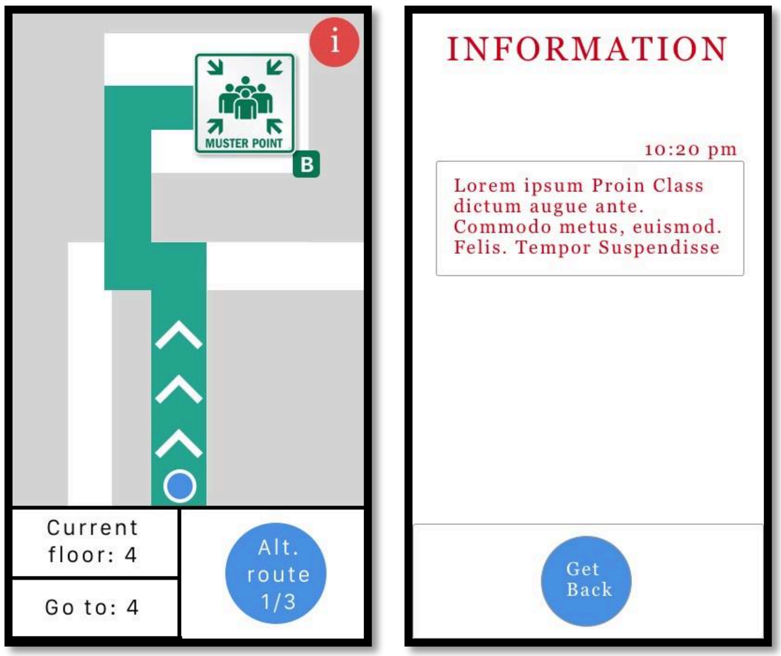

Evacuation on board passenger ships with the use of mobile application

Diploma thesis in the Master Mariner Programme

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Cover:

Example of an application layout for informational and navigational guidance created by the researchers of this study.

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Abstract

Passenger vessels have become larger and larger with time, and some are now able to transport thousands of passengers. Most passengers have no previous experience with evacuations, making the efficient evacuation of these vessels particularly challenging. Therefore, focus needs to be put on developing the technical evacuation systems on board passenger vessels. Today, almost everyone possesses a smartphone that is used daily. The idea with the study is to investigate the need of a mobile application, that provides real-time information and navigational guidance in emergencies. The purpose is to achieve a less stressful and more time efficient evacuation, in which the use of the mobile application reduces the number of casualties.

The research was conducted by semi-structured staff interviews and a survey on board a passenger vessel, with the passengers as respondents. The theory consists research from scientific articles about evacuation and human behavior during evacuation.

The result of this study proves that it is difficult to navigate onboard for passengers, especially in dark and smoke-filled environments. There is room for improvements of current distress information systems, since they have several flaws. This study was not sufficient enough to fully answer the question about what the different needs are for a mobile application during evacuation. However, the results of this study suggest that a mobile application could be a great help during evacuation and could function as a complement to current evacuation systems.

Keywords: (Mobile application, evacuation, passenger vessel, human behavior, distress information, navigational guidance, indoor positioning)

Sammanfattning

Passagerarfartygen blir allt större och större med tiden, och vissa har möjlighet att transportera tusentals passagerare. Fokus måste framförallt läggas på att utveckla de tekniska evakueringssystemen ombord på passagerarfartyg, eftersom passagerare har oftast ingen tidigare erfarenhet eller träning av evakuering vilket gör dessa fartyg en svår utmaning att evakuera. I dagens samhälle äger nästan alla en smartphone som används dagligen. Idén med projektet är att undersöka behovet av en mobil applikation med realtidsinformation och navigeringsguidning. Syftet är att uppnå en mindre stressfull och tidseffektiv evakuering, där användandet av den mobila applikationen bland passagerarna minskar antalet dödsfall.

Undersökningen genomfördes genom semi strukturerade intervjuer med erfaren besättning på passagerarfartyg och en enkät tilldelades passagerare ombord ett passagerarfartyg. Teorin innehåller forskning om evakuering och mänskligt beteende vid evakuering från vetenskapliga artiklar.

Resultatet visade på att det var svårt att hitta ombord för passagerare, speciellt i mörka och rökfyllda områden. Det finns rum för förbättringar av de nuvarande nödinformation systemen, då de har en del brister. Denna undersökning var inte tillräcklig för att besvara frågeställningen om vilka behov som finns för en mobil applikation under evakuering. Däremot finns det ett behov av applikationen vid evakuering som ett komplement till de nuvarande evakueringssystemen.

Nyckelord: (Mobil applikation, evakuering, passagerarfartyg, mänskligt beteende, information vid nödsituation, navigationsguide, inomhuspositionering)

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The authors would like to thank the crew from *Stena Jutlandica* for making it possible for us to come onboard to conduct interviews and handout surveys to the passengers, along with crew from *Star Pisces* for the participation in the interviews. The authors would also like to thank the supervisor Martin Larsson, head of division at department of Shipping and Marine Technology Institution at Chalmers University of Technology, as well as the examiner Monica Lund.

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1. Introduction

Since the mid-19th century, new technologies have made ships increasingly safer and faster. Nevertheless, several accidents at sea have taken place, often because of unsolved problems concerning the technical safety of ships (Lozowicka, 2006). In every accident at sea, evacuation of the ship must be taken under consideration. It is of great importance that the focus of new technology for assisting evacuation is on passenger vessels, since they have a large number of persons onboard who could be at risk during evacuation (Lozowicka, 2006).

Previous incidents have proven that the most significant effects on evacuation time are the movement of the ship, crowd density and human response to emergencies (Hongtae, Jin-Hyoung, Dongkon, & Young-soon, 2004). An important factor in this report is how these psychological factors affects the ability to navigate onboard. There are several factors that have a great impact on human behavior during evacuation that this report will consider, like signage, dark and smoke-filled surroundings, etc (Gwynne, Galea, Filippidis, & Lawrence, 2000).

An emergency is obviously a very stressful situation and according to Ozel (2001), the capability of making rational decisions and receiving and interpreting information, both of which are essential for navigating properly, is remarkably reduced in stressful situations. Reduced stress can be achieved in several ways, such as providing sufficient information and escape guidance early on.

Passenger vessels are the most difficult to evacuate since the majority of the passengers have no previous experience of these situations. Swedish Accident Investigation Authority (SHK) stated the importance of finding new life-saving appliances for passenger vessels after the *Estonia* catastrophe in the Baltic sea (haverikommissionen, 1998).

As mentioned above, there are numerous aspects to take into consideration when studying evacuation. To get the best results from a study, all aspects should be included in the examination. However, this is a very complex matter, which allows us to only look at a certain number of factors regarding optimization of evacuation systems (Kim et al. 2004).

In this report, we will introduce the idea of a mobile application with ambition of achieving a less stressful, more safe and time efficient evacuation on board a passenger vessel by providing real-time information and navigational guidance to passengers throughout emergency situations. Many lives are lost annually due to maritime incidents, so it is of outmost importance to study and develop technology in order to reduce the number of casualties. In this case, it could be beneficial to employ technology that many people use in their daily lives.

Ever since the mobile phone applications were introduced to the market, they have been a skyrocketing success. Today mobile applications are used in everyday activities and have a great impact on our daily lives. Smartphone apps have become key marketing tools for businesses as well. Today it is possible to get real-time announcements from authorities via applications, which is yet another mean of guidance in emergencies (Wada & Takahashi, 2013).

1.1 Purpose

The purpose of this study is to determine if passengers are in need of a mobile application that could provide them with real-time information and navigational guidance during evacuations, a lifesaving system that can increase the efficiency of an evacuation.

1.2 Questions

- How easy do the passengers find it to navigate onboard?
- Is there room for improvement of distress information available for passengers?
- What needs is there for a mobile application during evacuation?

1.3 Delimitations

This report will focus on human behavior during emergency situations, with focus on how people interpret information and navigate in stressful conditions. We will study if there is a need for another aid during evacuation, in this case a mobile application. The technical aspects will be excluded from the report, due to limited amount of time.

2. Theory

The theory chapters will describe the important factors regarding the time it takes to evacuate a passenger vessel. It describes the process of an evacuation and the technical systems aiding passengers to evacuate, along with the prevailing regulations. How people reacts in emergencies, and the consequence when passengers perceive inadequate information. It will also cover new potential aids during evacuation, such as indoor positioning systems and a mobile application as an aid.

2.1 The evacuation process on board passenger vessels

There is always a risk of accidents occurring at sea, for example grounding, cargo shift or collision. In some cases, the accident may cause the ship to sink, in which case the ship needs to be abandoned before it is too late. This is a difficult task for the crew and captain, especially for vessels who are carrying thousands of people. It is always the captain who makes the final decision to evacuate since he has the ultimate responsibility for the ship. He is only allowed to make the decision to abandon ship, if he believes that there is no other way to save everyone onboard (Föfattningssamling för den svenska sjöfarten, 2012, DEL A, Ch 6 § 6).

The captain need to make important decisions since he has the ultimate responsibility throughout the event, for example, deciding if they must abandon the ship or not (Föfattningssamling för den svenska sjöfarten, 2012, DEL A, Ch 6 § 6). It is a decision were many lives are on stake. To ease these kinds of decisions, the captain on passenger ships will have a decision support system that consist of emergency plans with different predictable scenarios (SOLAS, 2009, Ch. III Life-Saving Appliances and Arrangements). SOLAS has also made guidelines for the safety crew to follow and drills to practice to be more prepared for an accident.

The process of abandoning the vessel is described according to drill instructions by SOLAS, Ch. III Life-Saving Appliances and Arrangements (2009). The abandon ship alarm will sound, followed by an announcement from the captain through a PA system (public address system) to all passengers and crew with information about the accident and other instructions, to make sure they are aware of the of the order to abandon ship. The safety crew has different duties and individual assignments that is described in the ships muster lists. Some will be at the muster station and assemble the passengers, other crew will prepare and launch the survival crafts (SOLAS, 2009, Ch. III Life-Saving Appliances and Arrangements).

All passengers are counted when they embarked on the ship and if someone is missing at mustering, the crew will have procedures to search and rescue the passengers who are trapped in their cabins. The vessels will have enough survival craft capacity for the total number of passengers on each side of the (SOLAS, 2009, Ch. III Life-Saving Appliances and Arrangements). The crew will count all embarking passengers on the survival crafts and make sure that the maximum capacity of each craft is not exceeded. The craft will then head for shore or be picked up by another rescue vessel.

