Aalto University
School of Engineering
Department of Applied Mechanics

Jonna Nevalainen

Modeling Passenger Ship Evacuation from a Passenger Perspective

Master's Thesis

Theses submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology

Espoo, September, 1, 2015

Supervisor: Professor Pentti Kujala, (Aalto University)

Thesis advisor(s): Markus Ahola, Master of Arts (Aalto University)

Author Jonna Nevalainen

Title of thesis Modeling Passenger ship Evacuation from a Passenger Perspective

Degree programme Mechanical Engineering

Major Marine Technology **Code** K3005

Thesis supervisor Pentti Kujala

Thesis advisor(s) Markus Ahola

Date 01.09.2015 **Number of pages** 80 **Language** English

Abstract

Current passenger ship evacuation modelling is mostly based on mechanical simulation, which tends to ignore passengers as active agents. However, maritime safety doesn't concern only the technical side of ship safety and more attention should be paid to the appropriate interaction between environment and people under emergency. This is important because, human survival depends on their perception and interpretation of the environmental and societal cues.

Comparing and contrasting the subjective perception of passenger with the physical environment helps us understand the safety environment more comprehensively during an accident. Therefore, this study uses passenger ship accident investigation reports to map environmental factors, which have an impact on human behaviour under emergency.

Current research revealed that in emergency people trust more in their own perceptions and intuition than given instructions. Human behaviour is guided by instinctual urge to get away from the danger, while rational thinking needed in way finding is secondary. Furthermore, if there's a lack in safety instructions people tend to follow each other's, which often results crowding in places that should be untrammelled in order to ensure efficient evacuation.

Current evacuation modelling doesn't consider human-environment interaction in acceptable level and given insight to affect of the human cognition on the evacuation process can be used to develop evacuation analysis onwards.

Keywords passenger ship, evacuation, human behaviour, safety

Tekijä Jonna Nevalainen

Työn nimi Matkustajalaivan evakuoinnin mallintaminen matkustajan näkökulmasta

Koulutusohjelma Konetekniikka

Valvoja Pentti Kujala **Koodi** K3005

Laitos Sovelletun mekaniikan laitos

Työn ohjaaja(t) Markus Ahola

Päivämäärä 01.09.2015 **Sivumäärä** 80 **Kieli** Suomi

Tiivistelmä

Nykyinen evakuiontimallinnus perustuu matemaattiseen mallintamiseen, missä ihminen on ympäristössään passiivinen toimija. Tarkastellessamme evakuointiturvallisuutta, huomiota tulisi kiinnittää ihmisen ja ympäristön välisen vuorovaikutuksen sujuvuuteen. Se, miten hyvin ja tehokkaasti kykenemme tulkitsemaan ympäristön tarjoamia vihjeitä sekä hyödyntämään niitä omassa toiminnassamme,vaikuttavat selviytymiseemme hätätilanteessa.

Tutkielmassa kartoitetaan onnettomuusraporteista ihmisen käyttäytymiseen ja toimintaan vaikuttaneita ympäristöllisiä ja sosiaalisia tekijöitä. Tarkastelemalla yhteyttä ihmisen subjektiivisen käsityksen ja todellisen ympäristön välillä, voimme muodostaa kuvan siitä, millä tavalla ihminen kokee ympäristönsä onnettomuustilanteessa.

Tutkimus paljasti, että ihminen luottaa onnettomuustilanteessa omiin vaistoihinsa ja havaintoihinsa ympäristöstä. Ihmisen toimintaa ohjaa vaistonvarainen halu päästä turvaan ja tässä tilanteessa ihmisen rationaalinen käyttäytyminen on toissijaista. Miehistön opastuksen ja informaation puuttuessa, ihmiset seuraavat toistensa käyttäytymistä ja toimintaa. Tämä johtaa usein ruuhkien muodostumiseen paikoissa, jotka turvallisuussyistä tulisi pitää vapaina.

Tutkimustulosten perusteella voidaan todeta, ettei nykyinen evakuointimallinnus huomioi riittävällä tasolla ihmisen ja ympäristön välistä vuorovaikutusta. Ihminen on ympäristössään aktiivinen toimija, jonka kognitiiviset ominaisuudet, kuten havainnointi ja päätöksenteon prosessit vaikuttavat evakuointiprosesssiin merkittävästi. Kehittääksemme mallinnusta vastaamaan todellista onnettomuustilannetta, ihmisen kognitiiviset ominaisuudet tulisi huomioida ja liittää osaksi laivan evakuointimallinnusta.

Avainsanat matkustajalaiva, evakuointi, ihmisen käyttäytyminen, turvallisuus

Acknowledgements

I have completed my theses as a research assistant in Aalto University's school of engineering and department of Applied Mechanics. My theses was supported by Maritime innovation hub Meridiem.

I would like to thank to my instructor, Markus Ahola, for his support, advice and sharing the knowledge about the topic which has been valuable for my theses. I would like to express my gratitude to my supervisor Professor, Pentti Kujala, for giving advice and moreover letting me freely choose my theses subject which approach to the ship modeling from very different perspective than normally used in naval architecture. In addition, I also would like to thank Commander Jukka Savolainen, for sharing his long experience of dealing with ship rescue operations. I have also get good feedback from Cruise and Ferry board members and fellows from ”Triad project.” It has been very helpful during working with my theses.

Overall, it has been an interesting and enlightening journey of writing my theses. I am thankful many of my friends and especially to my parents and sister, who have been giving them unconditional love and support for me. I would like to thank my friends Maija, Heidi, Aki, Paula S and Paula J for supporting me in my theses and studies but also sharing the free time with me when I have needed the most. Especially I want to express my gratitude and respect to my dear friend Tiina for sharing this project with me, proofreading and giving me though of happiness. The graduation to Master of science and completed successfully my theses has been my own work but I could not have made it without all of your support.

Thank you.

Espoo, 01.09.2015

Jonna Nevalainen

Table of content

1.Introduction

1.1. Designing for safety in passenger ships

Over the past decade cruises have become ever more popular among vacationers when, at the same time, the development of passenger ships has lead to larger ships being built, increasing the capacity to thousands of passengers on board. Even though still rare, the consequences of a serious accident have now potential to be even more disastrous than before. Safety on a large passenger ship is therefore an acutely sensitive issue. (Vanem and Skjong, 2005, p. 112)

During its existence the IMO has introduced a series of methods and measures to prevent accidents from happening, as well as adopted several regulations to be followed in order to minimise the consequences of accidents. Many of the disastrous accidents occurred in the past - for instance the capsizing of Herald of Free Enterprise in 1987 and later on the sinking of the Estonia in 1994 - have critically sharpened the improvements on the safety regulations for passenger ships. (Vanem and Skjong, 2006, p. 112)

The design objectives for safety are defined in the mandatory regulations entitled The Guideline for Evacuation Analysis (circ. 1238), approved by Maritime Safety Committee (MSC) and issued by the International Maritime Organization (IMO). The purpose of the regulation is to ensure that evacuation performances meet the requirements stated in the guidelines, which have been set to a maximum of 60 minutes of evacuation time in total for RORO ships, and 80 minutes for passenger ships. Total evacuation time can be calculated with formulas provided by the IMO and it should also be in line with the ship's classification and the ship owner's reguirements (IMO, 2007).

Even though evacuation modelling has evolved during the past decade, unfortunately human behaviour has not gone through a similar process (Park et al., 2004). Current evacuation modelling is mostly based on simulations of physical phenomena, which still tends to ignore passengers as active agents. For instance, it is impossible to distinguish the route choice of an individual through the modelling process because the human way finding process is far more complex than simply choosing the shortest path or the most optimal route, which are used as criteria for the simulation algorithm (Golledge,1992). Since the modelling purposes have focused on the quantification of human performance in the evacuation, the models are unable to explain why people act in a certain way and what are the factors triggering their (sometimes inappropriate) behaviour. In other words, human behaviour is mostly understood and modelled by physical quantities such as gender, age or walking speed, rather than considered through the cognitive process of a person. These methods thus neglect important value in human performance, which is also essential to the assessment of the evacuation process.

1.2. Problem statement and objectives

During an evacuation a person has to overcome several decisions and activities in order to survive. How people succeed in an emergency depends on their perception and interpretation of social and environmental cues. It is crucial to include human perception in the safety design process because it affects the behaviour significantly. Furthermore, when there is a comprehensive understanding of how these particular features in the ship environment influence the behaviour of passengers, we are able to identify critical safety drivers in an emergency (Ahola et al., 2014, p. 230).

This study uses mostly passenger ship accident investigation reports to map environmental and social factors affecting human behaviour under an emergency. Comparing and contrasting the subjective perception of a passenger with the physical environment helps us understand safety environment during an accident more comprehensively.

The main research question is: "What are the most important factors influencing the passengers during evacuation process?" Additional questions are: "What kind of environmental cues have people used in their decision-making process in an actual emergency?" and "How does panic affect information processing and decision-making in an actual emergency?" And finally, "How can the research outcomes be utilised to develop evacuation analysis in the future?"

1.3 Study framework

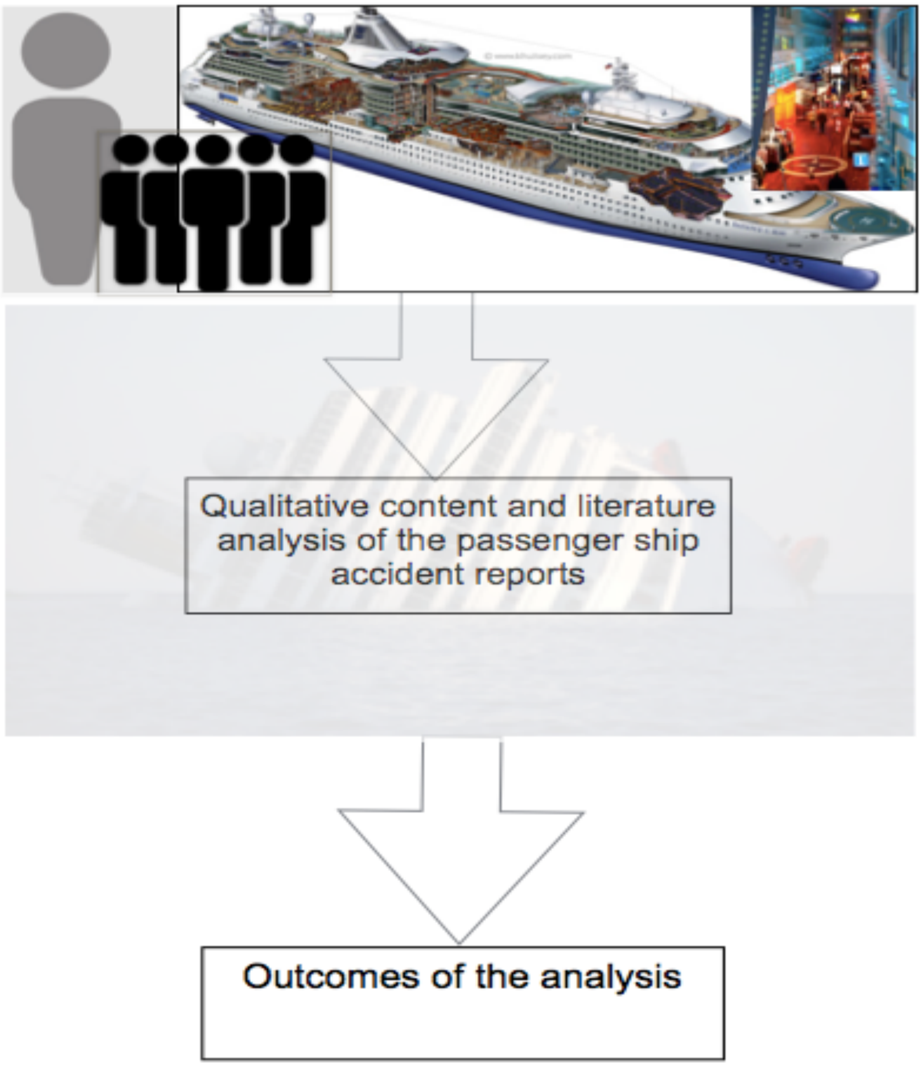

Figure 1 Study framework

In the framework Human-Environment elements interact with each other. This is described as a process of an ongoing action, interaction with the environment or social groups, as well as emotions experienced in response to the situation. Human abilities are defined as the core element, to which other elements (the environment and social groups) acting in the framework are related. Human actions, interaction and emotions occur throughout a period of time, involving sequences of inter/action and emotional responses whose ultimate purpose is to reach or handle the goal, which is defined by the accident event. However, any action or emotional response to accomplish the goal depends upon the circumstances and how a person or group perceive and interpret the ongoing situation. The element of environment in the framework represents the circumstances and stimuli to human behaviour. This theses does not study the crew behaviour, culture, attitudes or knowledge in accident situations and its influences to passengers as in one element. Therefore, the crew have been screened out of scope of the theses framework. However, crew activities as a part of the procedure is taken into account in the theses. Analysis examines passenger's behaviour and interaction with environment through features of qualitative content analysis and literature reviews. The aim of the analysis is to provide answers to research questions based on what can be deduced from the study outcomes and consider them through the design and modelling perspectives.

2. Literature review of evacuation planning

This section provides a review of the fundamentals of evacuation planning and guidelines behind it. It describes the evacuation modelling process, modelling parameters, especially focusing on parameters on human behaviour during emergency evacuations and gives an example how evacuation is currently simulated.

2.1 Fundamentals of risk-based design

The ship design process in 90's relied on prescriptive goal-based way of thinking. Goal-based design means that ships are built in accordance to high-level standards, rules and regulations to ensure the operational safety of the ship. However, in the past decade, the market of cruise industry has been stable in growth. Since 1990, over 200 million passengers have taken a cruise (FCCA, 2013). The meet demands of the market meant also enlarging ship sizes (FCCA, 2013). Current passenger ships carrying up to 8.000 people onboard surely are safety-critical and knowledge-intensive systems which makes safety indeed a significant design driver (Vassalos et al, 2006). In this respect, the regard for human life has continuously increased. These facts challenged the usage of goal-based approach for design purposes.

When changes in design philosophy started in the early 2000s they were linked with major accidents having intolerable consequences in respect for human life, environment and property. Improvements in safety have been driven by accidents thus far. For instance, the sinking of *Estonia* (1994) inspired improvements in the safety regulations for passenger ships but accidents like that also emphasised that accidents at sea happen often as a result of human error (Cacciabue, 2004). In goal-based approach safety was considered merely through technical analysis, which was not seen as a proper and holistic way to improve safety (Wang, 2001). In order to override problems within the goal-based design philosophy, it was replaced by risk-based methodology with an advanced view of integrating safety cost-effectively within the design process (Vassalos, 2006).