2.2 Rules and guidelines from SOLAS

The safety crew on board a passenger vessel needs to be well prepared and know what actions to take in case of an emergency. They need to know how to handle large crowds, life-saving appliances and survival craft. SOLAS, Ch. III Life-Saving Appliances and Arrangements (2009) provides rules and guidelines for how to train the crew with fire drills and abandon ship drills. It states that “Every crew member shall participate in at least one abandon ship drill and one fire drill every month.”

According to SOLAS, Ch. III Life-Saving Appliances and Arrangements (2009), all new embarking passengers shall be given a safety briefing with clear instructions to be followed in case of an emergency. It also states that information must be given about their muster station, the essential actions they must take in an emergency and the proper method of donning lifejackets. This shall be given with the PA system, and may be supplemented by information cards, posters and videos displayed on TV screens. If the passengers stay onboard is scheduled to last more than 24 hours, they shall participate in a muster drill. There they will be familiarized with the muster station and be given instructions in the use of a lifejacket and actions to be taken in an emergency.

2.3 Current technical and navigational aids onboard

This chapter describes the current technical aids for passengers onboard during emergencies. Both visual and audible system are used to inform and guide passengers. It will describe both pros and cons with each system, and the different effects it has on the passenger when they receive information.

2.3.1 PA system

All passenger vessels shall be fitted with a PA system that is clearly audible above noise in all spaces. It shall also be connected to the emergency source of electrical power (SOLAS, 2009, Ch. III Life-Saving Appliances and Arrangements).

People today are used to receiving information on ships through speakers. Most of the information does not concern them and therefore they automatically weed out a great amount of information. Experience shows that people have difficulty understanding different alarms and have become more immune to sounds, which leads us to not react to alarms that we do not recognize (Günther, 1988).

On board passenger vessels, the PA system are used for different purposes like traffic information, advertisements and music. Advertisers are well aware of the fact that we weed out information, so they often add sounds such as car horns and sirens. Emergency announcements must be distinct from all other sounds. Ferries and cruise ships have discotheques with loud music, different lights and smoke, which makes it difficult to hear announcements made through the PA system (Frantzich, 2000).

2.3.1.1 Pros of the PA system

The PA system is a quick way to give out information and to reach a large number of passengers at the same time. The information comes directly from or contains orders from the person who is overall responsible, the captain onboard. The risk is consequently minimal that the content of the message will be distorted. Announcement through speakers during evacuation has proved to be effective, and the result is a faster evacuation (Proulx & Sime, 1991).

2.3.1.2 Cons of the PA system

Although the PA system has many pros, it has some serious disadvantages. This system is not an interactive system, meaning that passengers are not able to ask questions and start a dialogue. The fact that the PA system only provide sounds is a great disadvantage, since people with impaired hearing cannot receive the information through the PA system. It can also be difficult to hear the PA in loud and noisy environments. Another disadvantage is that it is challenging to adjust the announcements to different situations at different locations onboard (Stoke & Kite, 1994).

Human factors can also affect how the message is delivered and understood by the passengers. If the speaker is in a state of distress, the message may be poorly executed. Additionally, the number of tasks the bridge team must carry out at the same time as they are supposed to do the announcements on the PA may result in the crew prioritizing other tasks before informing the passengers (Chute, 2001).

The speaker must take into consideration that most of the passengers probably are unfamiliar with nautical terms, such as port, starboard and stern. These words should be adapted for the passengers in a more everyday language. It can also be necessary to make the announcement in multiple languages depending on the passengers onboard. When passengers hear an unfamiliar language, insecurity increases and passengers are at greater risk of making mistakes. Moreover, the volume and activity in the passenger areas will increase rapidly after the first announcement in the main language (Timstedt, 2004).

Studies show that during the Great East Japan Earthquake (GEJE) only 40% of the evacuees heard the emergency alert warning from the loudspeaker. 80% of the people who heard the warning recognized the urgent need to evacuate and 20% did not fully comprehend the message because of a noisy and confused environment (Wada & Takahashi, 2013).

2.3.2 Alarm signals

There are different types of signals that are used at sea, which are heard from speakers around the ship. One example of a signal passengers may hear on board is the general alarm, which is seven short blasts and one long blast. When the signal is heard, everybody is supposed to gather at designated muster stations. This alarm provides a small amount of information even though it is relatively long. Explanations of the different signals are posted on emergency information posters onboard. However, experience shows that the passengers only take in a limited amount of information from these posters (Ohlsson & Johansson, 2002).

In an emergency situation, there is a great risk that passengers miscalculate the number of blasts, which will result in confusion. They may not even understand the alarm. The PA system is therefore a crucial complement (Timstedt, 2004). A general emergency alarm system must be provided on all open decks as well as a supplement in the form of a PA system or other suitable means of communication (SOLAS, 2009, Ch. III Life-Saving Appliances and Arrangements).

2.3.3 Low Location Lighting (LLL)

Navigating onboard can be challenging and confusing for passengers. Unlike crew members, passengers are not well familiarized with the ship's arrangement of spaces and corridors. With this in mind it is important that there are navigational aids onboard that can guide the passengers during emergencies (Lozowicka, 2006).

LLL is a photo luminescent marking strip located close to the floor with the purpose of marking the evacuation routes, exit doors and firefighting equipment. In case of an emergency when smoke is present LLL is necessary for evacuation, unlike signage and emergency lighting located at high levels, which are not very effective in these conditions. Passengers would have to crawl or stoop to avoid visual obstruction and smoke inhalation (Rei, 2006).

LLL systems are essential and should be considered primary signage, together with the high-level signage. Since the LLL systems are located close to the floor, the ambient light is much reduced. Therefore, these signs must be sensitized with much less ambient light than the requirement for the other signs. ISO 16069 states that LLL systems as well as signs must have the capacity of absorption and retention of energy sufficient for illumination. The system must be capable of recharging at a duration of 15 minutes. Today it is possible to obtain materials that not only meet the specifications, but exceed them (Rei, 2006).

2.3.4 Signs

The presence of a sign results in a more rapid exit during evacuation. (Tang, Wu, & Lin, 2009). A study conducted by O'Neill (1991) proves that addition of signage resulted in a 13% increase in rate of travel, a 50% decrease in wrong turns, and a 62% decrease in backtracking across the five settings. The experiment also shows that textual signage is the most effective when it comes to reducing wayfinding errors, like backtracking and wrong turns, while graphic signage on the other hand produced the greatest rate of travel.

High-level signage showing the evacuation routes, exit doors Thus it is important to position the signage at a high level, so that obstacles like furniture, people and decorations are not blocking the line of sight (Rei, 2006).

There are different kind of factors affecting the visibility of a sign, for example its design and the illumination conditions (Collins, 1991). Likewise, the color of a sign’s content (green or red) increases the recognition distance by about 6 m in smokeless environments (Ouellette, 1988). The identification performance of a green emergency sign proved to be high for both color-normal and color-deficient observers (Eklund, 1999).

Since most passengers have little knowledge about the ship’s layout, purpose and location of the muster stations, it is required that signs are readily identifiable, that theirs purpose is clearly conveyed and the routes to the muster stations are clearly apparent. The doors leading from passenger spaces to open deck must have one or more signs marked “EXIT”. Each deck onboard must also be clearly marked with a sign (Maritime and Coastguard Agency, 1990).

2.3.5 Floor plan

The layout of floor plans is as important as to other architectural features, such as the availability of signs, in terms of ease of wayfinding (Beaumont, Gray, Moore, & Robinson, 1984). The study made by O'Neill (1991) show that the presence of signage cannot compensate for wayfinding difficulties due to the complexity of the floor plan. Even though the participants had access to signage in the most complex floor plans they still had poorer wayfinding capability, than those in the simplest floor plans with no signage.

2.3.6 Emergency information for passengers

According to SOLAS, Ch. III Life-Saving Appliances and Arrangements (2009), PA systems can be complemented with information cards, posters and video programmes displayed on the ship's TV screens. The regulations also states that instructions and illustrations shall be posted in passenger cabins in appropriate languages and be conspicuously displayed at muster stations and other passenger spaces. These posters give passengers information about their designated muster station, the essential actions they should take in an emergency and the method of donning lifejackets.

These are just requirements for what must be provided to the passengers, but if the passengers do not embrace this information then it is useless. For this reason, it is of paramount importance that we convey and emphasize the importance of this knowledge. One way of encouraging passengers to read the emergency instruction notices is through the PA system. Another way is by making announcements at the terminal before boarding (Maritime and Coastguard Agency, 1990).

The emergency instruction notices can be in the form of video programs onboard or in shore terminals, a page in the ticket folder or information in magazines and brochures for passengers. They should include proper a contingency plan for their evacuation from the ship, actions to be taken during evacuation and how to use the life-saving equipment (Maritime and Coastguard Agency, 1990).

2.4 Human behavior during emergencies

This chapter will focus on a person’s behavior in stressful situations such as an emergency, how individuals react and act different from each other. It also describes the behavior of the “large crowd”, and the negative impact passive behavior can have on the evacuation time onboard.

2.4.1 Actions

People will naturally react and act differently from each other in emergencies depending on their character and previous life experience. A study made by Harbst & Madsen (1991), claims that when an alarm is sounded, 60% of people will be passive, misinterpret or even ignore the signs of an accident. 30% will investigate the situation and try to find further evidence that something is wrong and only 10% will directly recognize the danger. Timstedt (2004) divided those who recognized the existing danger into action groups as shown in table 1.

Table 1 Distribution of passenger behavior when they identified a situation as dangerous. Based on (Timstedt, 2004)

Actions	Percentage
Egress	10 %
Fight the hazard	5%
Warn and instruct others	10%
Await instructions	60%
Become incapacitated	12 - 14%
Panic behaviour	1 – 3 %

2.4.2 Reactions

After the emergency alarm has sounded, it will take time before the passengers react. By giving out information early on, one can minimize the response time. The strength of a reaction will also differ between persons; some will stay calm and think more rationally, while others might express more intense fear and in some cases even panic. There exists a misconception about the term panic; Andersson (1991) states that it is a rare state in which a person disregard information around you and act irrationally, but the term is sometimes sloppily used by the media to make it sound more common than it is. As shown above in table 1, a mere 1-3% of people will express panic when they realize there is danger. The dominant action is to do nothing, be passive and await further instructions.

According to Timstedt (2004), passenger vessels can be very large and give the impression that they are invulnerable, and people overrate the durability of the vessel. People believed in the year 1912 that the Titanic was unsinkable and at the time of the accident, the vice president of White Star Line announced to the public (History on the net, 2017).