Risk-based design is a formalised design methodology including formal risk assessment framework that facilitates the system integration of risk analysis in the design process with prevention or reduction of risk treated as a design objective (Vassalos, 2006). Safety awareness has come to the forefront and it is seen as an integrated part of the design process rather than considered isolated or fixed by add-on (Papanikolaou, 2009; Vassalos, 2006). In practice, it offers freedom to the designer in the early state of the process to choose an optimal solution for meeting safety objectives. However, decisions made within the process are always reflected with costs, whereby safety investment is targeted to achieve the greatest benefit and performance with proactive manners to guarantee complete regulatory requirements responding to the severity of risks (Lois et al., 2004; Vassalos, 2006). A successfully achieved design objective of risk-based assessment is a comprehensive and numerically efficient risk-cost model depicting knowledge of integrated ship systems and their relation to prioritised risks, consequences and risk control options.

2.2 Evacuation modelling process

Evacuation is the protective action used in cases of ship emergencies and it can be seen as the withdrawal action of people from a specific area because of a real risk. An essential element of ship evacuation plan is a well-defined layout plan where accurate preplanning adds to the effectiveness of the evacuation process. Evacuation in case of any critical ship risk scenarios result in drastic movement inside the ship and in the demand over the ship's evacuation system. Therefore, the time used to complete the evacuation has critical importance and especially affects the success of the emergency evacuation. In emergency circumstances the overall objective is to muster the passengers as quickly as possible and any lack of ability in unequivocal decision-making process could lead to delays in abandoning the ship. Failure of evacuating people in time will be fatal and the time spent escaping the ship will be crucial. (Vanem and Skjong, 2006).

Today, the objective of evacuation planning is to identify not only the best but also the shortest evacuation routes and provide estimates of time needed to evacuate the people onboard. Evacuation time estimates due to different risk scenarios provide sufficient warning to the crew (or master) and reduce people's exposure to the risk. Analysing the risk scenarios provides the knowledge needed to reach a balance between risk and time awareness, given the last possible time for orders to evacuate and to avoid evacuation without people losing their lives.

The effectiveness of an evacuation process is measured by the estimated time for evacuation. It is defined as the time required to evacuate people from the risk sphere of influence. An evacuation model is a system to simulate and evaluate the effect of evacuation parameters. Because evacuation is mainly dependent on the behaviour of individuals, evacuation parameters are those which describe the physical behaviour of an evacuated individual in case of an emergency. (Hongtae et al., 2004).

2.3 Human behaviour parameters

Prior studies (Galea et al., 2011; Ha et al., 2012; Lee et al., 2003; Park et al., 2004; Vassalos et al., 2002) have shown that predicting human behaviour during the evacuation is very complicated. This is mainly because quantifying parameters for modelling purposes is challenging since many physical and psychological factors vary due to different types of accidents and environments. Consequently, human behaviour is evaluated in the evacuation analysis based on velocity only (Ha et al. 2012). The valid parameters are presented in the guidelines on evacuation analysis for new and existing passenger ships, IMO/MSC Circ.1238 approved in 2007. It should be noticed, that the aim of the guideline is to provide approximation of the ship's total evacuation performance rather than to model an actual emergency (IMO,2007). Since interests are solely directed towards identification of bottlenecks and assessment of the ship layout, developing an alternative chain of events in the emergency would increase the knowledge of how different choices influence the escape route efficiency and total performance.

However, guidelines suggest two distinct methodologies for evaluation purposes. In the guideline, a simplified method is obligatory and used as a first stage analysis. In this case, human behaviour is modelled only on a group level. Accordingly, method utilises predefined individual data of walking speeds on stairs and corridors which are derived from civil building experience. At the method, total evacuation time is quantified as a flow time. It is based on a calculation of flow of people via escape routes from corridors and staircase either/or doors or public spaces. Flow time calculation is repeated for every space on the ship and the total evacuation time is defined by the flow times added with specific predefined congestion and counterflow factors. Furthermore, total time of evacuation is calculated separately for both day and night cases. (IMO, 2007).

Another method introduced in the guideline is an advanced evacuation analysis. However, verification of simulation tool as well as validation of parameters are still on process and for this reason the advanced evacuation methodology is not totally ready for use (Galea, et al., 2013; IMO, 2007). The model proposes a set of parameters which specify a person's physical abilities on a more detailed level. These parameters are categorised into four; environmental, geometrical, procedural and population (Vanem and Skjong, 2006).

In short, the environmental category describes static and dynamic condition of the ship but assessment of listing effect is still uncompleted (IMO, 2007). More reliable data need to be gathered before these parameters can be used for modelling purposes.

The difference between static and dynamic conditions is defined by sea environmental and ship operational conditions. Intact conditions are understood as a static conditions which means that ship is in normal operational configuration. In contrast, ship dynamic conditions are related to ship damage conditions. For damaged conditions are affected by risk scenario and behaviour of the sea. Flooding increase the heeling angle and decrease stability of ship. Together with the external environmental factors it cause the ship heel at an angle. In methodology heeling angle and its dynamic nature are not taken into account and thus intact and damaged conditions have not been differentiated from each other yet (Ginnis et al., 2010; IMO, 2007). Considering passengers, listing decrease humans pedestrian in inclined plane and further availability of some designed evacuation routes might not be in use because of listing. These factors together emphasize the necessity to facilitate way finding in complex environment.

Procedural category in turn recommends four scenario cases to be modelled instead of two (night/day). Added evacuation cases consider longest possible evacuation time during night and day time (IMO, 2007). However, for example, crew guidance under emergency is not suggested to be considered in any manner. Population is the only category containing detailed data from speeds and response time. It presents a composition of individual walking speeds consisting of a wider range of values regarding gender and age (IMO, 2007).

The model itself is based on dynamic movement of pedestrians. Equation is adopted from the model of social force, which measures each of individual's internal motivations to perform in a certain situation. The model produces a detailed data of interaction, crowd and counterflow-avoiding behaviour.

Ha et al. (2012) tested social force model in a ship environment by using a cellular automata model (CA). CA is a two-dimensional simulation tool, in which every agent occupies one grid at the beginning and then by using a rule-based algorithm moves from one grid to another toward the preferred direction (exit) with desired velocity. The movement of each individual is recorded. The tool is used especially when examining the exit dynamic in a passenger evacuation case.

The social force model was tested in different evacuation scenarios (day, night) and spaces (cabin, corridor) in order to verify the proposed model but also to make sure that software components worked as planned. Test results were confirmed by comparing those with requirements of total evacuation time by IMO. In case of RORO passenger ship with total number of 1892 persons onboard test result was satisfactory, 37 minutes 50 seconds in total which is less than the required 60 minutes. (Ha et al., 2012). However, despite the fact that the total evacuation time was under the maximum requirement, it is difficult to make comparisons with corresponding accidents that occurred in the past, because there are no post-stage evacuation analysis about total evacuation times in such cases. But when reflecting the CA model results to these real-life accidents, the evacuation time usually differs quite a lot. For example, in case of RORO passenger ship Sally Albatross grounding incident in 1994 in the Gulf of Finland an orderly evacuation of 1550 people took 2 hours 20 minutes (Sally Albatross Accident Investigation Report). Reflection indicates that perhaps using only a mechanist simulation is not accurate enough to evaluate evacuation time.

Counter flow is also simulated by the CA. This shows that the total evacuation time increases with relative increase in the number of persons in the room (Ha et al., 2012). Helbing et al. (2000) have simulated crowd dynamic similarly but for building environment purposes and concluded that individual movement to counter direction has an obstructing influence which at its worst can trigger panic in the crowd. For this reason, it would be necessary to prevent counter flow entirely. In reality, prevention is perhaps impossible, because people have a tendency to behave similarly to people surrounding them. Affecting people's behaviour by offering environmental anchor points, way finding in complex or unfamiliar environment will likely decrease way finding errors and chaos among people (Colledge,1992). In addition, in the evacuation models are missing puzzle of escape behaviour where the speed of movement is directed down stairways in a threatening situation.

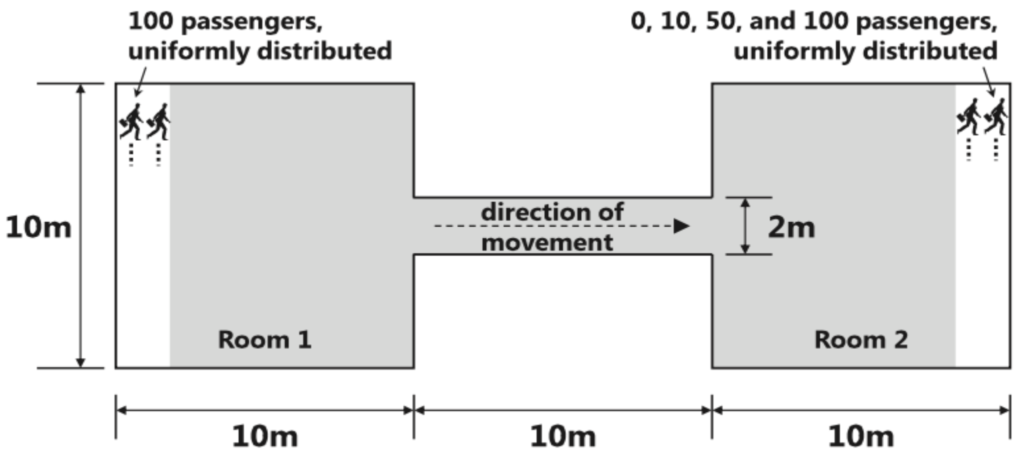

Figure 2 Simulation of counter flow (Ha et al.,2012)

To summarise the guideline methodologies, the simplified method is easy to use but contains weaknesses, because it consider identical characteristics for all passengers, which reduce the quality of the method. Furthermore, in the simplified analysis, human response to emergency alarm sound is considered and determined collectively only.

Based on scenario setting response times are 5 minutes during the day time and 10 minutes at night. However, the advanced method brings up response time as one parameter in the evacuation analysis. Response time reflects the time spent in the pre-evacuation phase. As opposed to the advanced method, simplified analysis does not consider the dynamic flow of population with crowd behaviour and interaction. Furthermore, the ship motion has not yet been taken into account in either methods. (IMO 2007).

2.4 Human behaviour data collection from full-scale trials at sea

One way of collecting human related data about response times is by conducting empirical exercises. In maritime industry, the main purpose of data collection is to implement acceptable criteria for response and assembly time in an emergency in order to test and validate ship evacuation models. It has been stated that collection and characterisation of human performance data facilitates understanding of people's behaviour in an emergency and fills the lack of comprehensive data regarding human response times with a sufficient collection size. Data has been collected during the past few years with the help of three sea trials onboard of cruise ship and ROPAX ship at sea (figure 3 and 4). Experiment design differentiated from previous trials, because before trials were conducted in the port. For the experiment two different ship types were used for generating diversity to passenger response activities. (Galea et al., 2011; 2013).

Figure 3 Jewels of the Sea, Royal Caribbean Cruise Line (Cruise ship)

Figure 4 Olympia Palace, Minoan Lines (ROPAX)

Trials consist of three types of data settings. First, passengers' response time is collected by using video cameras. Cameras are positioned throughout the ships to record passengers' response time and activities during that time. This phase also included information and action tasks completed in response phase. Second type of data comprised of assembly time for evacuation model validation purposes. In the trial each of individuals' paths were tracked from their initial location to the assembly station. This was based on the usage of IR tagged system. This method provided details of the escape routes taken by individual passengers but also the average speed and population densities in certain areas. The third data collecting method consists of a questionnaire filled out by each passenger participating to the trials (Galea et al., 2011). However, the results of questionnaires were not presented in articles, thus it was not clear what the questionnaires were for and what kind of role the answers had for the analysis of response time and the final results.

These semi-unannounced trials followed the process of evacuation procedure and thus were carried out in ideal conditions. Passengers were informed that the experiment may take a place during their cruise however, the exact time was unspecified. The trial started by the ship Master sounding the alarm in the morning, after which the crew was guiding the passengers into the designated assembly areas. Passengers had their assembly points indicated in their keycards. The end of trial was determined by the Master and the trials were usually completed within 10-12 minutes until the most of the passengers were assembled. (Galea,et al., 2013).

In the trials the onset of stimulus was presented in audio and the response times and activities involved were analysed by video footage. When measuring response time in trials it is generally assumed that people's responses to auditory stimulus spread out in time. In functional sense, conditions were generated on a basis of explicit instructions.

The results of the experiments were presented dividing the data setting in distributions of response time and assemble time. Simulation of the validation data was conducted by maritimeEXODUS software. The software suits for determining the performance of passengers as well as crew under emergency with variety of scenarios. The model is advanced and has several different unique abilities but especially due to time, simulation outputs are able to e.g. predict time frames required to assemble or for individuals or groups to perform specific tasks as a part of a given scenario. (Deere et al.,2009).

Each response time setting in a specific area was fitted in the log normal curve and further constructed in overall distribution of response time. The response times of 1228 passengers in the cruise ship trial were determined as follows: the passengers' overall response time distribution with key parameters were minimum of 0 seconds and maximum of 1379 seconds, whereas the log of the mean response time is at 5.012 seconds with standard deviation 0.89. (Galea et al., 2013 p.162).

In ROPAX ship trial, response times were determined in regional spaces of the ship's public places (Galea et al. 2013, p.160) and similarly to the cruise ship trial the starting regions of passengers were known. Response time distribution was determined for each region separately, because some of the passengers did not want to be tagged, but still participated in the experiment. However, the response time distribution for passengers in the bar region was a the minimum of 0 seconds and maximum of 402 seconds whereas the log of mean value was 3.432 seconds with standard deviation 0.924 (Data for day 2 trial) (Galea et al., 2013, p.161).

Recommendations to improve the response time distribution from current guidelines have been generated by distributions from new data collection. Current guidelines consist of two alternatives; day and night case response time distributions, which are suggested to be 300 seconds (5 minutes) in the day time and 700 seconds (10 minutes) at night. On the basis of results from the trials, ROPAX and cruise ship response time distributions are proposed to be presented separately. In order to generate a more representative and robust distribution ROPAX trials results at sea could be combined with existing day case response time distributions (generated trials in port). Being statistically almost identical, the current day case guidelines could also represent ROPAX response time distribution in the future. Since there is no appropriate data available, night cases should remain unaltered for now. (Brown et al., 2012).