> " We place absolute confidence in the Titanic. We believe the boat is unsinkable."

Claims like this were also made by shipbuilders and media at the time and these were deceptive to the public. However, The *Titanic* sank over a hundred years ago and since then vessels' construction, design and overall safety have increased substantially. Nevertheless, severe accidents in which vessels sink still happens today and a person`s over confidence in that nothing bad will happen decreases their ability to react in time and to realize the potential danger in an emergency (Timstedt, 2004).

According to Malinek & Booth (1975) people rarely respond directly to an alarm. Therefore, it is important that the crew provide substantial information about the threat to the passengers. It is better that they respond and react instead of being passive.

2.5 Evacuation causes stress

A virtual experiment was conducted by Meng and Zang (2014) with forty participants. The intention of investigating the way-finding behavior and response during a fire emergency. Participants were divided into two groups; the so called "control group" was not exposed to fire, while the other "treatment group" was. The age range was between 20 and 25, respectively, and the 20 male and 20 female participants were divided evenly among the two groups. The requirements were to find the emergency exit as quickly as possible in a virtual hotel building.

The test consisted of computer screens displaying the surrounding environments, presenting a 360° field of view. Each participant was placed in the middle of the surrounding screens. The skin conductivity, heart rate and eye movements of the participants were constantly documented throughout the experiment. They had no prior knowledge of the hotel and were only told to complete two exercises according to voice clues given by the system. While they were reading a text on the computer screen, a voice was heard that stated "the hotel is on fire, please stop all tasks and find the exit as quickly as you can". The treatment group had virtual fire, explosions, a fire alarm triggered and smoke appearing at the scene, while all the conditions at the hotel were normal for the control group.

The skin conductivity and heart rate increased significantly in both groups when they were carrying out the wayfinding task compared to the reading task. However, the treatment group had greater values in comparison to the control group. A psychological response questionnaire was completed by the participants before and after the experiment, including an escape time estimation, wayfinding difficulty and subjective stress evaluation. The subjective stress level increased in both groups (Meng & Zhang, 2013).

2.5.1 The physiological reaction in the human body

It lies in human nature to experience stress in certain situations, such as when we are in danger or need to perform a demanding task. According to Karatsoreos, Bruce, & McEwen (1997) the central organ of stress is the brain and it decides what we perceive as a potential threat. Increased production of stress hormones adrenaline and cortisol results in increased blood pressure and heart rate. It is commonly said that our brain activates a flight or fight response in order to help us survive.

2.5.2 Effects of stress

In a study conducted by Karatsoreos, Bruce and McEwen (1997) results showed that stress does not only occur in dangerous situations; there are, of course, other factors that contribute to a person’s stress levels in general, such as mental health, personal habits and sleep quality. When we experience stress, we feel anxious, frustrated and sometimes angry. They also describe that there is different types of stress, it can be positive or negative depending on the situation and the amount of stress we experience. A low amount can sharpen our senses and improve our capability to make decisions during difficult situations, while a higher stress level can have the opposite effect (Karatsoreos, Bruce, & McEwen, 1997).

2.6 What causes stress?

Human behavior, stress and the evacuation time are linked together, this chapter describes external factors that cause stress for people in emergencies and how it can affect our way-finding ability.

2.6.1 Lack of Information

A high level of stress is a significant negative factor in one's ability to interpret information and act in a beneficial way during emergency situations (Ozel, 2001). There are several factors and aspects to consider in order to evaluate what causes stress during emergencies.

For instance, a greater amount of information given to people regarding the nature of distress can have a positive impact. It will serve as a foundation for making decisions, especially if it is provided at an early stage of the emergency. As the emergency situation develops, new information will become available. If it is given infrequently and is ambiguous to passengers, they will experience lack of information, resulting in uncertainty and more intense time pressure regarding the basis for their decisions (Ozel, 2001).

2.6.2 Surrounding environment

The surrounding environment during an emergency on board a passenger vessel plays a large role in the individual's stress level and their wayfinding ability. Several factors must be considered to understand the cause. Ozel (2001) states that disturbing surroundings can overload us with unnecessary environmental information; for example, glass windows, store signs and different lights can make exit signs difficult to spot.

Tang, Wu, & Lin (2008) created a simulation with participants who were told to find the way out of a building in a virtual reality. This was done in different scenarios, one in which they could follow signs and labels to an exit door, and an another in which there were no exit signs to follow at all. The participants found the way more efficiently in the scenario with exit signs. They also found that people tend to pass by and ignore exit signs the first time they spot them.

Tang et. al. (2008) express the importance of having many signs along the way to an exit door since participates tended to become more aware of the signs the more they saw along the way. They also concluded in the simulation that people are drawn to doors in an emergency, even if a door does not lead to the correct way out. It is therefore important that the true exit door was clearly labeled and distinguishable from other doors.

According to a study made by Kobes, o.a. (2009) exit signs become even harder to spot in smoke-filled surroundings and this increases the risk that individuals will pass by without noticing the exit signs. Smoke has a negative effect on our ability to find the most efficient way out and this could increase the evacuation time.

It is worth mentioning that the pitching, rolling and listing of the ship have a huge impact on the individual's stress level and have a direct relation to the evacuation time and the number of survivors in the total outcome of the accident. Haverikommissionen (1998) wrote in the conclusion about the tragic disaster of *MS Estonia* that the rapidly increasing listing contributed to the large number of casualties, as the list made it very difficult for the people to evacuate their accommodations. A ship's movement can be affected by the weather and the stability of the vessel, and the stability can be greatly reduced in case the vessels is damaged, shifting cargo or taking in water.

2.7 Results of being stressed during evacuation

This chapter describes what happens in our mind when people experience high stress levels, and the many negative effects it has on our ability to make rational decisions. Along with the dangerous consequences of making poor decisions during an evacuation, and how this might slow down the evacuation process.

2.7.1 Defense mechanisms

The human mind’s defense mechanisms assist us by perceiving the surrounding environment and helping us in our decision-making process. High stress levels and difficult situations activates our defense mechanisms in order to protect us from harsh impressions that we cannot handle psychologically. The mind can make a situation appear less dangerous or even deny the existence (Stokes & Kite, 1994).

Humans have many kinds of defense mechanisms according to Timstedt (2004), they could be mature or more primitive. When we experience stress that is manageable, we can take mature actions. But when it becomes too much to handle, our mind falls back to a more primitive state. One example is regression, in which a person reverts to a more childish state where it is difficult to differ between fantasy and reality, and reality is perceived as chaotic. This can be associated with people who curl up in their cabin and hides.

Another more normal defense mechanism is repression, in which a person shuts out information that is to unpleasant to deal with. This could lead a person to act normally in a dangerous situation. These are only a few examples out of many defense mechanisms we can employ in a stressful and unpleasant situation (Timstedt, 2004).

2.7.2 First actions

Meng and Zang (2014) reveals possible results of being stressed during evacuation. The psychological stress that the participants were prone to was reflected in an overestimation of time, which subsequently led to a feeling of high time pressure. These factors may induce unnecessary panic.

This experiment also demonstrates that the participants need time to become aware of the fire, decide to start egress motions and choose which path to take. Only 8 out of 20 persons in the treatment group noticed the evacuation signs when the fire initially broke out (under 30 seconds from the ignition), while most of the control group (17 out of 20) noticed the signs and followed their directions within 30 seconds. Ultimately all the participants noticed the signs and followed their directions in order to find the exit. The explanation as to why there were fewer people from the treatment group who noticed the evacuation signs is attentional narrowing caused by high stress levels. The higher the stress level the greater the decrease of attentional capacity (Meng & Zhang, 2013).

As has been previously noted, when people experience high stress levels and time pressure they tend to make random choices or choices according to momentary stand-out characteristics of choice alternatives instead of the making rational decisions. Therefore, the aimless travel resulted in wasted time and poor navigating performance. This could explain why the treatment group had a shorter fixation duration before taking action in comparison to the control group (Meng & Zhang, 2013).

The results from this experiments show that when the participants managed to stay calm, they saved time and took proper measures (as did those in the control group). However, the results should be treated with caution, since the study was conducted in a virtual fire emergency. The research should be further developed by improving the verisimilitude of the virtual fire environment in order to achieve a higher stress level similar to a real fire emergency (Meng and Zang 2014).

2.7.3 Following others

As mentioned above, the ability to make decisions is affected in a negative way when one is in stressful situations. According to Pan, Han, Dauber, & Kincho (2007) individuals in unfamiliar environments who feel that they lack information about the ongoing emergency situation are likely to seek guidance from surrounding people. Pan et al. (2007) argued that it is known as “social proof” when individuals do not take initiative, but turn to others in order to not appeal protruding and deviate from the group. This could slow down an evacuation since some people will act passively and follow others who might not know the way. It could be even worse if an individual misleads a group of people and chooses a dangerous route towards the hazard (Pan et al., 2007).

2.7.4 Clogged exits

There are both positive and negative aspects of following others. It can be positive in the sense that passengers might find exits that they are not familiar with and would not find otherwise in an emergency. Pan et al. (2007) created a simulation in which they described this as “herding behavior”, which occurs when people decide their route towards an exit based on one or more of the following three rules. First: A person is walking randomly until they see an exit. Second: A person spots several exits and chooses the most popular one. Third: A person directly seeks the exit.

In a complex environment with many deck levels and several alternative exits, people who follow each other tend to not exploit all possibilities and end up clogging a single exit (Pan et al., 2007). This could be a serious problem and slow down the evacuation considerably, especially with a larger and denser crowd.

2.8 MONALISA 2.0 - Indoor Positioning System

The MONALISA 2.0 is a large project with 39 partners in 10 countries that introduces innovations in the maritime sector (STM Validation, 2015). One of the ideas is an indoor positioning system, a "Person Tracking System" (PTS) was developed that makes it possible to keep track of a person's position and movement inside a ship. Interest in Indoor Positioning Systems has rapidly increased over the past few years, and marked demand is strong in the maritime sector. However, the greatest development in this area has been made on land facilities where many patents have been issued for this topic (Indoor Positioning System: PTS Design, 2015).

2.8.1 The purpose

The purpose was to make a reliable PTS for crew members and integrate it with a state-of-the-art Safety Management Control System (SMCS). The report Indoor Positioning Requirement Definition (2015) claims it would be possible to effectively coordinate emergency reaction teams and have real time monitoring of their movement. Crew members could also react more quickly in case of fire in a CO_2-protected engine room, and efficiently withdraw the crew to make sure the room is clear before they release the CO_2.

It is also suggested that if a system like this existed for passengers, it would be possible to effectively coordinate and guide passengers through safe escape routes in an emergency. The system could also count passengers automatically, and identify them in critical situations, resulting in reduced total evacuation time (Indoor Positioning Requirement Definition, 2015).

2.8.2 Technology

It is a considerable challenge to construct such a system on board a ship because of a ships´s already complicated infrastructure. The MONALISA 2.0 PTS system had high requirements for the precision of position and quick and reliable detection, along with ability to withstand damage to the ship since it must be operational in an emergency (Indoor positioning System: Requirement definition, 2015). To achieve these goals, five technical solutions was proposed in the report and picked the most promising one for a real test. The first three systems were based on stationary technology in a room that could detect people with scanners. The other two systems required people to carry a device. These systems were more promising and came the closest to fulfilling the requirements above.

They chose a system called RFID (Radio Frequency Identification) for testing on board the cruise vessel *Ruby Princess*, which had the greatest advantages and was optimal for their requirements. This system consisted of fixed readers that were placed in rooms and aisles, which could communicate through radio signals with a mobile device worn by the crew. According to the report Indoor positioning System: PTS onboard validation (2015), a person's position could be viewed and followed through an operating station in the areas that were covered by the fixed readers.

The second system is based on Wi-Fi signals, and it is similar to RFID mentioned above. A mobile device is connected through several fixed Wi-Fi access points in a room and measures the strength of each signal which is converted to distance. The position is then confirmed by an additional fixed reference device that sends a low frequency signal. This together pinpoints a position (Indoor Positioning System: PTS Design, 2015). One major advantage is that wireless LAN is a common system that usually provides internet service to phones and computers. This Wi-Fi-based PTS system could take advantage of already existing infrastructure on board passenger vessels.

2.9 Evacuation with mobile application

A mobile application as an evacuation aid is described in this chapter and what types of advantages it may provide. Together with the importance of making the application layout design easy to understand and use.

2.9.1 Why an application as an aid?

Today, almost everyone possesses and is familiar with smartphones. A technological solution that people are familiar with can help during an emergency, especially when a situation can change rapidly and emergency information reaching the passengers is vital for a smooth evacuation (Wada & Takahashi, 2013). The guidance systems should be similar to applications used in everyday life, because if there is a lack of familiarity the system can be ineffective even though it provides helpful information during emergencies (Turoff, 2002).

Proper evacuation guidance is the key to a smooth egress during evacuation. An application could provide more useful information than static information like floor plans or announcements on the PA. In fact, there is a risk that there is a deaf passenger onboard who is unable to hear the PA system. An application has visible information that makes it possible for deaf people to receive guidance. A system that can function without internet would be beneficial in this type of situation, particularly because of the risk of a blackout (Wada & Takahashi, 2013).

Averill, Mileti, Peacock, Kuligowski, & Groner, (2005) states that after the evacuation of GEJE and the terrorist attack on the World Trade Center, people's behavior changed when they received alarms and subsequent guidance by authorities. When they understood the situation, received information and building layouts as well as assurance of their families' safety were addressed, they could apply the information provided in the PA system. They also found it beneficial that people were communicating with each other. Because of the rapid change of situations during an emergency, people did not get sufficient guidance from the announcements and people on the impacted floor did not even notice the announcements (Averill et al., 2005).

2.9.2 Layout of evacuation application

As mentioned in the study of Wada & Takahasi (2013) an app was developed for participants in the International Conference on Autonomous Agents and Multiagent Systems 2013 by the organizers. The first display of the application is a map with the location of the hotel, next is a floor plan of the hotel and finally the conference program. It was useful for people who were unfamiliar with the layout of the hotel to situate themselves. The situation is identical during an emergency situation. Floor plans are limited to specific places and therefore it is difficult to inform a large amount of people simultaneously but a smartphone application helps people egress smoothly (Wada & Takahashi, 2013).

Two different layouts were presented, one for everyday use and one for emergencies. The function of the emergency layout is to provide a safe and fast route to the nearest exit. The system is based on information from maps, GPS and data specific to an application. Internet connection supports data necessary for the service, while the GPS determines the smartphones' locations. However, during an emergency there is a risk of electricity failure or routers being overloaded with internet traffic, which can disrupt communication among people within the application (Wada & Takahashi, 2013).

2.9.3 Guidance and information provided

Information about the floor layout and the direction of the evacuation are crucial for achieving a smooth evacuation. For instance, a person needs to be informed of a fire nearby so that person can adjust their route and exit safely. Disaster prevention centers and authorities create evacuation plans for emergency situations by simulations. Later they create simple guides for evacuations.

The idea is to present and offer the app to people before they enter the building or vessel, like giving out a flyer. If an emergency occurs, the intention is that people would switch from the everyday use to the emergency layout of the application, and receive guidance regardless of location. The person's position is then tracked and circles are formed at the same place showing by movement the safest route to the exit, routes based on simulations (Okaya & Takahashi, 2013).

With this type of application there is the potential to assist more people evacuating at the same time, while at the same time improving emergency prevention plans. The study conducted by Wada & Takahashi (2013), proves that the number of people who are well informed about a situation has increased. Smartphones can provide new possibilities for evacuation guidance systems (Wada & Takahashi, 2013).

3. Method

A case study was made according to Denscombe (2014), with the idea that a mobile application could work as a potential evacuation aid for passengers during emergencies. The method used for answering the purpose in this report is divided into primary and secondary research. The primary method consisted of quality interviews with safety crew on board a passenger vessel, along with a quantity survey of the passengers view on the difficulties navigating onboard.

The secondary method employs scientific material regarding human behavior and evacuation, which forms the base of the theory chapters. The primary method consists of a crew member's real-life experience with emergencies, which is a trustworthy source of information. Along with a passenger's own view on navigating on board a passenger vessel. These are the optimal information sources for the purpose of this report.

3.1 Secondary research

Denscombe (2014) describes the secondary research should consist of several different documents as a source of data. The articles used for this research is produced for other purposes than the specific aim of this report, the articles will however aid and strengthen the conclusions and answers for the study.

The research was conducted according to Denscombe (2014), on what regulations exists regarding evacuation of passenger vessels, and what current methods and technical aids that exists to provide information to passengers during emergency situations. A summary of human behavior throughout evacuations was made by reading and evaluating scientific articles. We studied current researches about indoor positioning and applications for evacuations.

The search of relevant reports was mainly made on the search engines Scopus and The Chalmers library. The following search words were used, "Evacuation", "Human behavior in emergencies", "Stress" and "Public address systems". Further research contained reports from previous accidents, found on SHK. Rules and guidelines for life-saving appliances and arrangements from

SOLAS and other reports concerning indoor positioning projects from STM, MONALISA 2.0 projects.

3.2 Primary research

This chapter describes the method used for the survey and the interviews. How they were carried out, who participated and how the selection was made along with the time and place they were executed. It also covers how the analysis of the data from were made, and finally how ethics were taken in consideration in the interviews and the survey so no harm would come to the participants.

3.2.1 Interview

The interviews were constructed as a one-to-one, semi-structured dialogue according to Denscombe (2014), with staff in the safety organization on board passenger vessels. To gain sufficient content, each interview lasted 20 – 30 minutes. The interview material was sent in advance, giving the respondents time to consider their answers.

The selection of respondents was made according to Denscombe (2014), respondents that was relevant for the study and was likely to give valuable data in terms of the topic of the research. Staff from the safety organization were handpicked for our interviews, because of their knowledge and experience in the subject of crowd management, evacuation drills, and the current technical evacuation systems and aids onboard. A total of 7 participants, which consisted of a safety officer and a safety manager from Star Cruises, along with a captain, chief officer, two evacuation group leaders and a medical deputy group leader from Stena Line, as shown in table 2.

Table 2. Description of the interview respondents' position / role in an evacuation, years of experience on passenger vessels and their gender.

Position or role in evacuation	**Experience**	**Gender**
Captain	35 years	Male
Chief officer	10 years	Male
Evacuation group leader	28 years	Male
Evacuation group leader	8 years	Male
Medical deputy group leader	5 years	Male
Safety manager	4 years	Male
Safety officer	4,5 years	Male

Predetermined questions concerning evacuation together with an explanation of the mobile application and its purpose was sent in advance to the respondents. The interviews were conducted individually in two different ways; the two officers from the passenger vessel *Star Pisces* were interviewed via Skype, and the five persons from *Stena Jutlandica* were interviewed face-to-face on board during a voyage from Gothenburg to Fredrikshamn.

The analysis of the quality data was processed according to Denscombe (2014) in the following five steps: preparation, initial exploration, analysis, presentation and validation. The dialogue was recorded, transcribed and analyzed, then translated from Swedish to English. The analysis began with a review of the dialog to find underlying messages. Then all the answers in each question were reviewed in order to find obvious issues and trends among the respondents. The answers were then broken down in to smaller text components and placed in categories regarding the interviews different issues. The answers in each category was compared with each other to conclude a valid result. The relevant answers from the interviews concerning this reports questions and purpose was highlighted and is shown in the result chapter.

3.2.2 Survey

A survey for the passengers on board *Stena Jutlandica* was compiled according to Denscombe (2014), in order to investigate their knowledge about evacuation plans and current navigational methods. It consisted of closed questions, for which the participants' answers could only fit within the established categories. The answers to the questions could have a range from 1 to 10, or consist of multiple choices, or be as simple as a yes or no. To obtain a high quantity of respondents, the survey designed to be crisp and concise and only take about 5 minutes of their time.

As mentioned in Dencombe (2014) the participating respondents should have relevance to the research and give valuable data to the research. Passengers on board a vessel would likely answer our question about how passengers find it to navigate onboard, and is therefore a relevant group to target. Our aim was to interview as many passengers as possible, both men and women with a wide age range in order to get more accurate statistics. The participants' age could not be less than 18 years old, since this is the limit to travel alone on *Stena Jutlandica*. There was no upper limit for the participants' age.

The survey was conducted during an evening voyage between Gothenburg and Fredrikshamn. It was conducted as an individual face-to-face survey, making their answers as unaffected as possible by friends and other people in the vicinity.

The quantity data analysis was made according to Denscombe (2014), in the same steps described in interview results. The results from all the respondents' answers in all categories were inserted in into a compilation on Excel. Then the question individual answers where counted and compared to identify if the majority replied for example yes or no. The result from each question was made in to either a column table or circle diagram in Excel. It was then analyzed to find trends among the respondents' answers regarding their age, knowledge of muster stations location and understanding of floorplan etc. The relevant data from the survey concerning the questions and purpose of this study is then presented.