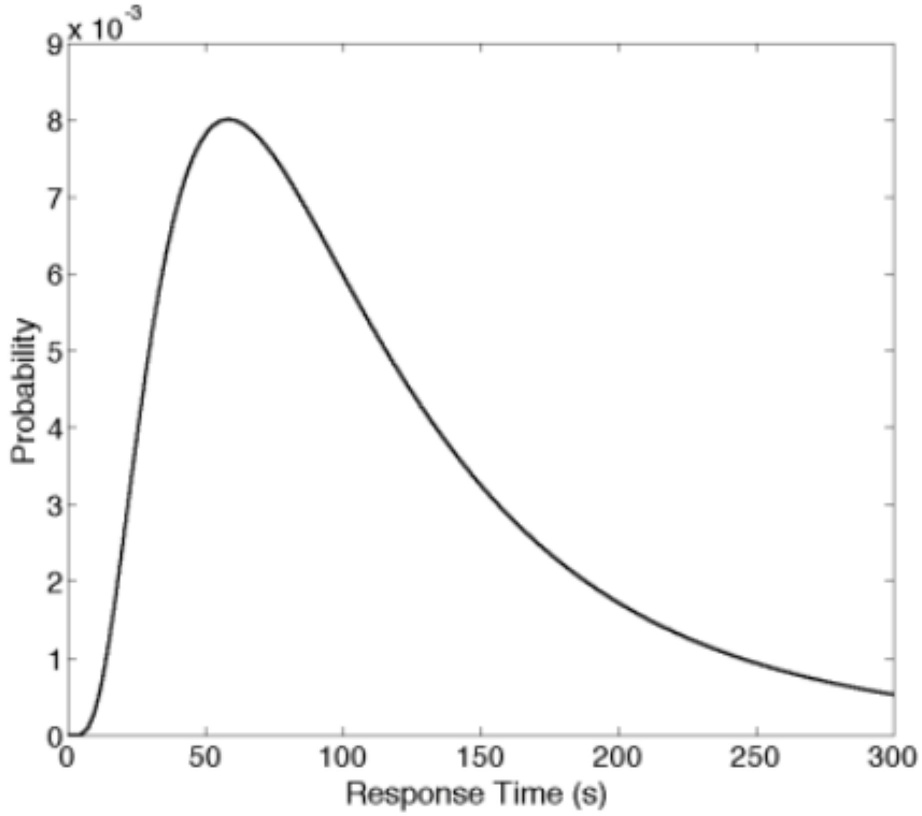

Figure 5 Suggested new IMO day case for cruise ships (Brown et al., 2012)

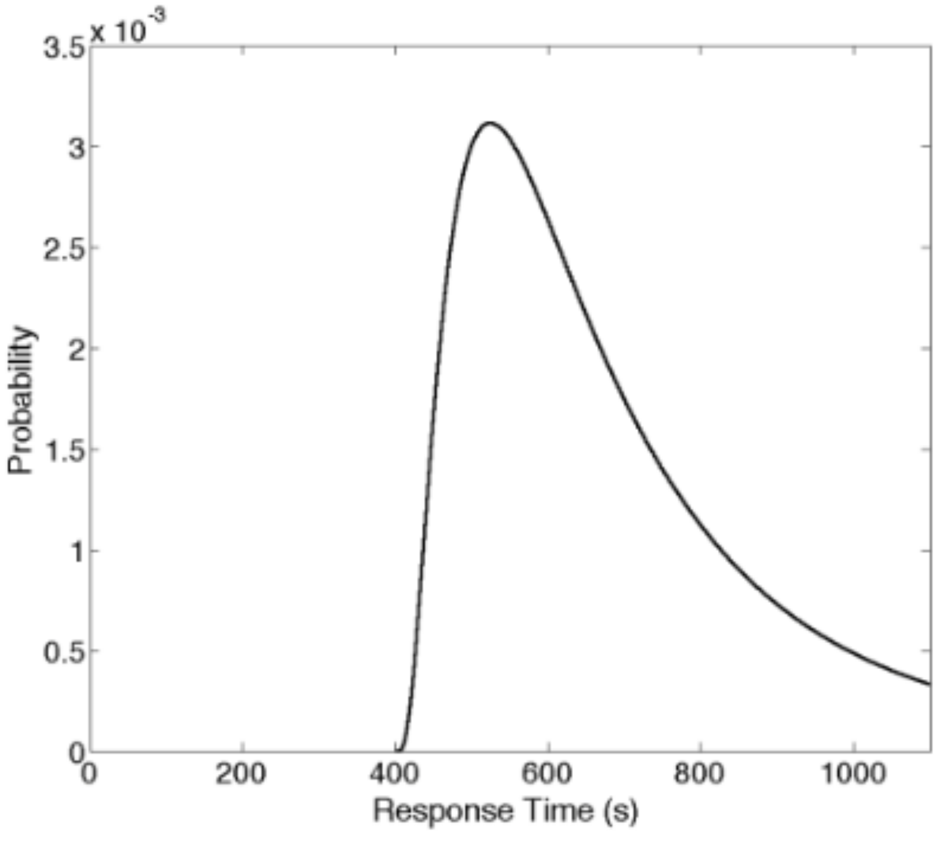

Figure 6 Suggested new IMO night case for cruise ship (Brown et al., 2012)

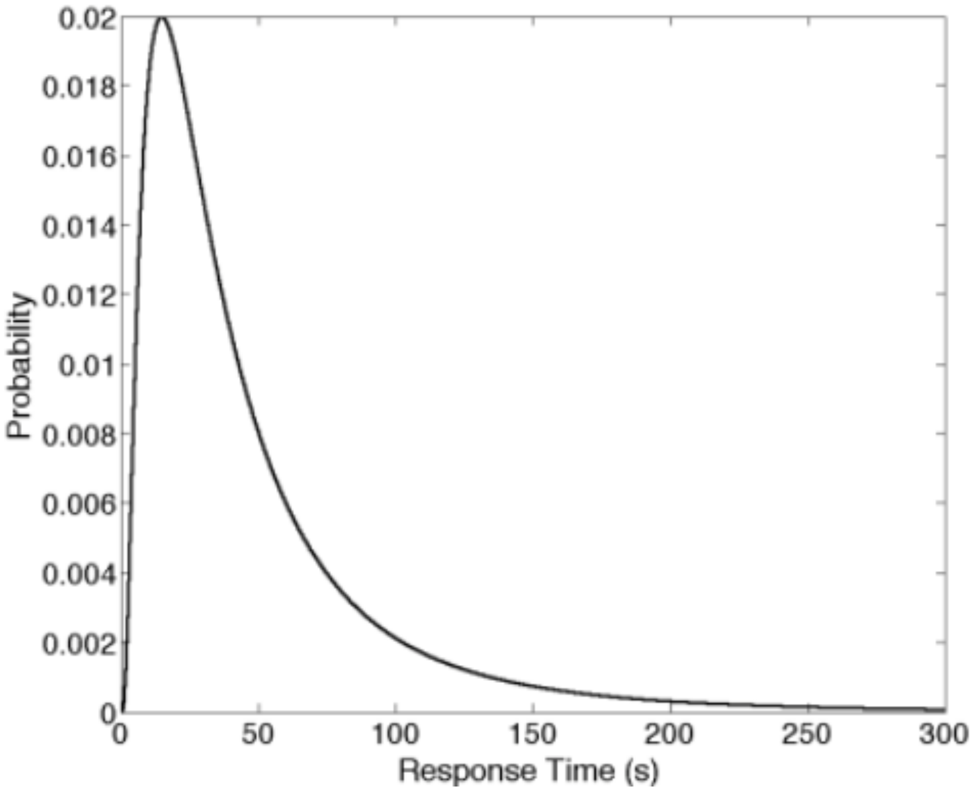

Figure 7 Suggested new IMO day case for ROPAX ((Brown et al., 2012)

Since it is suggested that the guidelines are modified to separate ROPAX and cruise ships, the proposed new response time distribution for day cases on cruise ships is generated from public areas on the ship. Similarly to the current IMO day case response time distribution is truncated at 300 seconds. Response times for night time cases are derived from trials on cruise ships' cabins area. To represent considerably more reliable response time distribution for night time, the tail extends to 1100 seconds and it is shifted by 400 seconds to account for the assumption that passengers are sleeping. (Brown et al., 2012).

The objective is to go towards realism in the experiments (Galea et al., 2013). However, the generated distributions of response times represent a functionally and operationally intact ship in the day time. Furthermore, the passengers' response time cannot be disassociated from the human cognitive processes - such as attention or perception which are related to human reactions - and limit the study to the time scales alone. The lack of realistic conditions in experiments causes missed responses, because they are not representative of actual accident conditions.

2.5 Simulation models and tools for evacuation analysis

Evacuation analysis covers the probability of risk occurrence and the expected consequences in each scenario. The evacuation simulation used together with risk assessment provides an estimation of the consequences related to specific situation. In its simplest, simulation usually indicates the expected numbers of fatalities for each defined scenario. Utilising risk-based tools offers an ability to address any accident scenario to facilitate a systematic risk prevention/reduction by any passive (design) or active (operation) means, thus effectively containing risk (Vassalos, 2006). However, this kind of perspective ignores the evacuation effectiveness in case the prevention of the risk fails.

Human behaviour and computer simulation are two topics of particular interest in emergency evacuation modelling. From the beginning, evacuation simulation is playing an important role in the iterative design process. However, using simulation as a post-evacuation stage analysis to analyse evacuation system in cases of accidents would likely improve the evacuation process further. Simulation tool assists the designers in evacuation planning and provides information about evacuation parameters to support the performance of evacuation. In addition, simulation as a training tool could offer support to decision making process and operative functionality of the crew.

Simulation models are based on algorithms that handle both the dynamics of the population and the physical behaviour of an individual. Evacuation simulation models are divided into three different levels according to their scales. (1) In microscopic models, movement is described on the level of individuals and their interaction with each other or the environment. The behaviour of any single person is modelled individually. It enables to understand one part of the evacuation system on a more detailed level, because individual behaviour is captured in some set of rules of behaviour. (2) Macroscopic simulation is the flow model, where evacuation dynamic is based on the similarities of gas-kinetic continuum flow model. Evacuees' movements are calculated by using supplemented data in conjunction with speed-density relationship. (3) A third level of simulation model is the mesoscopic model, a combination of aforementioned models. It fills the gap between individual interaction of the microscopic approach and the larger level of macroscopic simulation. (Lee et al., 2003).

Developments around the simulation models have generated several similar softwares for evacuation analysis purposes. There are approximately 20 different evacuation models available. Different software packages utilise different methods for calculations, this is much dependent on model scale. Maritime EXODUS, EVI software or cellular automata model are all developed for evacuation simulation and pedestrian analysis purposes. First of these simulation tools in use was EVI. (Deere et al., 2009; Vassalos et al., 2002).

Code-name EVI means passenger evacuation performance capability specialised in evacuation at sea, and the abbreviation is derived from the term evacuabilty. EVI is a commercial simulation tool developed by SSRC (The evacuation simulation Group of the ship stability Research Center, University of Strathclyde, UK) in collaboration with Deltamarin Ltd. This multi-agent mesoscopic model works in 3D environment and thus provides a multi-level planning capacity. The model consists of a number of escape and rescue scenarios with a range of hazards whilst accounting for ship dynamic motions in a sea environment. However, this beneficial property is only considered in the simulation model and has not been adopted into the guidelines. Weakness of multi-agent model is the absence of any obstacles and fellow evacuees, which means that every agent will flow towards the evacuation direction without any collision with neighbouring agents or space obstacles along the way. This means that the agents are dummies without any defined characteristics of an individual. In a real situation avoiding contacts with other evacuees is nearly impossible. For example, the behaviour of a large number of people trying to escape from a fire through a narrow corridor is surely affected by the toxic gases, smoke, physical obstacles, and etcetera. It should also be scrutinised if and how much a person falling down in this situation affects other people and their progress, time and flow (increasing the time and decreasing the flow). (Vassalos et al., 2002).

For summarising key factors from the chapter, today's ship design process relies on risk-based design which integrates risks to traditional design process producing design solution that meet safety performance cost effectively. Proactive perception to accident preparedness includes minimising the consequences of risks as a part of the design process. The purpose of evacuation planning is to find efficient design solutions for ship evacuation, passengers' exposure to risks and further. Predicting ship evacuation performance is modelled by the efficiency of human behaviour and the escape arrangements.

In the past decade human evacuation performance has focused on tuning human physical abilities for simulation models in order to improve the safety of evacuation performances further. Sea trials, for instance, are a novel experiment type for collecting human related data. However, the perspective is moreover quantitative and snips off the larger context of human behaviour. Simulation relies on mathematical modelling of human behaviour, ignoring that human behaviour is linked to a larger context of cognitive system. For instance, psychological aspects in human behaviour are still extracted from evacuation modelling.

3. Literature review of evacuation planning

Theoretical approach provides insight to the relationship between human-environment iteraction. This chapter reviews factors interfering the compatibility of human and environment interface and on the other hand highlights what sort of environment would support basic cognitive processes. In addition, panic and time pressure, which are related to highly stressful conditions are taken into account for this compatibility of human mental processes and the environment. Linking this approach to ship environment and human performance in accidents aims to facilitate awareness and understanding about the passengers' efforts to function during an evacuation in this specific environment.

3.1 Introduction to perspective of human behaviour

As a part of human nature and demands of the existing world, individuals are born to perform. Hence, performance has a central role in the lives of many of us. Performing successfully means that one is engaged in a goal-directed activity. Individual's urge to perform in a purposive manner is seen as a key driver for achieved goals successfully (Matthews et al., 2000). However, the behaviour within one’s performance is related to the environment. Research of the congruence of behaviour in environment relies on the action required by situational demands that underlie predictability of behaviour (Kaplan,1983). It is found that for the most part human behaviour is predictable. This perspective emphasises fitting the person into the environment. It could be argued that the human behaviour is predictable also in accidents or predictably un-predictable instead. Another perspective of interface is the purposive action an individual attempts to carry out in given situation. This comparably fits the environment to a person. This kind of optimisation of the behaviour-environment interface, where a person's behaviour becomes a central concern is a key element in research (Kaplan,1983).

Environmental psychology is a field studying interaction between human and environment. This interaction produces a circle of closed feedback system, where individuals change the physical environment, which then as a result affects their behaviour. It is called a molar environment (Baum,1989). Thus, environmental psychology is not sufficient when focusing on understanding individual's intrapsychic processes such as perception or emotions in reaction to the stimuli impinging one in a specific situation; the goals are rather directed towards molar environment (Gärling,1998). Furthermore, as opposed to environmental psychology, cognitive psychology is seeking to understand individual's real-life behaviour and the psychological processes of a person in any given situation, thus it emphasises also the failure or even breakdown of human performance (Matthews et al., 2000).

However, the compatibility of human-environment interface model and the cognitive perspective of human behaviour are linked together with a common factor which is information processing. Creating suitable environment for people, the model highlights information processing as a starting point of human effort for functioning in the physical environment. Incompatibilities interfere the relationship of person and environment and thus one might not experience environment as supportive (Kaplan,1983). Further, in discipline of cognitive psychology the success of performance depends on information processing (Matthews et al., 2000). Interference in human information processing affects judgment and activities. In this perspective human performance is significantly influenced by stress factor. Under stable conditions stress is caused by e.g. heat, fatigue or a noisy environment (Matthews et al., 2000). The presence of stress is very typical in uncertain situations. In physical sense, stress in nonspecific response of the body to noxious stimuli (Choo,1995 p.613). Conceptualising the definition of stress, it can be specified through three different perspectives; stress can refer to the response of a person placed in a challenging or threatening environment. According to another perspective stress is defined by the changes provoked in the person. The third view considers stress through the transactional model, which is connected to a widely used definition of stress provided by Lazarus and Folkman (1984 p.19) *Psychological stress is a particular relationship between the person and environment that is appraised by the person as taxing or exceeding his or her well-being.*

This highlights the nature of the misfit between the individual and environment (Choo, 1995 p.613). Furthermore, individuals differ in their ability to handle stress and motivations when called upon stress.