3.3 Ethics

Ethics is important to take in consideration when executing the investigation, to ensure that the research does not cause harm to the respondents. The dangers of a social research can be substantial and real for the respondents. Possible precautions and risks of the questions should be considered before presenting it to the respondents. The research should give worthwhile results without causing harm to the participants (Denscombe, 2014). All respondents were asked in advance if they wanted to participate and answer questions to support a research regarding evacuation onboard passenger vessels. The research was made according to Denscombe’s ethics.

4. Results

In the result chapter, relevant data is presented from the interviews and the survey. First the results from the interview are shown, the respondents' thoughts and experiences regarding the challenges of mustering passengers and flaws in the current systems that provides passengers with information. The potential of a mobile application is also discussed, including its pros and cons and how it could be an aid to the passengers in emergencies.

The survey was conducted on the passenger vessel Stena Jutlandica, at the sea voyage Gothenburg to Fredrikshamn. There were 40 participants of ages between 18-60, both men and women. The questions asked concerned their knowledge about muster stations and if it was difficult to navigate and find their way onboard in normal circumstances. Layouts of the application were presented, and participants were asked if they would trust a mobile application to guide them in an emergency.

4.1 Interview results

This chapter presents all the relevant data collected from the interview in a structured way without discussion. Experience from the respondents is first displayed regarding real incidents, drills and current information systems onboard. Then their thought about an application as an aid for passengers in emergencies onboard, the pros and cons and how it could help.

4.1.1 The background of the respondents

The interview consisted of seven respondents with different responsibility areas in case of emergency. They have experience between 4 and 35 years on passenger vessels as shown in table 2. Two have experience of real-life emergencies on board, grounding and fire situations where passengers had to muster.

4.1.2 Drills and previous experience regarding mustering of passengers

Star Cruises regularly hold drills during which passengers voluntarily participate in a muster drill. However, both the safety officers from *Pisces* said that it was a challenge to get them to participate. Passengers are generally not interested, although they see a trend in which younger passengers are more engaged than older passengers. The crew from *Stena Jutlandica* are not required according to SOLAS to conduct drills in which passenger's muster.

As mentioned above, two respondents have experienced a real-life emergency, one of whom is the host of *Jutlandica*. He said that during the emergency, passengers claimed that they felt lack of sufficient information. He also stated that this was probably not the case, as sufficient information was provided and it might have been solely the passengers' perception.

4.1.3 Current information systems on board

In an emergency when passengers need to muster, all respondents said that the PA system was used together with the crew to deliver the alert messages to the passengers. Four out of seven respondents saw several flaws in the PA system. Disadvantages including the difficulty hearing announcements in noisy environments. The evacuation group leader on Jutlandica said that the PA system is also used for commercials purposes, which can result in the passengers not reacting when there is an important announcement.

One of the evacuation group leaders stated that the PA system reaches a lot of people and is therefore an effective means of communication. However, he also mentioned that a mobile application could be more clear and a better alternative in those cases where people cannot hear the PA.

4.1.4 Mobile application as a guidance aid in dark and smoke-filled environments

Both officers from *Star Pisces* stated that every crew member on board the ship must perform an evacuation drill in a dark smoke-filled environment. It can be very difficult to navigate out, as the light from the signs becomes less visible after a while. The safety officer stated "It is common that crew members crawl the wrong way and are confused when they get out, and some even break down completely".

The two officers from *Star Pisces* thought that the mobile application would be a great aid in those situations. The Safety manager said that a user of the application would have light directly from the screen, and would therefore not need any external light. The application could make it possible to navigate in dark and smoke-filled environments. He thought it is important that to know which direction the app is showing in relation to the ship. The captain highlighted that it is especially a great aid nowadays when almost everyone possesses a smartphone.

The respondents of *Stena Jutlandica* explained that the smoke divers also had drills in dark, smoke-filled environments. All five *Stena* respondents agreed that it could be difficult to navigate in these situations. The evacuation group leader said that it is only smoke divers who can enter smoke-filled areas and search for passengers, so it would be good if the application helped passengers navigate out themselves. The Host of the ship confirmed that people get lost quickly in smoke-filled environments, and a mobile application could therefore be useful.

4.1.5 Cons of a mobile application

The respondents highlighted several problems with a possible mobile application. One of the evacuation group leaders on *Stena Jutlandica* stated that a mobile application could be difficult to handle when passengers are stressed. The first officer on *Stena Jutlandica* said there is a risk the passengers become overconfident with the application and it could lead to confusion if it gives incorrect directions. The Host of the ship also said that it could be a problem to get all passengers to use the application. However, he mentioned that passengers who are unable to understand the language on the PA, can still understand a picture on an application.

Both the captain and the first officer on *Stena Jutlandica* thought that a mobile application system would be another task to handle on the bridge and that the personnel on the bridge are already under pressure during emergencies. The safety manager on Star Pisces said that the application could complement current systems well. One of the evacuation leaders said that our idea about providing distress information in the application is a good way to be proactive.

4.1.6 Pros of a mobile application

Everyone agreed that this was a brilliant idea, with good intentions and that the first layout we presented was deemed good as well. The first officer raised some concerns about how to change the information in the application, such as determining the main muster station, because the information depends on the accident. He also said that there should be a function that makes it possible for the crew on the bridge to apply restricted areas to the application. If the user is heading the wrong direction, the app should sound an alarm to the user. For further research, he suggested that we could create integrated systems with functions like opening cabin doors with the app. The safety officer on *Star Pisces* said it could be a good idea to include position of firefighting equipment and lifesaving appliances, so that they are easy to notice and locate during an emergency.

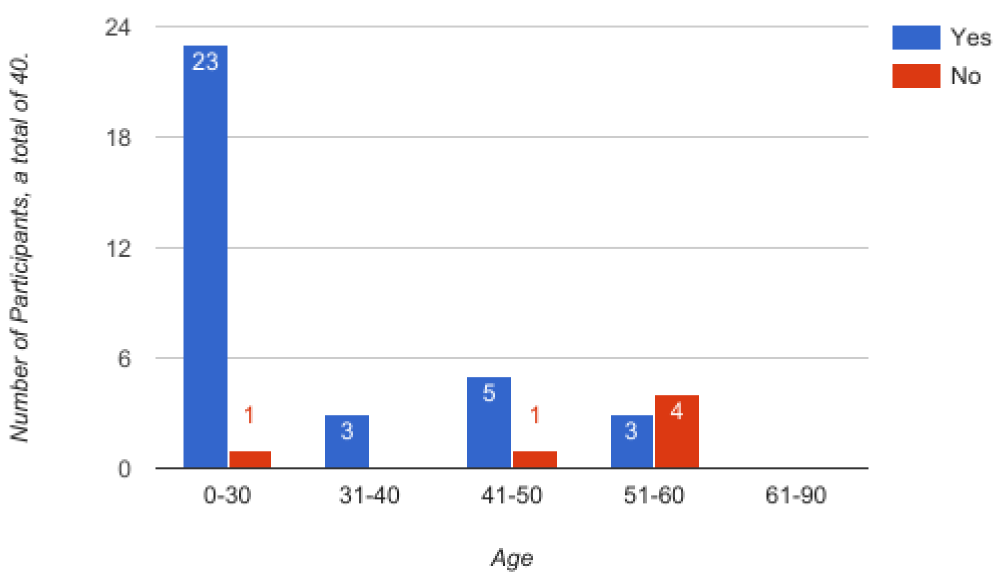
4.2 Survey results

There were 40 participants in this survey. Participants were between 18 and 60, both men and women. It was conducted on the passenger vessel *Stena Jutlandica*, during the sea voyage from Gothenburg to Fredrikshamn. The survey results are presented as column diagrams for questions in participants chose one of several alternative answers, along with pie charts where data is presented as a percentage of total participants.

4.2.1 Participants age and smartphone ownership

Table 2 presents the total number of participants divided into five age groups. It also displays whether they owned a smartphone, that is those who answered “Yes”. The result was that 85 % did own a smartphone, and 15 % did not. The purpose with this table was to find a relation between participants age and smartphones ownership. Four out of seven in the 51-60 age group did not possesses a smartphone. This was notable compared to the participants in the 18-30, 31-40 and 41-50 age groups, in which almost everyone possessed a smartphone.

Table 3. The relation between age and smartphone ownership.

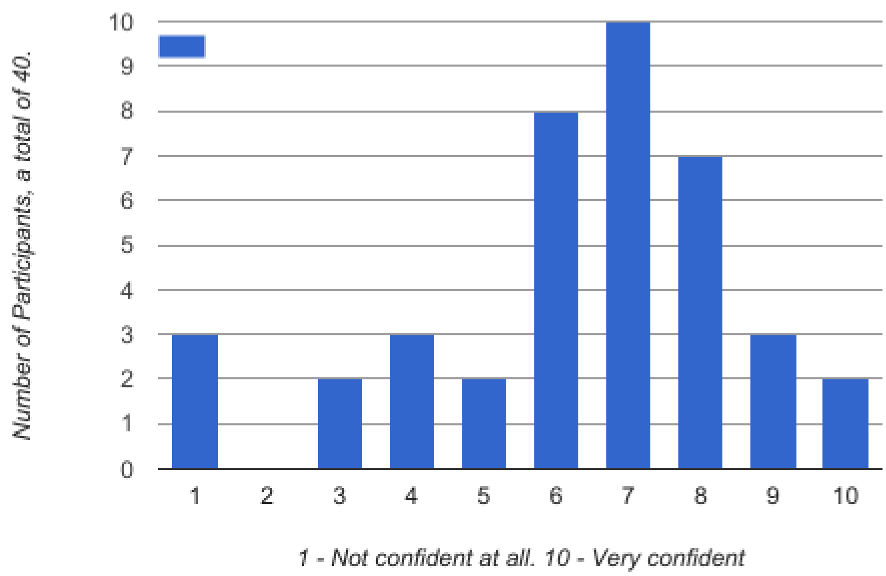


4.2.2 Participants knowledge about muster stations

4.2.2.1 Where to go in an emergency

The participants were asked if they felt confident that they knew where they should go in case of an emergency on a scale from 1 to 10, with 10 being "very confident". The average confidence was 6.3 (table 3).

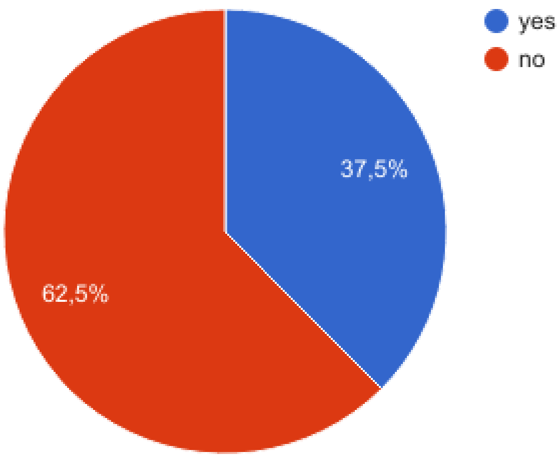
Table 4. Participants confidence on where to go in an emergency situation onboard.



4.2.2.2 Muster station

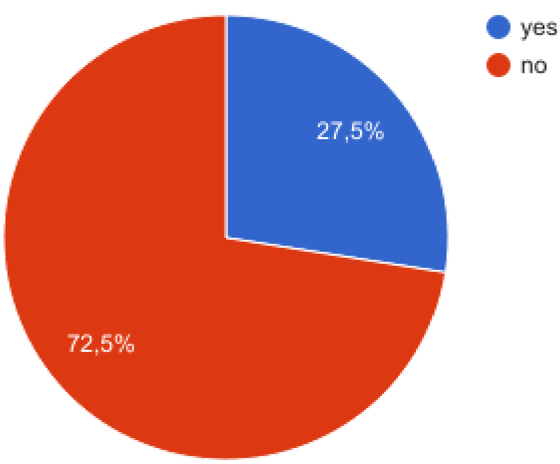
Stena Jutlandica has two muster stations. The participants were asked if they knew the location of the muster stations after the question "about whether they were confident that they knew where to go in an emergency". The result was that 62.5% did not even know what a muster station or assembly point was (circle graph 1).

Circle graph 1. Participants who knew what a muster station was.



Even fewer knew the location of the muster stations; the result was that 72.5 % did not know the location (circle graph 2).

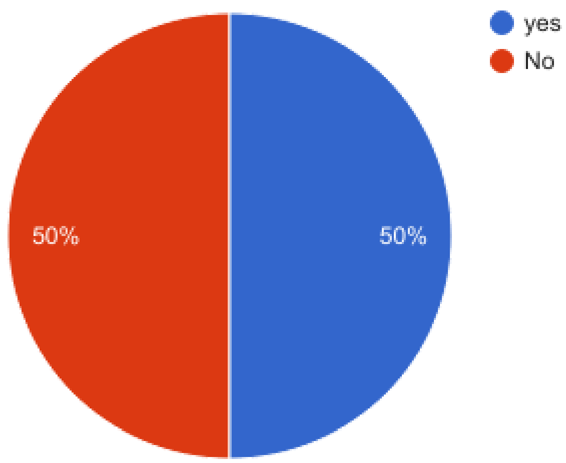
Circle graph 2. Participants who knew the location of muster station.



4.2.2.3 Information about muster station

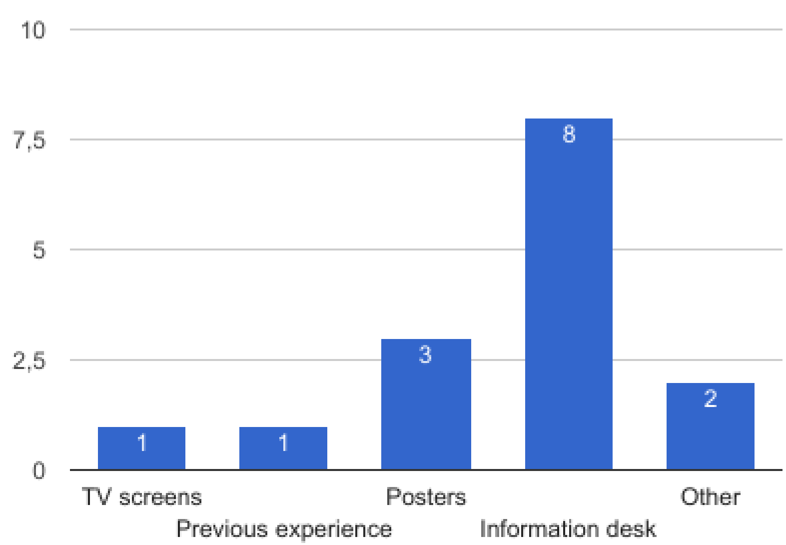
The participants who did not know the location of the muster stations were then asked if they knew where they could get that information. 50 % said “Yes”, as shown in Circle graph 3.

Circle graph 3. Participants knowledge of the location of muster stations.



Those who knew the location of the muster stations described in circle graph 1, replied that they got that information from TV screens, previous experience, posters, the information desk and elsewhere (“other”) as shown in table 4.

Table 5. Where the passengers got information about the location of muster station.

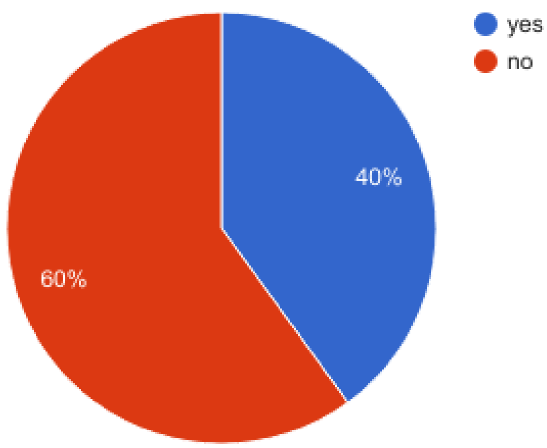


4.2.3 Passengers ability to navigate in normal circumstances

4.2.3.1 Floor plan

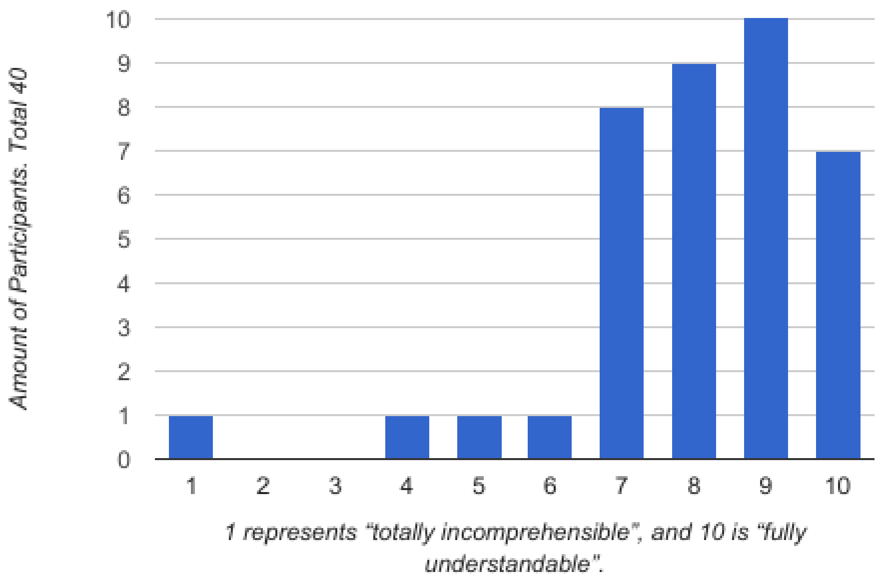
A floor plan is an overview map of the ship where passengers can find stores, restaurants, deck levels and stairs. Floor plans help passengers navigate on board a vessel. They are often placed in aisles and entrances. As Circle graph 4 shows, 60 % of those surveyed did not know what a floor plan was.

Circle graph 4. Participants who knew what a floor plan was.



A floor plan was shown to all participants, and they were asked if they understood it. Many claimed they understood it well. The average result was 8.1 on a scale of 1-10 (table 5).

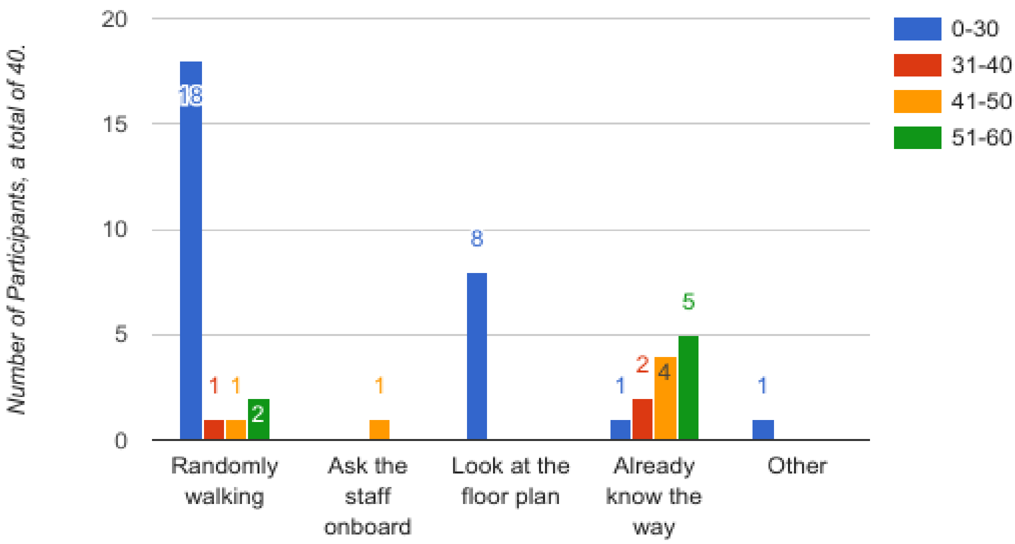
Table 6. How well the passengers understood the floor plan.