In addition, performance psychology stems from cognitive psychology and is related to the quality of behaviour by examining factors such as speed and accuracy of response. Furthermore, testing a model against empirical data is habitual in the field. For instance, the measuring of reaction times or revealing errors in the performance represent themes of performance psychology testing. However, understanding the set of factors that control reaction times requires extensive understanding of cognitive modes of response (Matthews et al., 2000). The factors affected can be distinguished as competence, which is the capacity of the mind to perform tasks, while performance refers to what the mind does compute in the situation. It may fall short, if competence of person is interfered by various factors affecting the mind and causing for instance stress. Summarising, all perspectives are needed when creating and achieving a successful understanding of the relationship between human-environment connection, especially in complex and closed ship environment.

3.2 Human cognitive process

In this section the human mental activities are explained on a theoretical level in order to reach a basic understanding of the processes of human behaviour in any environment. Later on behaviour is discussed in detailed by the means of incompatibilities disturbing the human-environment relationship and linked in the ship environment and passengers functioning in the environment.

In an article about human-environment interaction Kaplan (1983) applies a basic model of sources and types of cognitive processes affecting the relationship between behaviour and the environment (Figure 8). The quality of human-environment interaction depends a lot on information patterns that make up the environment (Kaplan,1983). Human information processing continuously interprets available information to maintain a good understanding about present situation surroundings (Shager, 2008). Perception of the surrounding environment is organised in mental maps which are serving and supporting an individual's perceptual processes. This particular model emphasises the relations of actions and plan concepts of human mental activities within an environment. In the model, sources of mental activities are divided in external and internal information that correspond further with the mental activities, which in turn are distinguished as images and plans/actions.

Source of Mental Activity	Types of Mental Activity	
	Images	Plans/Actions
Environment (external)	1. Environmental perception and knowledge	2. Required or necessary action
Person (internal)	3. Reflection	4. Purposive action and inclination

Figure 8 Sources and types of cognitive processes (Kaplan, 1983)

In the model environmental perception and knowledge is derived from information of external environment, just as much as the required actions. Plans are presented in the model to be a cognitive component for actions considered and taken. Thus, it plays a central role in human-environment compatibility.

Similarly, an individual's knowledge or expectations of the external world have their own place in the mental process. Individual’s perceptual world has a role to be a facilitator or even functioning as enabler when carrying out one’s plan. Reflection means that individuals pull together a broad range of previous knowledge in order to make a better sense of it for another purpose and anticipated possibilities in the future. Especially, outward and vigilant reflection has an important supportive role in human mental processes if one has to face uncertainty. Individual reflection in a safe place can have a protective and supportive meaning and actions required in emergency could be far more effective.

Legible environment supports individual intentions to be favourable for carrying out almost all sorts of purposive plans and actions. On the opposite, distraction and illegible environment tends to undermine any kind of activity (Kaplan, 1983). The problem of illegible environment lies as much on how the environment is remembered or anticipated as on how it is perceived (Kaplan, 1983).

3.3 Human information processing

Human information processing can be described in terms of a number of stages in which the information is transformed and transmitted. In its simplest, information processing can be described as a process where information is received through senses (figure 9). For instance, sight, hearing and smelling are designed to be sensory receptors recognising external stimuli from the environment, further transforming the information into an internal representation and then being transmitted in the response (Shager, 2008). In addition, the form in which information is presented can change during the situation.

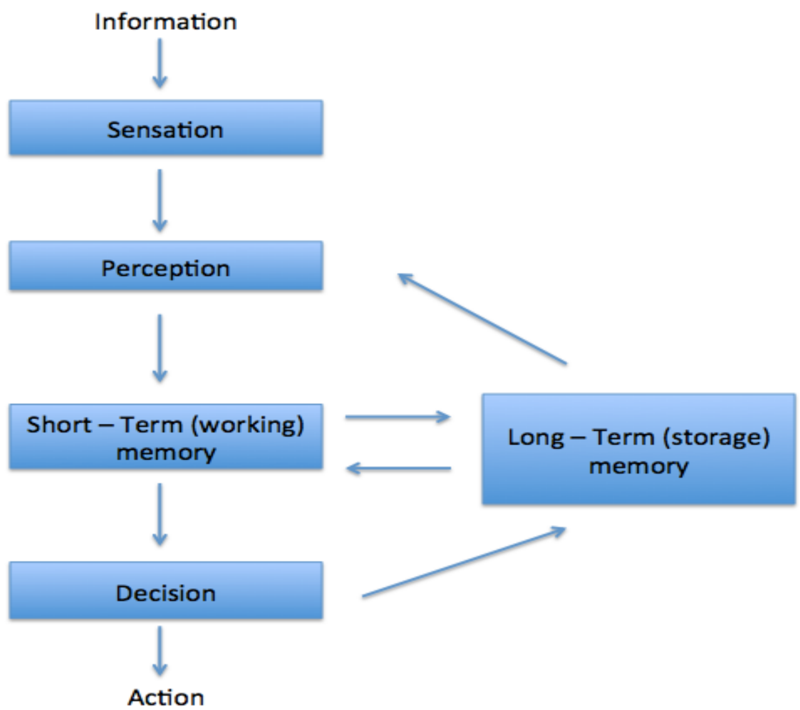

Figure 9 Human information process

Information processing is fundamentally important in human performance, because of the representation of information; judgments, decisions and choices made on the basis of the represented information.

Incompatibilities arise largely from the lack of what one requires from the environment. Often focus is targeted on what is absent in the environment rather than what is present. Incompatibilities can be caused by stimulation where the presence of stimuli in the perceived environment can cause distractions. Typical example is inadequate or lacking information which creates difficulties for action made necessary by environmental pressure (Kaplan, 1983). In addition, when environment is systematically unresponsive it fails to provide information, for example, for way finding in the environment, it also is likely to complicate one's purposive activities. Perception and knowledge from the environment can be used to form an action plan, in other words, cognitive maps, which connect the human internal information processing to actual behaviour. Maps are suggested to support purposive course of actions and minimise efforts to reach destinations or goals (Chen and Stanney, 1999). In case that one does not get any responses from the environment, the corrosive incompatibility by environment is called helplessness (Kaplan, 1983). Uncontrollable environmental stressors such as noise or crowding might expose a person to helplessness (Evans and Stecker, 2004).

Information processing depends on a variety of factors which are not part of the current models. Basically all existing models used for evacuation modelling purposes and have basis on the physical science model, similarly to fire safety models in building fires, do not recognise the information processing and variation of information representation (Pires, 2005). The models are rather generic and for instance, do not take information processing and decision-making under consideration in the very beginning of the emergency. In other words, simulation models are not modelling the time when people become aware of a threat such as fire and do not take into account the time needed for information processing in order to decide further action - usually movement towards a safe place and deciding on route choices, possibly even the changing the route along the way. Modelling the way finding process as a hierarchical decision process (Løvås,1998) or emphasising the natural selection of way finding may not be so obvious in design principles.

Simulation as a part of design process among ship designers is assessing potential escape alternatives within the ship layout. In addition, escape behaviour is studied by using physical factors, such as speed of movement in the different spaces, while ignoring psychological factors in the physical models. Even though the models have extended the possibilities in engineering design and computer modelling works as significant value bringing synergy in many ways to designing and planning, it also has a limited sense regarding human cognition, including models used in ship design (see chapters 2.4 and 2.5) e.g. EVI, maritimeEXODUS.

The model must incorporate a way to simulate people's behaviour. The simulation must be based on what information is really available in the environment and not what is assumed to be available (Pires, 2005). For instance, evacuation procedure in ship environment rely much on information and guidance coming from the crew. Demands of purposive action taken in the situation emphasise person-to-person relationship which results in making the passenger a very passive actor regarding the environment. What happens when information is not received from the crew at all? Then the environment has a key role to provide an answer regarding the spatial cognitive processing for supporting human activities. In addition, understanding interaction between two people is significant also because cultural diversity is growing in the global cruise market. Thus conditions are not short-lived but rather continuous phenomena. The cultural differences surely have an effect on how information is presented, because cultural habits are dictating individuals' way of thinking, behaving and communicating (Oliveira, 2007). The effectiveness of such interaction is determined by mutual understanding between the guide and the guided in this specific situation but also in extended context.

Evacuation models are programs run by external agents. However, people pursue goals actively and flexibly within complex environments. The computers suggest human cognition to be unduly passive (Matthews et al. 2010). This is caused by differences in the function of computer operation and operation of human brain. Where the computer's operational functions are covered to abide by rule-covered logic, human do this poorly. Humans instead are able to form generalisations, make inferences and understand complex patterns and further, have emotions. Computer processing is not able to cover this behind processes (Matthews et al., 2010). However, computer simulation should not be abandoned, especially in those fields that are linked to real-world performance. There internal information processing would be seen as a part of a wider cycle of interface of person-environment and further bringing benefits for modelling objectives (Matthews et al., 2010).

3.4 Human decision-making under uncertain conditions

In its simplest, decision making is a continuous cognitive process in which a person is identifying and choosing a course of action based on the alternatives one has in the situation. In cognitive perspective, the decision-making process is integrated with interaction with the environment. Decision is a response resulting always in a final choice which may or may not lead to action. However, for the final choice mind applies logic, statistics or heuristics. Each of these mental frameworks are suited to a particular kind of problem. Rules of logic and statistics are linked to rational reasoning while heuristics involve error-prone intuitions or irrationality (Gigerenzer and Gaissmaier, 2011).

Research on judgment and decision-making has identified important limitations in cognitive and, more recently, emotional processing. The message of decisions errors and biases may have widespread effects. In addition, considering physical science models, emotional effects are not include in any way in the modelling parameters. Sime, (1983) argues that since modelling handles humans as non-thinking objects it may lead to wrong predictions or failure of design solutions.

Many areas of human knowledge are researched in several decision-making theories. Descriptive theory focuses on the *how* of individual decision making, while rational and normative theories investigate how a person should decide. Culture is suggested to have a major influence on the preferences of life and thus affect on how people think, behave and what they believe in. Furthermore, culture works as a simplifying mechanism facilitating people to process information and interpret the surrounding environment (Oliveira, 2007). Rational theory of decision-making has been defined as the compatibility between a choice and value, which tends to highlight weighting mechanism between these two factors. In rational behaviour, the optimisation of outcomes is focused on the process of choosing rather than what is chosen. Therefore, it emphasises how decision makers analyse a number of outcomes in order to select the final choice. Furthermore, chosen alternative is always expected to have greater value than other potential choices. (Oliveira, 2007).

However, people rarely adhere to logical models of choice in their decisions, because rationality would require knowledge of all the relevant alternatives, their consequences and probabilities. The world around should be predictable without surprises and in reality, such conditions can rarely be met (Gigerenzer and Gaissmaier, 2011). Moreover, deviations from rational behaviour might not always even be explained by any theories of decision-making. Suggestions as to why people's behaviour deviates from rationality may be found in the individual's set of beliefs, culture or/and incomplete information processing (Oliveira, 2007). In addition, the knowledge of emotion influencing judgments and decisions have increased across disciplines (Lerner et al., 2015).

Decisions have an effect on how people behave and solve problems. Decisions and behaviour can be determined as the main elements of the decision-making phenomena which involves information processing and reacting to stimuli from the external world. Passengers as decision makers in the uncertain environment are continuously making decisions affecting their physical safety and mental health. Decision-making situations are often coloured with emotions. Furthermore, decisions are likely made under time pressure, because evacuation is a time critical event. Simply, the nature of decision making differs from conditions where future is certain and the optimal solution to a problem can be determined. In uncertain conditions it can no longer be assumed that rational models of behaviour would automatically provide a proper answer to the situation (Gigerenzer and Gaissmaier, 2011). Therefore, it is important to recognise the factors present in the uncertain conditions and examine how those are linked to the decision-making process. Furthermore, recognising the drivers and their consequences may facilitate predicting an individual or a group's behaviour under uncertain conditions. In uncertain situations unwanted effects are likely to arise in the decision-making and reduce the capacity of the decision making process.

The first factor that has value on decision-making is emotions. Emotion has a crucial influence on decisions and the outcomes of a decision correspondingly have an effect on emotions (Lerner et al., 2015). Emotions in the decision-making are defined as multifaceted, biologically mediated and concomitant reactions relating to survival-relevant events. Emotions have a tendency of being dominant drivers in most meaningful decisions in life.

Indeed, positive feelings are likely to increase and facilitate problem solving and integration of information (Meller et al, 1998). Vice versa, negative feelings may influence negatively on the decision-making process.

Loewenstein et al. (2001), divide emotions into *anticipated* and *anticipatory* emotions. *Anticipatory* emotions are the immediate reaction to risks or uncertainties indicating extreme negative feelings such fear and dread. Contrarily, *anticipated* emotions are typically those which are expected to be experienced in the future. Individuals are motivated to avoid such emotions as disappointment and regret and thus decisions are targeted to minimise the likelihood of negative anticipated emotions. However, these emotions are taken into account when determining the utility and expected outcomes of decisions and courses of action (Schwarz, 2000). The models that focus on the *anticipatory* emotions are more relevant in the evacuation point of view as the presence of feelings influence decision-making in that time.

Prior models emphasise a valence approach to emotions focusing on positive versus negative states of feelings extending the feelings-as-information approach. Models compared the perception of two negative emotions, fear and anger, and propose how these emotions affect judgment of risks. It has been found that fearful individuals make pessimistic judgments about future events, whilst angry individuals make optimistic judgments (Lerner et al., 2015; Schwarz, 2000). In addition, the feelings-as-information theory conceptualises the role of subjective experiences (Schwarz, 2000) and highlights anticipatory emotions in judgment (Loewenstein et al., 2001).

Models assume that people use their feelings as a source of information following the same principles as with the use of any other information available (Schwarz, 2010). Furthermore, emotional reaction often has a dominating role on behaviour (Loewenstein et al., 2001). Serving as a basis for judgments, feelings inform people about the nature of a current situation and thinking processes are tuned to meet the situational requirements. However, people do not rely on their feelings when they attribute them to another source. Moreover, it could be undermining their informational value for the task at hand (Schwarz, 2010).

Second factor involved in decision-making is the time pressure experienced under uncertain conditions. Furthermore, stress is typically related to time critical events. There are various situations where people are pressed to make decisions by deadlines. Information processing can decrease in the time available for processing, consequently increasing the information load and putting pressure on the decision task at hand. (Ozel, 2001).