4.2.3.2 How the passengers navigated and found their way around on board

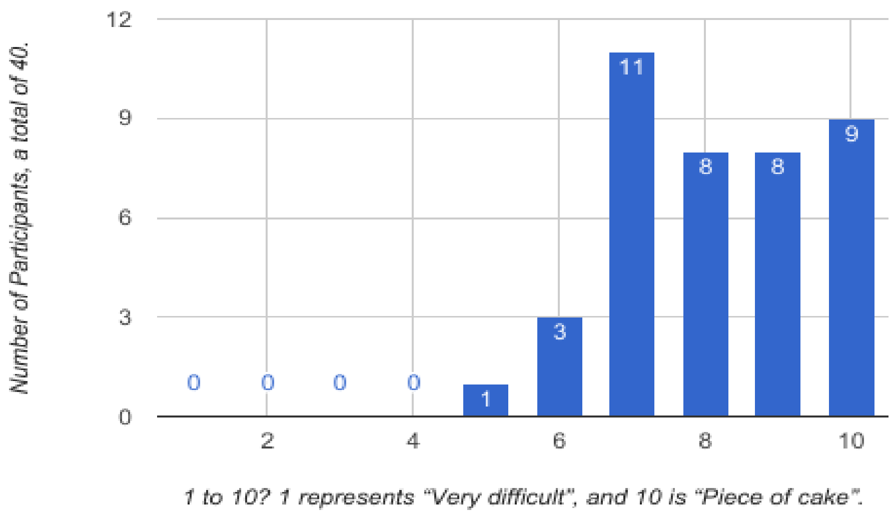
Most of the participants in the 18-30 age group seemed to walk randomly or look at the floor plan for directions when navigating. The majority of the age groups 41-50 and 51-60 replied that they already knew the way (table 6).

Table 7. How the participants navigated onboard at the moment.



Overall, the participants claimed it was fairly easy to navigate on board *Stena Jutlandica* in normal circumstances. As shown in table 7, the average result was 8.2 when they were asked if it is difficult to find their way around on board.

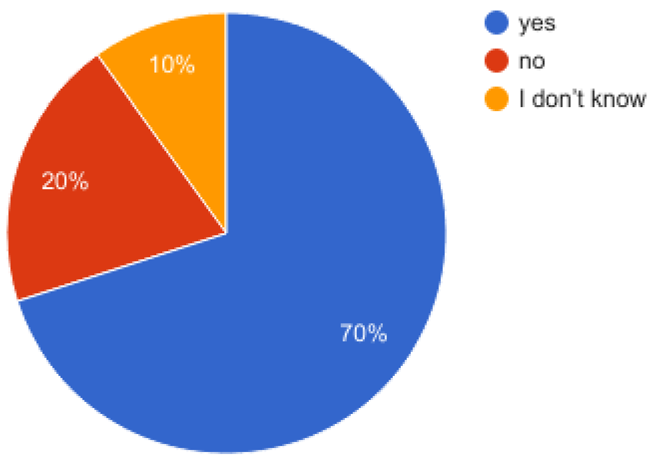
Table 8. How difficult the participants thought it was to navigate onboard.



4.2.3.3 Reliability of a smartphone application during emergencies

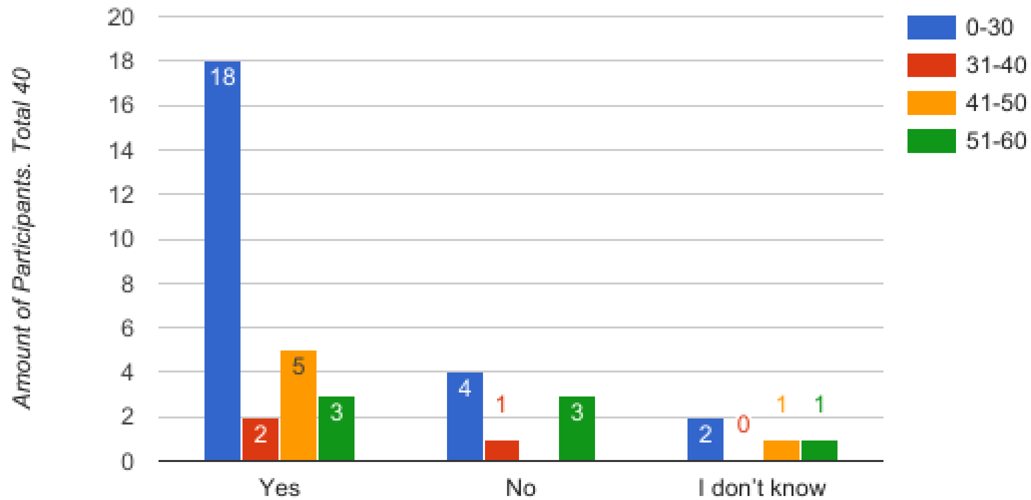
The mobile application was presented to the participants in the last question, a layout of the navigational guidance page and the information page. The participants were asked if they would rely on a mobile application like this during an emergency on board. The results are shown in Circle graph 5.

Circle graph 5. Would the participants rely on a smartphone application during emergencies, an application that would provide them with information and navigational guidance.



This table uses the same data as above, combined with the age groups. Three out of seven in the age group 51-60 would not trust a mobile application. However, there is no obvious relation between the other age groups and their trust in a smartphone application (table 8).

Table 9. The relation between age groups and trust in a smartphone application during emergencies.



5. Discussion

The result of the theory chapters is discussed with the response from the interviews and surveys regarding the usage of a mobile application during evacuation onboard passenger vessels. The challenges it faces concerning the operation of the system and the applications usability, along with the potential it presents to minimize evacuation time. How a application should function in order to safely help the passengers.

5.1 Informational guidance

As discussed in chapter 2.3.1.2, the GEJE accident show that fewer people are able to hear the PA emergency alert warnings than people who can hear it (Wada & Takahashi, 2013). One of the respondents from the crew interview have experience from a real emergency situation and could confirm this. The passengers claimed they felt lack of information, but he states that sufficient information was provided and this was solely their perception. An explanation for the passengers' experience could be ambiguous and infrequent information.

Figure 1 Example of the information page in the mobile application (Figure made by the researchers).

Displaying real time information from the bridge through the mobile application as in figure 1 above, could mitigate the feeling of insufficient information. The mobile application provides frequent information in the form of text, which makes it possible to re-read a message. This is an obvious advantage over PA announcements, which only lasts a short period of time, thereby increasing the risk of passengers misinterpreting or not even hearing a message. The crew members on *Stena Jutlandica* noted, that passengers are not always paying attention to the announcements. Receiving messages through the application can help passengers who might not listen attentively to the PA system because they are too used to it being used for things like advertising.

People understand the information from the PA system better if they understand the emergency situation, receive information and floorplans as well as assurance of their families' safety are addressed (Averill et al., 2005). Previous incidents show that people's behavior changed when they received alarms and subsequent guidance, as described in chapter 2.9.1. The application can provide this type of information in an early stage of an emergency. This will result in a better understanding of the messages given through the PA, which subsequently could result in a less passive behavior.

As pointed out in chapter 2.4.1, 60% of the people will be passive, misinterpret or even ignore the signs of an accident (Harbst & Madsen 1991). If sufficient information is provided early in an emergency, it would most possibly have a positive impact on passengers' ability to make decisions (Ozel, 2001). Therefore, a mobile application could possibly decrease the amount of passive behavior during emergencies, with its high informational guidance and user-friendly layout.

When people act passively they tend to follow others in emergencies and therefore can cause clogged exits (Pan et al., 2007). If the person taking lead goes the wrong way this can have a huge effect on the duration of the evacuation, as well as clogged exits. Therefore, if the number of people acting passively can be reduced by this application, the evacuation time can be minimized.

As mentioned in chapter 2.4.2 and 2.7.2, it takes time before passengers react when an accident occur and the response time can be minimized by giving information as early as possible (Harbst & Madsen 1991). The application leads to an increased availability of distress information during evacuation. Such information can be accessible at an early stage and even before an emergency occurs.

Another problem with the PA system was that noise levels affected passengers‘ ability messages from the loudspeaker (Stoke & Kite, 1994). The mobile application however, is not dependent of the surrounding environment. It is still possible to read messages on the application in a noisy environment. The same goes for the problem mentioned by the crew that some passengers might not be able to understand the language that is used for announcements, while others may have impaired hearing. In the application, it is possible to choose which language to receive messages.

A concern about the ability to adjust information on an app during emergencies was brought up by the crew. Information must be adjusted depending on different situations, and at different locations onboard. As an emergency develops, it would be possible to update and adjust the information on an application through a computer, and provide the passengers with the latest relevant information.

5.2 Navigational guidance

The figure below provides an example of how the navigational guidance would be displayed. It will show the phone’s position in relation to the ship and give guidance in form of arrows to the nearest or designated muster station. Users will also have, the possibility to receive directions by a voice. The display on the mobile phone is constantly lit up and is therefore not dependent on external lighting. All respondents agreed that the application would be a great aid when navigating through dark and smoke-filled environments for this reason.

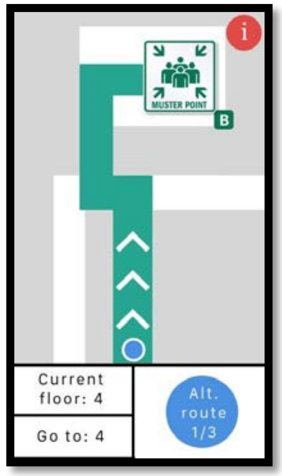


Figure 2 Example of navigational guidance layout (Figure made by the researchers).

During the interview one of the evacuation group leaders said that only smoke divers have the permission to enter a smoke-filled area, so it would be helpful if a passenger in that area could navigate out themselves with the help from the application. The application displays information necessary for evacuation, like the positions of lifesaving appliances and muster stations.

Several crew members expressed concern that the risk that the application could lead passengers towards a hazard, rather than away from it. As mentioned in chapter 5.1.1, it is possible to adjust messages on the information page depending on different situations so as not to mislead the passengers. There is also a function allowing the user them self to choose between alternative escape routes.

The answers from the survey and the interviews contradicts each other regarding the passengers' way finding ability during normal circumstances. Passengers claimed it was fairly easy to navigate onboard, while all interview respondents said that the passengers constantly ask for the way. In the case that the passengers find it difficult to navigate as the answers from the respondents indicated, the applications navigation function could possibly help them navigate and ease the workload for the crew.

In summary, the application has great potential as an informational and navigational guidance system. The functions of all current aids onboard mentioned in chapter 2.3 *Current technical and navigational aids onboard*, are covered by this single application. The PA system provides information by sound, signs as a visual guidance and posters with emergency instructions, these are all combined in the application. Thus, it has the possibility to function as a stressctive and reactive standalone aid. The survey demonstrates however that not all the passengers possess a smartphone and it cannot be assumed that all passengers have one. Taking this into account, the application should function as a complement previous existing systems rather than a replacement.

5.2.1 Challenges with the use of a mobile application.

During an emergency, the staff on the bridge will write instructions to the passengers that will be displayed on the information page in the application. The first officer on *Stena Jutlandica* thought that this would be another time-consuming task, that the officers do not have time to fulfil since they already have a high workload during emergencies, as mentioned in chapter 2.1.