Ozel, (2001) states that human behaviour during a fire can be described as episodic, where individuals in fire perform a variety of action sequences. Each of the episodes have a goal and a number of actions are linked with these goals. Similarly, ship evacuation is episodic by nature, where the ultimate goal is directed to be rescued from assembly stations to somewhere safe. Episodes can be described as a sequence of decisions and actions, each of them being equally important. For instance, the decision of selecting an exit requires that an exit needs to be selected for exiting (Ozel, 2001).

However, time pressure can influence identifying relevant cues from the environment when selecting an exit or escape route. Individuals tend to screen out essential environmental cues (Tversky,1977) which otherwise or in another situation would provide guidance. In the complex environment, salient number of stimuli from the environment can form a distraction to information processing and further activities. Clearly perceived and easily available environmental cues are important, since deficiencies in processing environmental information under time pressure and stress may have a crucial effect on spatial way finding.

Incompatibility linked around perception covers distraction and overload. This means being forced to necessary actions but having one's range of options limited it is liable to cause a negative reaction (Kaplan, 1983). Overall, negative information have placed greater weight and time pressure in an emergency, lowering the mental capacity of processing information and decision-making. However, the rate of information processing can also increase if the information provided during an emergency serves its purpose (Ozel, 2001). Further, it has been suggested that a low level of stress sustains a relatively high judgement performance, but consequently while the stress levels increase, a person's judgement performance decreases, because the effort to control the process increases (Choo, 1999).

All the same, the person-environment fit theory would suggest that individuals who have a poor fit with their environment may be more likely to experience stress (Sherry, 1991). When time pressure and stress felt in the situation decrease individual's range of cue utilisation to such level that it reduces functioning effectively in the environment, such reduction may become problem (Ozel, 2001).

3.5 Panic behavior in emergency

Psychological theories propose that panic is caused by a catastrophic misinterpretation of perception. A common agreement for the meaning of panic is missing. Thus, the conception considers panic an antithesis of organised group activities (Quarantelli, 1954). Such behaviour arises from individuals' feelings of isolation in a crisis, as well as sensation of collective powerlessness. Almost any kind of collective disorderly activity or an individual's acute fear reaction marked by loss is defined as panic. Regardless of the absence of distinctive criteria for panic, a little assistance to characterise panic is given by such general terms as irrational, antisocial, non-functional, impulsive or inappropriate instances of behaviour (figure 10). Similarly, as with the meaning of panic, there is also disagreement on the conditions which produce or facilitate panic. The presence of panic includes a various set of events, usually a situation which has a reference to a threat such as crowd and crisis, a lack or loss of leadership or a shattering of group bonds (Quarantelli, 1954).

Flight is a distinctive feature of panic and most frequently takes a form of actual physical running. In these threatening situations, there is no overt attempt to deal directly with the danger itself, rather attempting to escape from the danger. Furthermore, attention is never directed to the past, the focus is kept on what might happen. A panicking person sees the potential threat immediately and survival may depend on a very rapid reaction. Contrary to what one might assume, fleeing while panic-stricken is not done randomly: People maintain a general orientation for flight from danger (Quarantelli, 1954). The two factors in particular that are involved in determining the direction of flight are the habitual patterns and interaction among individuals. For example in fire, the danger may lie between the presumed safety and a perilous object, thus making the endangered person take a direction towards the danger, or ignoring a less frequently used door closer by in favour of a often used but more distant exit. Interaction among individuals is also involved in the decision making. This interactional factor, however, has only operational and functional sense, because only the physical setting can present actual alternatives for choosing the direction of flight. Furthermore, panic has also nonsocial and non rational features.

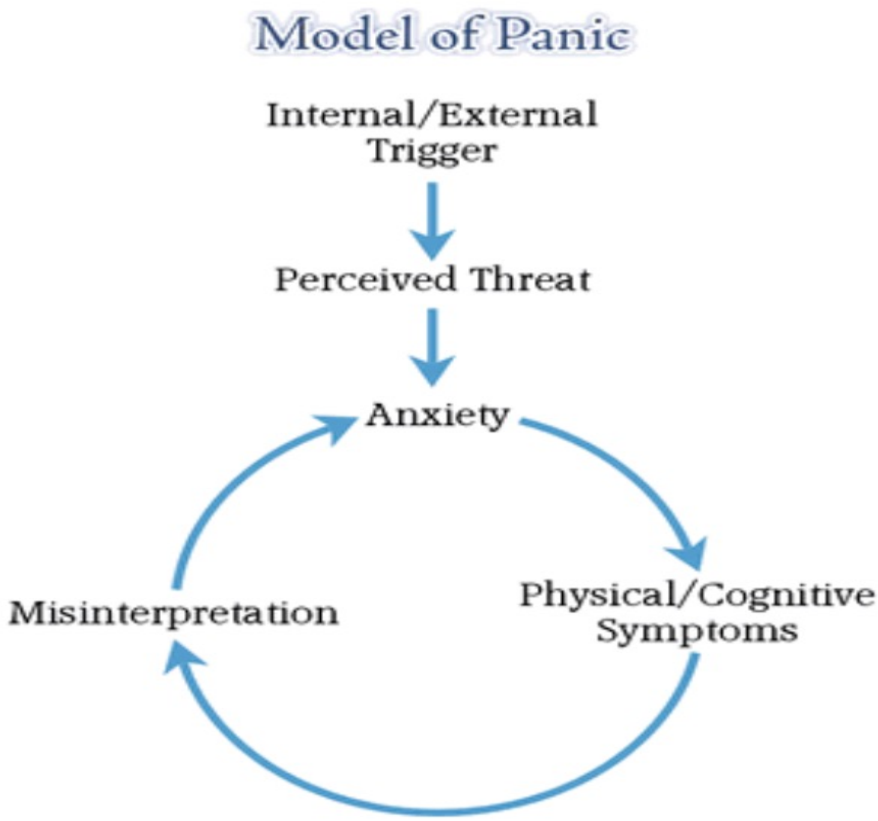

Figure 10 Model of panic

A panicking situation involving no unity of action and no co-operation with others, highlights individual behaviour and thus breaks down concerted behaviour. Sometimes, in a controlled withdrawal people may run around confused with partially disorganised activities included in their pattern of behaviour, but the whole structure does not collapse as it does in total panicking situation. In such cases panic causes even the strongest of primary group ties to shatter, discarding the most expected behavioural patterns (Quarantelli,1954).

However, not all panic is collective. People in panic know they are afraid for what usually is their own physical safety, but they are also aware what they are afraid of. This experience is never an obscure reaction, rather, an individual's fear is something very specific and personal which is never unknown. In this respect, defining the panic situation people need to see the threat and associate it in a definite place (Quarantelli, 1954). From a cognitive perspective, people in panic become highly self-centred. Subjectively it means processing the information how to get oneself away from danger. When focus is highly concentrated on saving oneself, it also means orientation of activities. Through information processing a person tries to create a sufficient awareness of the circumstances. A person in panic neither acts completely instinctually nor is totally unaware of anything else. People are at least partly aware of the presence of other people. However, the decisions and activities in the situation seem rational to the person, one's actions appear to be appropriate to the situation as one perceives it at that time. Thus, a fleeing person does not take into account the consequences of their activities that sometimes may lead to an even more dangerous situation than the original threat itself (Quarantelli, 1954). Panic in an already threatening situation causes further danger. The feeling that accelerates the occurrence and continuance of panic is entrapment without possibility to escape. The experience of entrapment does not necessarily have to do with physical obstacles, but can also be of psychological nature.

To summarise panic behaviour, it can be defined as an acute, individual fear with the loss of self-control. Panic behaviour is not random or totally irrational. On the contrary, it is followed by nonsocial and nonrational rules of flight behaviour. People in panic always have a target for their fear which is present in the situation and causes immediate and strong physical threat. Social consequences become irrelevant even to consider: the process of escaping is self-centred, where no consideration for alternative choices are made and interactional patterns are ancillary, even breaking social norms.

For summarizing, human behaviour and its relations to social and spatial environments are investigated in many different research scales. Human is assumed to be an active ”actor” in the environment, whose behaviour is affected by stimuli from the external environment. The way a human processes and interprets information resulting in a psychological response is further transmitted in the decision and action. These processes can be disturbed by several factors from the external environment or by the individual's emotions, which may decrease the quality of human-environment interaction and reduce human behaviour. Environment should have a supportive role in human-environment interaction when a human is directing attention towards a specific goal. However, physical science models do not take into account the variety of levels in human perception, information and decision-making processes. Knowledge about human cognitive behaviour is likely to increase the level of designed environments that support proper functioning of human behavioural processes.

4 Methodology

4.1 Qualitative approach in technical study

The nature of qualitative research is very human orientated and concepts are identified in as well as constructed from data. Research process differs from the rigid and structured format of quantitive method. Data analysis in qualitative approach determines meanings of an event or situation and embeds them within a larger context. The objective of data analysis is to understand and describe phenomena which are studied. For comparison, quantitative approach to literature uses elements of empirical data which is characterised in a numerical form, such as statistics and probabilities. For that reason it is sensible to use the method when mathematical modelling or other measurements are testing variables of data across several repetitions for classification and analysis purposes. In this perspective, quantitative method generates results from a larger sample of population and considers phenomena, theories or hypotheses in a more generalised manner (Forman and Damschroder, 2008).

The sources of problems in a qualitative research do not differ from quantitative one. Problems are derived for example from technical or nontechnical data or could emerge from the research itself (Corbin and Strauss, 2008). In this study, technical literature provided initial questions and concept as well as generated new ideas of theoretical sampling. Nontechnical literature, however, was used as primary data and act as the foundation for developing the model. Researcher has to be careful as to what role technical literature play. It can hinder creativity if it is allowed to stand between the researcher and the data. But on the other hand, if it is used for comparative purposes, it can foster identification of properties and dimension of relevant concept (Corbin and Strauss, 2008).

Researchers face subjective challenges when choosing to do qualitative research. A positive challenge and perhaps the most interesting one is the possibility to step beyond the known and get at the inner experience of participants. Seeing the situation from the participants' perspective and making discoveries that will contribute to the development of empirical knowledge can be very fruitful choice to researcher. Furthermore, subjectivity sometimes allows to suggest that a new approach is needed to solve an old problem even though it has been well studied in the past (Corbin and Strauss, 2008). Evacuation analysis is studied extensively in the maritime domain.

The gap between simulated evacuation performance and reality does exist. A new perspective is needed when there are difficulties to apply existing methods or there is little opportunity to tune the evacuation model. In this particular study, a refreshing approach to the process of data collection and the analysis is applied.

There are also pitfalls where researcher, if not careful, can fall into. Researchers always bring their own knowledge and perspectives into the research. This is called sensitivity and it has an important role in qualitative research. By means of sensitivity researcher is moved along in the analysis and with the help of personal knowledge and experience the researcher is able to pick up relevancies from the data. However, strong subjectivity involved in data analysis should be avoided because in qualitative research, objectivity is not dependent on the researcher's judgement of an event or situation (Corbin and Strauss, 2008).

4.2 Introduction to qualitative analysis

Content analysis is a family of systematic techniques used to analyse characteristics of language as communication with attention to the content or contextual meaning of the text (Hsiu and Shannon 2005; Forman and Damschroder, 2008). It is known as a method of analysing documents. Furthermore, it may be used in a inductive or a deductive way. Sometimes, both ways can be applied at the same time. Which of these ways is used depends on the objectives of the study. Inductive analysis is based on empirical evidence while deductive approach is derived from logic. Discrepancy between inductive and deductive approach is that in inductive process the facts acquired through observations lead theories and assumption while deductive study via logical reasoning theories or hypotheses are either accepted or rejected.

Inductive approach is elected when knowledge about the phenomenon is fragmented and data is originated from a small sample of observations. In that case, qualitative analysis process can be divided into phases as follows; preparation, organising and finally reporting (Elo and Kyngäs, 2007). In the preparation phase, attention must be paid to the unit of analysis. The sample must be representative of universe from which is it drawn (Elo and Kyngäs, 2007). It is necessary to construct units carefully. A unit of meaning can be constructed from more than one sentence with several meanings. Using this type as a unit of analysis, it may make analysis process difficult and challenging. On the other hand, if unit of analysis consists of for example a word, letter or one sentence, there is a risk of fragmentation. The most suitable unit of analysis is a whole interview or observational protocol which are large enough to be considered as a whole and small enough to keep in mind as a context of meaning units during the analysis process (Elo and Kyngäs, 2007). Researchers must also decide whether to analyse a latent content or manifest from data. If choosing to also find out hidden meanings from textual data, analysing those usually involves interpretation (Elo and Kyngäs, 2007).

Next in the analytical process, researchers strive to make a sense of the data. This means tying up elements available from the research data for creating an accessible understanding of what is sought from the data (Elo and Kyngäs, 2007; Zeisel 2006). The aim is to immerse in the data, read it through several times. Without becoming entirely familiar with the sense of the data, no insights or theories can spring up from it. In the inductive approach of content analysis process, the data is organised by an open coding system. The notes, headings and descriptive aspects of contents are written down while reading through data. After this, categories are grouped under higher order headings (Elo and Kyngäs, 2007; Hsiu and Shannon 2005). The purpose of creating categories like this is to provide a means of describing the phenomenon but also to increase the understanding and generate knowledge. However, organising data to categories is not only to aggregate the observations, instead, when data is classified to a particular group this implies a comparison between data and other observations that do not belong the same category (Elo and Kyngäs, 2007). Finally, the results are described according to the contents of the categories. A successfully performed content analysis requires categories that reflect with the subject of study in a reliable manner.

4.3 Discovering themes for data collection

This section contains definition and introduces themes and explanations relevant to this research connecting theories from literature review and current evacuation modeling to achieve the theses goal.

Before coding data from accident reports collection of themes must be constructed. The themes described have been decided upon the literature reviews including human behaviour which has value in theoretical orientation but also evacuation planning in maritime field. When combining these two literature reviews, it will give a widespread entity, which allows to step beyond what is the current situation of modelling. Themes describe the characteristics of the studied problem and phenomena. Data will be organised into four main themes under context of passenger ship environment and population.

Main themes are; (1) Source of stimuli, (2) Human behaviour, (3) Spatial environment and (4) Social environment. Categories have been structured under each of these themes and further codes shared with similar characteristic have been set into categories.

First theme (1) *source of stimuli* consists of stimuli from external environment and personal internal emotion. One of the most crucial influences are the sources of information that must be considered when making choices. Emotions are included under the theme, because how people feel affect actions they make. Thus, categories under this theme are important to recognise, since behavior is based on stimulus characteristics.