Similar to the PA system, this could be operated by anybody, as for example in *Star Cruises* where staff from the information desk execute the PA announcements during emergencies. In the application system, it can be possible to insert pre-written messages that will be posted on the information page in the application. When the captain decides what pre-written announcements to broadcast, the staff for both the PA system and the application will send out the same message. In the same fashion as the PA, it will be possible to create messages manually. This might be time consuming, demanding and it can leave room for more mistakes.

A concern among the crew was the challenge of distributing and encouraging passengers to use the application. According to the survey, 50 % of the age group 51-60 would not trust a mobile application, otherwise 72 % of the total would trust the application. The answers from the survey indicates that the older generation is harder to convince to use the application. The researchers aim is to create a QR code that will be accessible for everyone at several places.

A question many asked themselves was if it is possible to handle the application in a stressful situation. As demonstrated in chapter 2.5.1 and 2.7.1, our mind falls back to a more primitive state (Karatsoreos, Bruce, & McEwen, 1997), one can imagine it being more difficult to handle the application in this state. Since these situations can be critical, there can be no room for mistakes. These are the reasons why the application must be as simply designed as possible.

As mentioned in chapter 2.9.1, it is beneficial if a person is familiar with the design of the application (Turoff, 2002). That is why it should have similar layout as current navigational guidance applications. Our idea is to create an application that can be used for everyday purposes on board the ship, so the passengers are familiar with the functions and design in case of emergency.

As found in the survey, 60 % of the participants did not know what a floor plan was, but almost everyone claimed they understood it well after it was shown to them. As mentioned in chapter 2.9.2, the application helped the people to locate and navigate themselves even if they were unfamiliar with the mobile application layout, which was identical to the floorplan. The aim is to create an application that is clear and comprehensible for everyone in all situations, so that all the passengers who possess a smartphone have the opportunity for an additional helpful guidance system.

All respondents had a positive response to navigational guidance and information being provided through a mobile application, given that it displays correct information. The project executed by MONALISA, chapter 2.8, proves that there is an interest for positioning systems on board vessels. This also proves that the technology that is needed for this application exists and could be implemented on vessels today.

5.3 Method discussion

The validity and reliability of the answers in the interview and the survey from the participants is discussed in this chapter. How some answers are more reliable and some might have been untrustworthy or misleading, and the probable cause of this. It also includes if the reliability could have been higher if the question had been asked differently, or at different vessels.

5.3.1 The interviews

Many of the respondents were interested in our subject, and were eager to participate. A total of seven participants contributed, the high participation resulted in a wide range of opinions and experience. All respondents had several years of experience on board passenger vessels, which resulted in more reliable answers. The degree of the reliability would be even higher if the interviews were conducted on more than two vessels, because it would give a wider variety of the respondents' experience. Unfortunately, this was not possible due to limitations on time.

Denscombe (2014) describes three different structures of interviews, structured, semi structured and unstructured interviews. Semi structured interviews are more beneficial for this report than structured ones, because it allows the respondents to answer more freely and to speak from past experience without being interrupted. Unstructured interviews would not be optimal since the respondents easily could wander off topic and not answering the questions of this report.

Since each interview lasted 20 – 30 minutes, it gave sufficient content and a reasonable amount of data to transcribe and compile. The validity of the questions is considered good, and the answers provided addressed the purpose and the questions of this research in different aspects.

The recording equipment that was used during the interview functioned well. The quality of the recordings was high, and there was little disturbance and untranscribable material. The choice of a calm environment also contributed to clear, high-quality recordings.

5.3.2 The survey

The reliability of the survey was on the other hand quite low, and it might have given different result if it was yield again. This is mainly because the age group 18 – 30 represented 52 % of all participants. If the age distribution of the participants were more even, results might have been more trustworthy. The survey was conducted on a relatively small passenger ship. If the survey were carried out on a cruise vessel instead, the results could be expected to have a higher validity and reliability. Firstly, higher reliability would be achieved since the application would be more effective on board vessels with complex floorplans. Secondly, the answers would be more valid since there is probably a greater need for this application on larger passenger vessel.

The validity is considered low as well for questions number 7 in the survey. Our speculation for the low credibility is because in question number 2, most participants answered that they felt confident that they knew where they should go in case of emergency. However, in question number 7 “Do you know what a muster station is?”, 62 % answered no. These two answers contravene with each other in some ways, since passengers should go to designated muster stations in case of emergency. An explanation for possible dishonest answers could be that passengers do not want to appear ignorant. The given answers from the participants might also have been affected by surrounding people answering in the same fashion.

Another explanation could be that the participants did not fully understand the questions and that the questions should have been formulated differently. An example of a question that could have been better by formulating it differently is “Do you know what a muster station is?”. The participants did not always understand the term “muster station”, but when the term was replaced with “assembly station” some changed their given answer.

6. Conclusions

Based on this study, all the respondents from the crew interview confirmed it is difficult for them to navigate through dark and smoke-filled environments. Therefore, it is presumably even harder for the passengers who are not as familiar with the environment and infrastructure of the vessel as the crew. Passengers constantly ask the staff for directions onboard, which indicates that they need wayfinding guidance.

The theoretical background and the interviews conducted in this study indicates that current distress information and systems have flaws. Thus there is room for another aid during distress. A mobile application could address numerous flaws on current distress systems and improve the availability of distress information for passengers.

There is need for a mobile application for example when navigating through dark and smoke-filled environments. However, it is not possible to know exactly what needs that are required during an evacuation. To investigate what needs that are required in an evacuation, an evacuation has to be simulated or tested in a real emergency.

6.1 Further research

As mentioned above, an application needs to be prototyped and tested in a real emergency or a well-made simulation in order to know what needs there are for an application during evacuation. Another aspect that would be interesting to study is how a stressed person might handle the application.

It is possible to construct a better analysis regarding a passenger's ability to navigate onboard by observing people. There is a likelihood of dishonest answers from interviews in comparison to observations. All in all, this study resulted with a few unanswered questions that could be further investigated. Although this study was unable to answer all possible questions, it can serve as preliminary work, a basis for further study that will doubtless prove useful.

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Appendix

Passenger survey

1. Gender

Man Woman

2. Age of respondent

20-30 31-40 41-50 51-60 70 - 99

3. Do you possess a smartphone?

Yes / No

4. Have you ever been in an emergency situation?
   Yes / No

5. *If yes*, Can you tell us about it, How did you react?

6. How confident are you on where to go in case of an emergency situation? 1 to 10?
   1 represents "not confident at all", and 10 is "very confident".

1 2 3 4 5 6 7 8 9 10

7. Do you know what a muster station is?

Yes / No

8. Do you know the location of the muster stations?

Yes / No

9. *If no*, do you know where you can find that information?

Yes / No

10. *If Yes*, where did you get the information from?

TV screens   Previous experience   Posters   Information desk   Other

11. Do you know what a floorplan is?

Yes / No

12. How well do you understand the floor plan on a scale from 1 to 10? 1 represents "totally incomprehensible", and 10 is "fully understandable".

1 2 3 4 5 6 7 8 9 10

13. How important do you think this information is?

Very important   Good to know   Not so important   I don't know

14. How do you navigate onboard at the moment?

Randomly walking   Ask the staff onboard   Look at the floor plan   Already know the way   Other

15. How difficult do you find it to navigate onboard? 1 to 10? 1 represents "Very difficult", and 10 is "Piece of cake".

1 2 3 4 5 6 7 8 9 10

16. Would you rely on a smartphone application during emergencies, an application that would provide you with information and navigational guidance?

Yes   No   I don't know

Staff Interview

1. How many years have you worked on a passenger vessel? What position do you have onboard? What responsibility areas do you have during an evacuation?

2. Do you personally have any experience of a real emergency situation when passengers had to assemble at muster stations? Could you tell us about it?

If not, go to question 3.

3. Do you personally have any experience of a drill when passengers had to assemble at muster stations? Could you tell us about it?

4. Do the passengers often ask the crew for directions onboard, e.g finding certain deck levels, their cabins, restaurants, etc..?

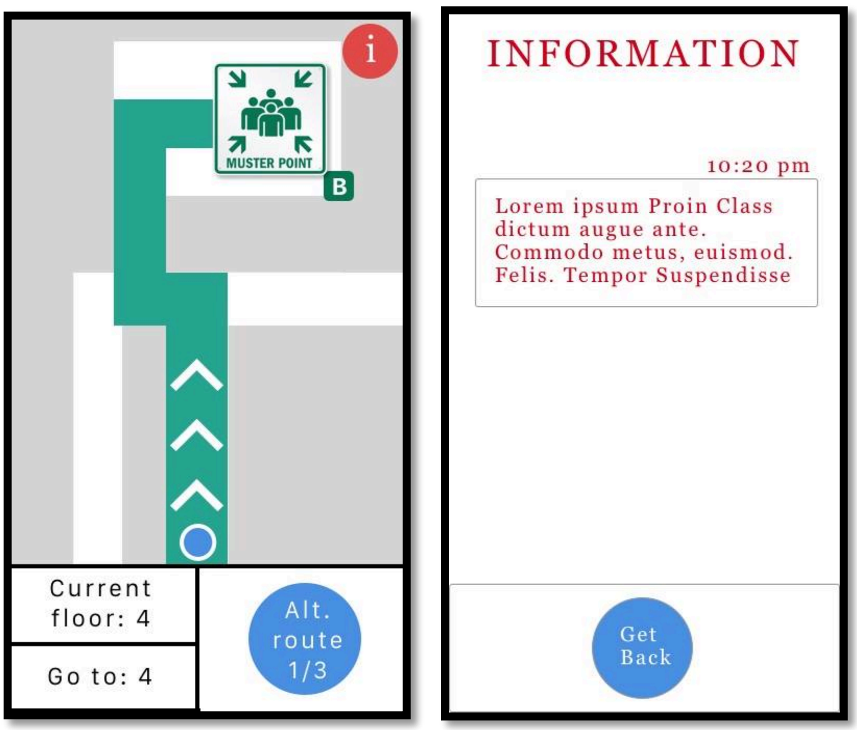
5. What existing systems do you have onboard that you use to give out information during evacuation? Do you think it is an effective mean?

6. Do you have a drill onboard where you navigate through a dark/smoke-filled environment. Explain! Do you have the drill on all vessels in the shipping company?

7. Do you think the app could be a mean of assistance? In dark/smoke filled environments? Explain!

8. Do you see any potential challenges/problems with the application?

9. Do you see any pros and cons with giving information through the mobile application from crew to passengers, in comparison to existing systems?



10. This is our first layout of the application, any comments?

11. What functions would you like to see in this application?