Second theme (2) *Human behaviour* consisting of elements of passengers' cognitive abilities have been divided into subcategories by means of the circle of cognitive processes. Current evacuation analysis does not focus on simulating actual emergencies, but rather assess the performance of ship in certain benchmarked scenarios (IMO, 2007). Therefore, guidelines do not consider human cognitive processes in the analysis. This leads to a problem of understanding the human cognitive process, involving factors such as risk perception, interpretation of emergency and actions. In addition, the limitation of information processing especially under stress restricts the accuracy of decisions made by individuals. In actual evacuation human cognitive processes affect on physical behavior, in other words, walking speed, usage escape routes and ultimately performance of ship in an emergency.

Third theme includes the ship’s (3) *spatial environment* which focuses on spaces where passengers have been located and objects they have used or paid attention to or used during the evacuation. Furthermore, key areas of action highlight spaces where most of specific activities happened during the evacuation. In the guideline, geometrical element considers schematization of escape routes by using hydraulic network. Identification of inadequate escape routes, congestion points optimization of evacuation arrangement are carried out by theoretical and mathematical point of view. For the purposes of this study, however, spatial environment is considered through human-environment relationship as referenced in the literature review.

Fourth theme characterises (4) *social environment*. This theme is related to the effect of other people on one's behaviour; forming of crowds, the importance of group ties (support or indifference towards others), panic of few escalating to a more extensive chaos, irrational behaviour, etc.

The figure 11 represents the current passive evacuation modelling, in which the human cognitive process is ignored and the external stimuli leads straight to action. The proposed model in the figure 12 is based on the themes, describing the information processing from external and internal stimuli through human cognitive process to decision making and action. These two tables can be considered a framework for the themes and a basis for the analysis.

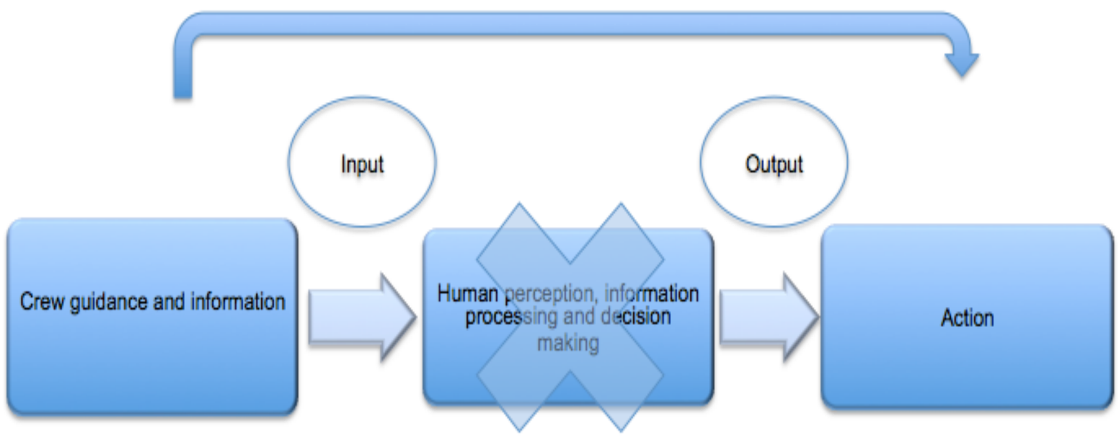

Figure 11 Current evacuation model

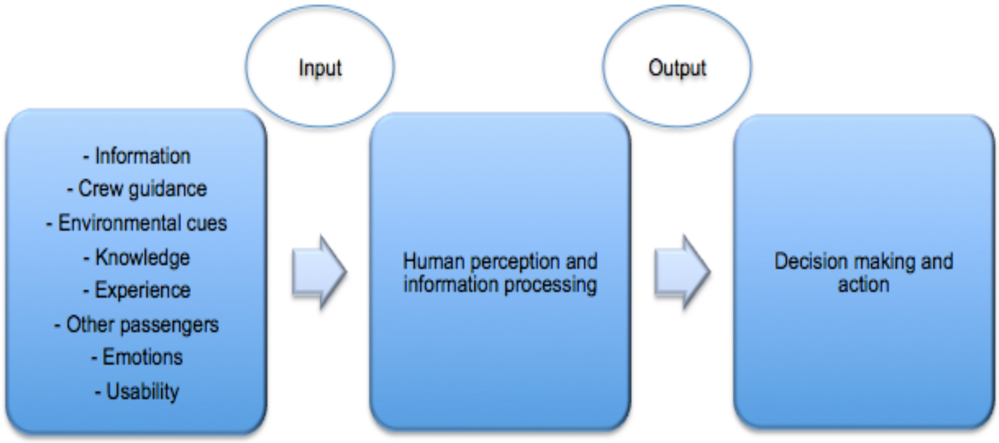

Figure 12 Proposed model according to themes

5. Analysis

5.1 Fundamentals of marine casualty investigation

IMO's Maritime Safety Committee adopted the Casualty Investigation Code providing a common provision for the Flag States to conduct marine safety investigations into marine casualties and marine incidents (MSC-MEPC.3/Circ.2). The code aims to prevent marine casualties and similar incidents from happening in the future. Specifying mandatory requirements and considering the variations in International and National laws related to investigation of marine casualties, it provides a framework to the States approving the code. The Flag States and Coastal States under the IMO's umbrella but also the shipping industry generally benefits from increased objectivity in jurisdiction and decreased differences in investigation standards.(A 20/Res.849, 1997).

Statutory investigation of marine casualties is dictated by the IMO Code. It clearly instructs the responsibilities and cooperation policies for the Flag State involved. It also considers casualties occurring in territorial waters, inland waters as well as on the high seas and exclusive economic zone of State. In addition, the United Nations Convention of the Law of the Sea, UNCLOS 94th article defines the extended legal duties to Flag States, including marine casualty investigation. It states the following; ”*Each State shall cause an inquiry to be held by or before a suitably qualified person or persons into every marine casualty or incident of navigation on the high seas in-*

volving a ship flying its flag and causing loss of life or serious injury to nationals of another State or serious damage to ships or installations of another State or to the marine environment" (UNCLOS, article 94.§7).

The code provides procedure and instruments for collecting evidence, identifying and analysing the causal factors of casualty but also making recommendations for safety improvements. The scope of maritime safety investigations should look beyond immediate causes and improvements should be made throughout the whole chain of responsibilities.

Europe has its own supervising authority EMSA (European Maritime Safety Agency) which works in cooperation with the EU commission and the Members States aiming to harmonise the way accident investigations are carried out in the European Union. The agency also maintains a database of serious marine casualties in Europe in order to facilitate accessible sharing of knowledge from past accidents. EMSA has been a very useful source while collecting data: At the moment there is no world wide database available and for that reason accident reporting is fragmented to amid Flag States authorities only without any obligation to notify ship accidents internationally if they happen in territorial waters. This considerably complicates data collection.

5.2 Data collection for analysis

When carrying out a safety analysis, it is fundamental to obtain a reliable data source. Also, to fulfil reliability data must fit together with the research problem and analysis objectives. Maritime accident report offers a source for quantitative and qualitative safety analysis. Accident statistics are often used as a source for quantitative risk analysis to determine probabilities of accident occurrence and identification of consequences of risks. Depending on the perspective and the user, statistical data has relevant and crucial value. Among shipping community as well as among researchers accident failure data is often used as a source because it represents a large amount ships. For example, classification societies' aims are directed towards compliance of rules in accident cases. On the other hand, for shipping companies and the insurance viewpoint is the economies of scale. For this study, accident data represent unique and authentic information from accidents occurred mostly from the passenger's point of view. In this approach accident statistics data has been moved aside and interests have been directed towards people's environmental behaviour under an emergency. Studying behaviour in a physical environment eventually generates data about people's activities in certain situations (Zeisel, 2006). Investigation reporting has mainly focused on elements of technical or human factors causing a marine accident. Even though those factors need to be identified properly, it is equally important to understand the passengers' behaviour and actions under an emergency situation.

In qualitative research there are many alternative sources of data. Researcher can use nontechnical literature such as interviews, drawings, field observations or like in this study, documents and reports including memoirs. Reports from ship accidents are obtained from primary and secondary sources as follows; investigation bureaus around Europe such as National Maritime Accident Investigation Bureaus (The Finnish safety investigation authority SIA and The Marine Accident Investigation Branch UK, MAIB) and The European Maritime Safety Agency, EMSA represent primary sources. Secondary sources, represent "lesson learned"-reviews collected from public sources (internet sites).

The quality of analysis depends on the quality of material sources one is analysing. This is connected to theoretical sampling, a method of cumulative data collection based on concepts derived from data. In some way, the differences between qualitative and quantitative methods involve trade-off between breadth and depth (Patton,1990). Qualitative approach permits inquiry into selected issues in a great depth with attention to detail and nuance. Qualitative data collection does not need to be constrained by predetermined analytic concepts the way that quantitative data is structured. However, breadth versus depth varies also depending on the strategic choices in qualitative design process. A specific set of experiences for a large number of people seeks breadth as a more open range of experiences for a smaller number of people seeks depth. Qualitative inquiry typically focuses in depth on a relatively small sample size, but there are no specific rules. Sometimes even a single case, selected purposefully is acceptable. Sampling strategy has a meaningful role, it must fit the purpose of the study, the resources available and the question being asked, among other things (Patton, 1990). As there are only a few critical cases to be studied, it does not allow broad generalisations rather produce a strong weight of evidence.

5.3 Accident report definition

The most valuable issue when choosing the case studies for analysis was the variety of maritime accidents and the circumstances present during the accidents. All of the factors considered - such as the ship type, classification of the accident, event type and circumstances - had a specific influence on the interaction between human behaviour and the ship environment. The variety in cases is beneficial because it gives a change to study differences in human behaviour when circumstances vary.

Ship accident reports used in this theses represent different classifications of maritime accidents. According to the IMO, maritime accidents can be divided into three categories based on their consequences; Very serious, serious and ”other accidents.” The range of accidents analysed in the theses fall in all categories from very serious accident to ”other accidents”. Maritime accident of MV *Estonia* is defined as very serious and *C/S Costa Concordia* as serious accident by consequences of human lives lost and the total loss of the ship. *MS Sally Albatross* in turn, falls into the category of ”other accidents” since the consequences of the accident were limited to economic losses.

Even though only flooding is represented in the event types, the cases are nevertheless used for comparison. The reason why only flooding is included as an event is caused by the lack of accurate and detailed qualitative data available on human behaviour during a fire in ship accidents. In addition, both ship types, cruise and RORO ships are represented in the case studies. The time of day and weather conditions also have an effect on accidents. Thus the duration of time is considered in the chosen accidents, along with weather conditions which vary from stormy to calm weather.

5.4 Case study: MV Estonia

MV Estonia departed in the 27th of September from Tallinn for a scheduled voyage to Stockholm, Sweden carrying officially 989 passengers and crew members altogether. The voyage proceeded normally at first, the sea conditions were moderate but became more rough as Estonia proceeded from the shelter of archipelago to open sea. Because of the wind conditions pitching and rolling increased. At 0100 hrs the ship heeled suddenly to starboard. According to many testimonies during the following ten minutes between 0105 hrs and 0115 hrs many passengers as well as crew members heard unusual, loud noises from the bow area. At 0115 hrs the bow visor separated from the bow and large amounts of water flowed on the car deck. Because of progressive flooding the ship listed very rapidly to starboard. The first mayday call was received at 01.22 and another mayday was sent from Estonia at 0124 hrs. At this time the heeling angle was approximately 40-45 degrees and the water level reached up to accommodation deck. As a consequence of rapid flooding at a considerable speed the starboard side of the ship was submerged and the ship sank as stern trim about 0130 hrs. Estonia disappeared from radar at 0150 hrs. 852 people lost their lives (JAIC).

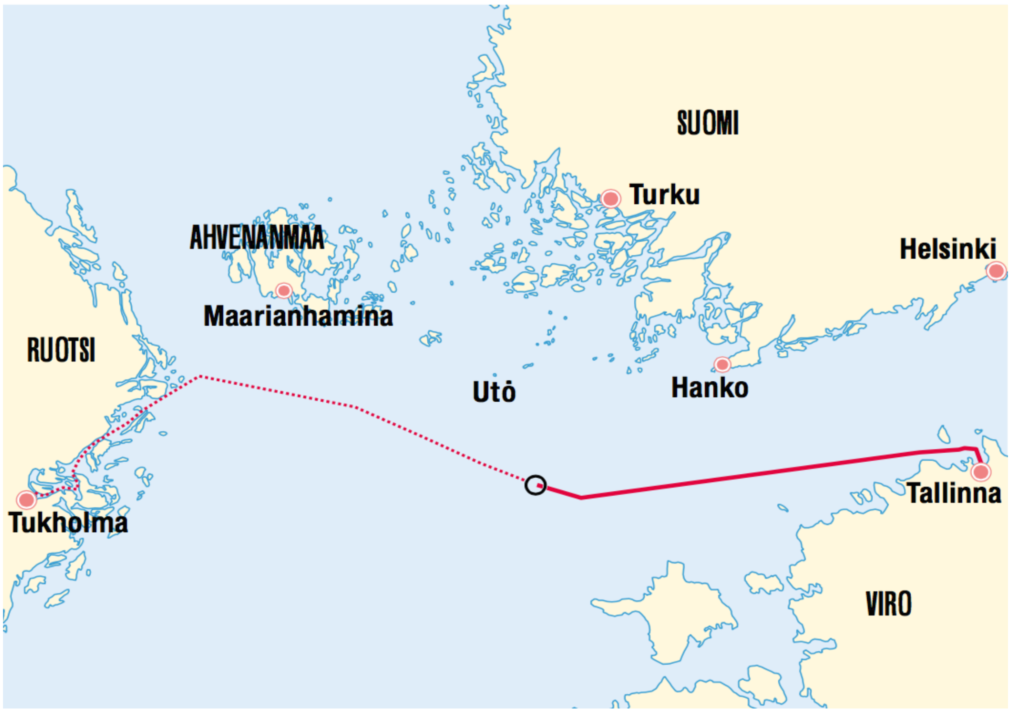

Figure 13 MV Estonia itinerary

At an early phase of the accident at 0045 hrs most of the passengers were in their staterooms. Some passengers stated that rough sea caused sea sickness and they were not able to sleep due to ship motions such as pitching and rolling. According to testimonies, the first perception due to noises and motions of the ship appeared to be strong indicators that everything was not as it should be. Many passengers, particularly those on the lower deck draw attention to unusual, loud noises. It caused extensive worry and unsafe feeling among the passengers. On the 1st deck, accommodation units were located on the front side of midship. Passengers from this location heard strong metallic noises coming from the bow area and responded more carefully. In one testimony *a female passenger heard loud thumping and clacking. She thought it was strange and talked about it with a friend. She got scared and left the stateroom* (JAIC p. 68). *Later on she sat on the 7th deck while major blow was heard and the ship started to list.* This happened approximately 10 minutes later *(*JAIC p.77*).* However, passengers on the upper decks reacted slower compared to the passengers whose staterooms were located on lower decks. Noises caused reaction among the passengers on public areas, *A group of passengers opined comments such as the ship colliding on an iceberg, but most of the passengers paid no attention to the noises at first. One passenger wanted to the Pub Admiral on 6th deck after hearing a loud crack but others told this particular passenger to stay and wait (*JAIC p.*74).*

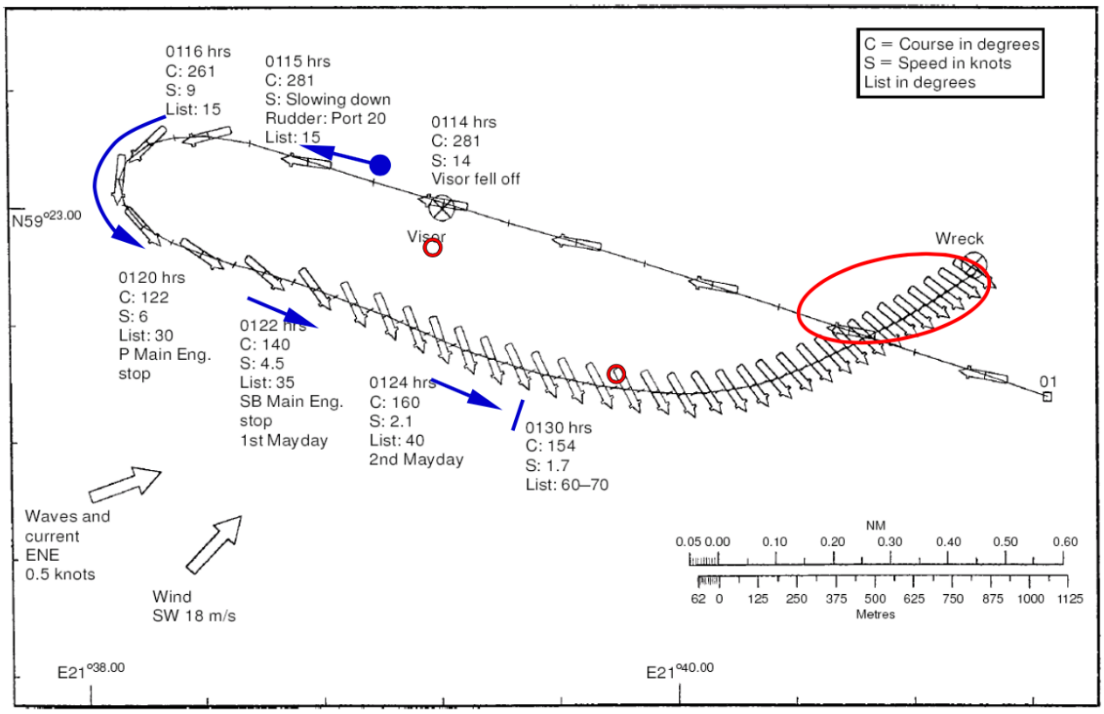

Figure 14 Simulated time line of MV Estonia

Evacuation time was approximately only 10-20 minutes. This is based on testimonies and composed a simulated timeline of the accident shown in figure 14 (HSVA, JAIC). During 0100-0122 hrs first 2-3 blows came from the bow with scraping noises though the ship's hull caused by the bow visor which detached from attachments. Immediately after, the ship suddenly started to turn port and heeled starboard very quickly. At the beginning of the evacuation, the key areas of action were at staterooms. Listing woke many passengers in their staterooms because pieces of furniture and other loose objects slid towards bulkheads. At this phase, passengers reacted and tried to look for a way out from the staterooms and to upper decks. From staterooms passengers moved into corridors, but it was rather difficult to proceed, because of drastic listing and open staterooms' doors. Passengers had no organised way to act in these circumstances. *People were screaming and rushing around in corridors* (JAIC p.70). At Cafe Neptune's *people sat completely still, apparently frozen and terrified* (JAIC p.72). Passenger reactions were characterised by confusion and disbelief about what was happening.

Listing caused immediate panic among people and they were running around (JAIC p. 74). During the evacuation bottlenecks are indicated at open spaces (e.g. the lobby, in front of staircases) and staircases. Listing affected drastically the movement of population in staircases. Frozen people clogging the exit to upper decks prevented access from ascending passengers, thus forming crowds in the staircases. Furthermore, when number of people tried to use guardrails at same time, with effect of listing, eventually forces directed to rails increased too high, thus guardrails pulled away. According to several testimonies, movement at staircase with heeling angle 20 degrees or more was extremely hard and people had to struggle to move upper wards. Relatively soon climbing became simply impossible (JAIC).

At large open spaces proceeding was difficult because of listing, moving property and slippery floors. Injured and fallen people complicated movement through open spaces on the way towards the main staircases. *Main lobby is a wide open space. Listing of the ship made movement really difficult. Staircases were situated at midship, on central line of the ship and it was very difficult to reach them* (JAIC p. 70).

Way finding happened more likely intuitively. On the 4th deck accommodation units were located in two sections, one at the fore and another at midships. The main lobby and staircases to upper decks situated between the units. At fore two transversal staircases on both sides of ship lead on the 7th deck. In contrast, at stern there was only one staircase to upper decks. *One female passenger came out of a stateroom located at midship, near the lobby and the main staircase. She moved towards the stern, fell down inside a stateroom through an open doorway. She managed to pull herself out and continue proceeding in the listing corridor* (JAIC p.72). However, the nearest escape route located near her stateroom, in the main lobby (figure 15). There are many similar testimonies which indicate way finding to be more likely intuitive than steered by cues from the environment. There were no strong indicators suggesting people would have been trying to search for an alternative exit route - they likely did not have that chance because of the situation.

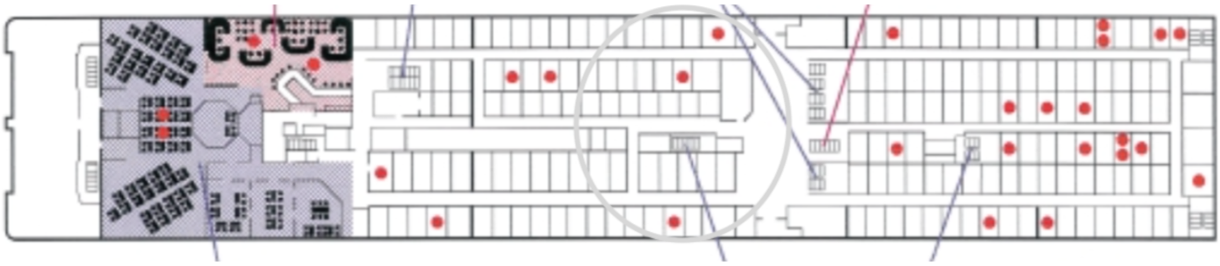

Figure 15 4th deck layout of MV Estonia (JAIC, 1994)

5.5 Case study: C/s Costa Concordia

C/s Costa Concordia was on its weekly cruise in the Mediterranean Sea carrying altogether 4229 passengers and crew members onboard when the ship departed on 13 of January 2012 at 1918 hrs from the port of Civitavecchia (Tyrrhenian sea, Italian coastline) with intention to continue to the port of Savonia (Italy) - destination which was never reached. The weather conditions in the area were favourable. At 21.39 hrs the ship is still on course as planned, heading towards ”Punta Capo Mario”. Immediately after, at 21.40 hrs the Master of Costa Concordia gives orders to change the course against initial navigation plan and the ship starts to approach the island of Giglio. As a consequence to that course of action, the ship is sailing too close to the coastline. Master of the ship causes true hazard to the ship and the people onboard when passing the Island of Giglio at an unsafe distance. At 2145 hrs the ship suddenly collides with the ”Scole Rocks” at the Giglio Island and immediately heels violently and the speed decreases. The ship loses its propulsion and the rudder remains completely blocked on starboard and no long works. The accident happens during dinnertime onboard, thus many passengers hear the crashing noises. At 2154 hrs crew member announces to the passengers a blackout onboard (Full accident report of Costa Concordia). According to a testimony, at this point it was informed that the blackout was caused by a technical failure and that the situation was under control (Lesson learned review, p.39).

Figure 16 C/s Costa Concordia itinerary

At 2230 hrs, 45 minutes after the collision some passengers start to proceed towards lifeboats, even though neither general nor abandon ship alarms have been given. At 2235 hrs the abandon ship alarm is given and at the same time it is announced that passengers should proceed to the muster stations and the first lifeboats are dropped. At 2300 hrs the ship grounded at the Giglio Island on starboard side has a heeling angle of 15 degrees at this point. The ship continues heeling during the evacuation and at 2314 the heeling angle is more than 40 degrees. At 2400 hrs passengers disembark from the ship starboard side using boarding ladders, since the heeling angle is too high for dropping off any more lifeboats. At 0617 the rescue operation of Costa Concordia is completed. Total of 32 people lost their lives and 153 were reported having injuries. (Full accident report of Costa Concordia).

At the time of accident, it was the busiest time of day onboard with the passengers having dinner or otherwise enjoying the evening activities. In a restaurant located on the third deck, an American couple had just started their dinner when they witnessed *a violent shaking of the ship followed by long crashing noises as the plates and glasses were breaking due to listing of the ship towards starboard (Lesson learned review, p.38).* Similarly, a cruise passenger in the ship's theatre witnessed the ship colliding on the rocks, the *ship shuddered and scraped against something solid (Lesson learned review, p.33).* Still, most passengers reacted quite slowly to the situation and the crew members continued their work as if nothing had happened. *Without waiting I stood up, and held my wife's hand and told her firmly, we are out of here. As we raced out the back door of the theatre, I noticed that 99 percent of people had not even stood up* (*Lesson learned review, p.33).*

In this early phase of the accident, reactions involved for some passengers a thought of having a lifejacket from the staterooms where jackets were normally held. A female passenger exclaimed to his husband a second after the collision *We need to get our life jackets! (Lesson learned review, p.33).* In another testimony people at the dining hall were having similar thoughts, *About 30 minutes into the situation we are in the dining room when my husband decides it's time for us to go and get at least our lifejackets from the room, because at this point we have no idea if we do not go back to our room where else can we get our life jackets from* (*Lesson learned review, p.38).* Furthermore, the sound of the alarm was not clear for all passengers*. I at that moment asked the room attendant where are we supposed to go, and she replied in a very irritated tone, saying, ''Madam, at this point there is no emergency. You do not need to go anywhere. Please stay here and wait for further instructions and for the emergency alarm to sound,'' which we had no idea how it would sound like* (*Lesson learned review, p.39).* This was likely caused by the fact that there were no safety drills after departing from ports, thus the passengers were not aware about the procedure in the case of an emergency (Full accident report of Costa Concordia). *Because Costa had this ability to sell a cruises embarking from many ports, in a constant circle, it is unknown to me when of if they performed a proper muster drill,* stated a testimony by a male passenger (*Lesson learned review, p.34).*

Moving inside the ship was hard from the beginning. In the large open spaces pieces of furniture had shifted due to listing causing a danger. In addition, water flow and darkness made moving across the ship more difficult. While passengers cross the ship from port to lower starboard side for the rescue, proceeding was difficult *I felt like the ship was in around 35 degrees tilt by now and it was very wet and very difficult to move about* (*Lesson learned review, p.35).*
Furthermore, it required physical strength to climb the staircases, since the ship was tilted and there was only emergency light guiding the passengers at staircases. Staterooms had no lighting, it was pure darkness and shifted furnitures complicated getting lifejackets out of the closets. *Somehow we did manage to get to our room*

holding the guardrails, very much exhausted and now panicked, stated passengers when they managed to find their way in the stateroom for lifejacket *(Lesson learned review, p.38).* Since people were proceeding to the assembly stations before any alarm had sounded, passengers mostly gathered in staircases, located near to lifeboats but some of the passengers sat outside the staterooms waiting for something to happen. Crowds formed in these areas. Furthermore, because of uncertainty and long waiting time, *People started to panic and felt frustrated as the ship was listing more by the minute (Lesson learned review, p.40).* Some passengers started to little by little move closer to the lifeboats. *We were getting frustrated, aggravated, and the crowd was pushing and shoving against each other, still no sign of any emergency alarms or any evacuation instructions from the captain. Finally the lifeboat crew let us on as they saw the crowd getting enraged and out of control. There was no order in boarding the lifeboat, and everyone was shoving, pushing, and kicking to get onto the lifeboat (Lesson learned review, p.40).*

After the alarm had sounded, passengers started pushing each other in the crowd while at same time the crew was in a hurry to launch the boats as fast as they possibly could at the state where heeling angle reached 20 degrees. *”Until this point I saw relatively little rude pushing from a small number of various people during the entire crisis... but only until the boats were deemed full...Now it began to get less courteous, more people wanted to push on* (*Lesson learned review, p.35).*

The situation was completely unclear for the passengers the whole time. It is evident that no real-time or reliable information was available by the Master or crew. This delayed the passengers' ability to process information for their decisions. In this respect the passengers had to make their own judgments about the situation, trusting their own perceptions. People asked each other about the situation and trusted more in third part information than the crew. Communication between the crew and passengers was nonexistent. A male passenger described the crew's behaviour during the emergency saying *One hour from the rocks, still the same story. No boats were launched on this side of the ship (starboard). No action by the crew. I felt again like the crew is now going to kill us* (Lesson learned review, p.34*).*

Same announcement was repeated during the emergency about electrical failure and that the situation was under control, *Everything is under control. It is an electrical* *problem. We heard that too often in the two hours (Lesson learned review, p.33).* Before abandoning the ship the alarm sounded at 2235, some of the crew members had ordered passengers to move back into their rooms to wait for instructions. This may have been in order to avoid panic among the passengers but the crew's behaviour was absolutely inappropriate for the situation.

Figure 17 Illustration of accident of C/s Costa Concordia

5.6 Case study: Ms Sally Albatross

Ms Sally Albatross departed on the 4 of march 1994 at 1104 from Tallinn, Estonia for a scheduled voyage to Helsinki, Finland carrying officially altogether 1202 passengers and crew members. The voyage proceeded normally until the Finnish coastline. Because of compressed ice initial navigation plan had to be changed during the voyage. Ice cover was 15-25 centimetres thick in the Gulf of Finland and there was packed ice along some parts according to the forecast from that day. Otherwise weather conditions were good. Near Porkkala, 54 miles from Helsinki at 1438 hrs the ship collided for the reason of a navigational error with ”Savin ice buoy” and continued over the shallows. The ship had a slight grounding with ”Savin” Shallows, which in its lowest is 4,6 meters while the ship's draft in the aft was 5,88 meters and in the fore 5,62 meters. The ship turned in the starboard side and heeled 2-3 degrees. After the collision situation remained stable for a while. The damage control procedures were started with an order by the master immediately. At 1608 hrs the Master of Sally Albatross ordered evacuation alarm. The crew started an orderly evacuation of passengers from the first deck, proceeding to upper decks. At 1613 hrs the evacuation order was implemented for abandoning the ship. At this point the heeling angle was at 6 degrees on starboard side and the ship had subsided 1,22 meters from original draft. Passengers were rescued to Navy ships, the ice breaker URHO and to a passenger ship on scene. At 1700 hrs the heeling angle reached 10 degrees and the Master ordered the crew to abandon the ship. Rescue operation was completed at 1800 hrs when the Master finally abandoned the ship. All passengers and crew members were rescued successfully with no casualties (Full accident report of Sally Albatross).

Since Sally Albatross was the ship transporting people and cargo in scheduled voyages between Tallinn and Helsinki, at the time of accident, the ship was nearly approaching Helsinki. Passengers spend their time at the ship mostly in public places during the journey. However, according the report there is no evidence that passengers onboard noticed the collision with the ice buoy. (Sally albatross accident report).

In the early stages of the accident at 1515 hrs, passengers were informed about the situation. This information included a short description of the accident. It was a clear announcement ordered by the Master. Still, the information did not reach all of the passengers, and therefore it was repeated several times to ensure everybody was aware of the situation. (Sally albatross accident report, p. 29). Passengers had a high awareness about the situation all the time, because information from the crew was clear and in addition the crew guided passengers to the assembly stations. No panicky behaviour patterns, irrationality or crowding was perceived. It was stated that passengers behaved mostly in a calm manner. Furthermore, the passengers did not question the situation and crew behaviour during the evacuation. However, some minor disturbance was perceived as, according to the report, *during the evacuation of the restaurant some male passenger wanted finish their dinner, but eventually obeyed the order from the crew without major difficulties* (Sally albatross accident report, p. 34).

Figure 18 Ms Sally Albatross heeling angle at 1700 hrs

Problems in the evacuation were connected to the staterooms corridors. Some passengers became distressed when they were unable to open watertight doors. Also the lighting conditions were indicated to be good, even emergency lighting gave light. However, daylight facilitated the situation and in this sense any major difficulties to proceed inside the ship were not indicated in the report. (Sally albatross accident report).

Passengers were rescued from the aft. Evacuation was conducted in an orderly fashion by the crew. Most of the passengers were assembled from the main restaurant. During the evacuation lifejackets were not handed out to passengers. *One passenger asked for a lifejacket for her daughter, but the crew told the passenger that it was not necessary because distributing lifejackets would only cause panic.* (Sally albatross accident report p. 36).

5.7 Context definition of analysed data

There are four main themes in which the data is systematically categorised. In the first phase of the analysis, data was coded to enable processing and organising on a conceptual level in order to facilitate the analysis. The purpose is to distinguish key information related to human-environment interaction in the evacuation situation from each of the reports separately.

In the second phase, propositional definitions of the categories were developed and then compared with each other to detect possible relationships. Since human behaviour is the core theme to which other themes are linked, the outcome proposition is based on their combination.

In the final phase, analysis outcomes are compared with existing theories and knowledge on human behaviour in an emergency, emergency research from other fields associated to high-risks, as well as with established rules of evacuation analysis.

Contents of the themes and their relations are presented as follows:

Theme 1: Source of stimuli

Category: External stimuli and emotions: Passengers share matters related to external environment stimuli, for example loud noises, violent shaking of the ship, listing or the received information from the crew whose quality varied between accidents. In addition, passengers experienced emotions such as fear, anger and panic during the evacuation process which were linked either to the external stimuli and as such functioned as motivation for response. Source of stimuli linked to human perception and information processes.

Theme 2: Human behavior

Category: Perception, information processing, decision-making and activities: Source of stimuli is related to the way passengers understand a situation and how they interpret incoming information in order to give a suitable response to situation or problem. Furthermore, decision-making is a thought process of selecting a logical choice from the alternatives available. However, stimuli, time pressure or emotions interfere the process of information and decision-making and the level of activities conducted during evacuations vary from rational to irrational.

Theme 3: Spatial environment

Category spaces and objects: Spaces represent key areas of action, in which main activities happen during the evacuation. Objects such as guard rails are used for facilitating movement inside, life jackets in turn increase the physical safety and emergency lighting serve as guidance for passengers in the way finding situation. Environmental cues are directly linked to human activities, how well potential action is made possible by a given object or environment.

Theme 4: Social environment

Social contacts among the passengers and connection between groups involve features which are linked to group ties, group information spreading or for instance, how passengers behave towards one other in an emergency situation. Social environment is linked to the circle of human behaviour.

Table 19 Mv Estonia coding framework

Theme	Category	Code
Source of stimuli	External stimuli	Abnormal noises Water purl Vibration and slamming Heeling angle and listing Ship motions Machinery noises
	Emotions	Unsafe feeling Worry Disbelief Sense of time Panicking Shock
Human behavior	Perception	Hearing Sense of touch Vision
	Decision-making	Panic escape Pre-warning before accident
	Activities	Illogical way finding Running around Climbing upward stairs Yelling Stampede
Spatial environment	Spaces	Staircases Open spaces Cabins
	Objects	Guard rails Furniture Escape routes Safety appliances Slippery floors
Social environment		Social connection and group ties Ignoring other passengers Chaos and disorder Crowd forming

Table 20 C/s Costa Concordia coding framework

Theme	Category	Code
Source of stimuli	External stimuli	Crashing noises Shaking of the ship Darkness caused by blackout Alarm sounds Listing False information
	Emotion	Frustration Panicking
Human behaviour	Perception	Hearing Vision Sense of touch
	Decision-making	Discussing options Searching for another escape route
	Activities	Climbing stairs Prolonged waiting next to cabins and stairs Hard to keep stable position
Spatial environment	Spaces	Assembly stations Staircases Cabin
	Objects	Guard rails Emergency lighting Lifeboats Lifejacket location
Social Environment		Third party information Crowd forming Enraged behaviour Pushing and shoving Kicking

Table 21 Ms Sally Albatross coding framework

Theme	Category	Code
Source of stimuli	External stimuli	Repeated information by crew Water purl Listing
Human behaviour	Perception	Hearing Vision Sense of touch
	Decision-making	Independent assembling
	Activities	Guided way finding Orderly movement Climbing Carrying luggage
Spatial environment	Spaces	Restaurant Assembly stations
	Objects	Watertight doors Cabin keycards Safety appliances
Social environment		Social connection and strong group ties No questioning of crew activities

6. Results

6.1 Human response to environmental stimuli in an accident

Passengers actively perceive their environment and sense external stimuli such as environmental conditions, ship motions, noises and other passengers in order to understand the situation. In some cases, pre-warning came from external stimuli to alert passengers of danger before the accident itself even occurred. In these cases, stimulus was a clear motivation and strong enough for response and further trigger action. However, not all passengers perceive the signs of danger and receive warning visually, audibly or physically from other passengers behaviour. According to the analysis, the quality and amount of stimuli might impair passenger information processing and interpretation of the situation. Furthermore, responding to dangers seem to be dependent upon the location of a passenger but is also situational. In extreme cases, those passengers who felt or saw the danger responded accordingly and thus had better chances of surviving the accident. Incompleteness of information and time pressure are likely to affect understanding the situation comprehensively, and further leads to misinterpretations and inappropriate actions, also delaying individual activities.

Usually, stimuli which comes externally to the person causes stress when it is linked to the demand of some response or change in behaviour. Thus it is linked to the condition of the environment (Choo, 1995). These three factors are linked together in the decision-making theories. Under time pressure negative information or incomplete information reduces judgement and decreases decision-making these situations (Ozel, 2001). Furthermore, physical threat in an emergency is considerably high, and constrains people to make decisions quickly. Time in this respect has the tendency to create stress and the level of stress to increase. More attention is redirected from judgement and the capacity of making decisions is lowered (Choo, 1995). In this respect information has a direct impact on the degree of stress and the amount of time pressure people experience (Ozel, 2001).

However, the studies investigated show the importance of understanding the human cognitive processes under an emergency. Nevertheless, no studies have paid attention on passengers cognitive abilities during an emergency in the maritime field. This might stem from the general premise to assume that the crew's ability to provide information and guide passengers is enough to conduct evacuation efficiently, which is not always the case.

According to the accidents investigated the process of evacuation follows three different procedures resulting in differences in passengers' behaviour and survival from accident; (1) Early stage alarm and crew guidance, (2) delayed alarm, without crew guidance and (3) no alarm sounds after the accident nor guiding. These two latter cases vary significantly from standard evacuation (first case) and from the passengers' perspective, affect their behaviour during the accident, for instance reducing their performance. For future proposals concerning people's behaviour and performance, the two latter cases should be empirically tested in a safe environment, such as virtual reality in order to gain a full understanding in respect of time consumed in evacuation and also to identify different behaviour pattens among passengers.

There are fundamental differences between onboard trials and real accidents. In this chapter the response time and experiment design are reflected through psychological sciences. The first issue is related to the flow of evacuation. Sea trials obey the procedure of evacuation determined in the guideline evacuation analysis MSC 1238. To subdivide the process in phases, the evacuation begins with alarm sound, which in passengers' perspective means listening to the instructions given by the crew, following the guidance to assembly station and further rescue. However, according to the accidents investigated in this study, the evacuation is not always conducted this particular way. In addition to the process described above the evacuation is followed by two other procedures, where early alert and clear instruction to passengers were missing or delayed alarm and inadequate information complicated the evacuation.

In reality people are perceptive of their environment and that means the evacuation in fact starts before the alarm sounding. Thus, the time pre-warning has a significant meaning in the process of evacuation especially in the situation where the alarm is delayed. In operational sense, this seems to define the direction of evacuation process and highlight the importance of relevant and efficient information with properly timed alarm announcement. Comparing real accidents to trials, in the case of Sally Albatross, ideal procedures were followed and the evacuation process happened similarly as onboard trials. Precise and efficient information, as well as having real time information available the whole time prevented irrational behaviour among the passengers. However, on Costa Concordia and Estonia relevant information was missing and therefore the passengers had no way of making correct judgements in order to decide the right course of actions, thus behaving in a way that seemed inappropriate for the situation.

Another issue is related to data collection. The purpose of sea trial experiments is to collect time data for further analysis (Galea et al.,2011, 2013). The manner in which the experiment is designed and conducted has an effect on the results. The measures of response time of passengers focused on response time per se. The time itself is directly meaningful. This means that the response time measures have only statistical significance. Response time data was presented as a distribution, with an emphasis on the mean values.

Response time has value in physiological sense, because it has direct effect on infomation-processing of human being. In psychological field, the goal of response time measurements is to understand basic human psychological processes (Pachella, 1973). Response time can be most typically defined as an interval between presentation of the stimulus to a subject and subject response (Pachella, 1973). Trials were conducted semi-announced, meaning that experiments were generated on a basis of implicit instruction, assuming that people are then trying to minimise their response time.

According to Pachella (1973), in these situations a person waits for the stimulus to be presented in order to response in a correct manner neither rushing nor delaying the response. Thus, the response time is taken to be the minimum time needed to produce a correct response.

Sea trial experiments had little value in psychological sense, since subjective responses were not examined and further analysed. These kind of experiments tend to ignore artefacts due to information processing of a person, because it only measures time and assumes that people behave more or less similarly to one another. This does not correspond with findings from accident reports, where people's information processing had a significant role caused by variations in the evacuation procedures and errors in information processing due to incomplete information. Furthermore, in statistical sense this type data collecting attempts to skew response time distribution positively, because it presents a mean response time value, hence cutting possible errors out of scope (Pachella, 1973).

However, experiments were recorded by using the video footage method. This could be useful also in empirical studies, when collecting data about people's information processing resulting to response in the various evacuation procedures. In this respect, the response time measures have substantial meaning - it is necessary to understand people's behaviour in order to succeed efficiently in the evacuation process.

6.2 Way finding under an emergency

Way finding of passengers in the evacuation happens rather intuitively or nonrationally than by obeying the procedures of rational way finding. However, there were no clear indications of individuals' subjective way finding process in detail, for instance how signage assisted passengers in the situation, or if sign visibility was provided easily for perception purposes.

However, way finding is goal oriented, since a person's intentions are focused on reaching the destination. General flow of way finding can be described through the cognitive process. During the process, humans develop an understanding through their senses of the existing world and interrelate it with stored spatial knowledge. Creating a cognitive map to plan activities transfers decisions into physical activities (Chen and Stanney, 1999). In this respect way finding emphasises efficiency of the environment to provide spatial information, since accuracy of information can influence the way finding performance (Tang et al., 2009).

The case studies emphasised factors such as the absence of guiding, incomplete information, time pressure causing stress and panicking which were likely to reduce the quality of information processing and decision making and thus influenced way finding behaviour. Way finding was considered through these factors. However, people experience these factors differently and the way finding process may be strongly affected by personal experiences and environmental factors which may result in different spatial cues collected and used by individuals (Chen and Stanney, 1999).

Furthermore, it is expected that the crew guide the passengers to assembly stations and provide real-time information during the evacuation. Guiding especially facilitates passengers' way finding from their position to assembly station and also likely affects positively to decision-making, because provided information helps understanding for instance, which specific route should a person take in order to arrive in the desired assembly station safely. This highlights the core role of the crew to control situation as a whole. In the case studies there was clear evidence that information given in the evacuation situation along with the presence of crew guidance improved the efficiency of the evacuation conducted.

6.3 Social environment and panic

According to findings from the analysis, panic is associated with ship motion and architecture. In the investigated cases panic was situational, mostly triggered when people tried to escape from immediate danger in a situation that at times was extreme. These situations were dependent upon ship listing as well as architecture affected to movement of a person. For instance, the staircases and large open spaces caused danger to passengers, due to complications to the continuity of movement. In these situations people tend to use every effort they possibly have in spite of having to continue movement through the danger, in order to escape. The effort continues as long as a person sees a real chance to flee and survive (Shaw, 2001). Furthermore, during the escape passengers did not use the nearest escape route which would have been the first choice for escaping from danger and trying to get to safety.

The ability to act rationally is linked to the physical context of the emergency evacuation but also to the nature of the situation (Aquirre, 2005). Escaping from danger is dependent upon the degree of threat and motivation of an individual (Aguirre, 2005). Furthermore, under the threat people's desire to get way from danger is so high, that decision of way finding or escape direction are not always logical. People are tempted to use routes that are known or frequently used by them rather than use those closer by (Quaratelli,1954).

Usually, in literature panic behaviour is described through the activities (e.g. Aguirre, 2005; Quarantelli,1954; Shaw, 2001). However, in contrast, some passengers in the same situation while others escaped, just sat paralysed without ability to mobilise themselves. However, there is similar evidence from the aviation field, where passengers sat immobile after emergency landing. This behavioural inaction is related to denial of an accident (Shaw, 2001). On the other hand, some disaster researchers emphasise that when people are totally trapped, they are not panicking at all and no course of action is taken, because there is no hope of getting away from the danger (Quarantelli, 2001).

Traditionally, panic has been described through the behaviour of an individual. However, panic does have features of social interaction and highly collective behaviour. Aquirre (2005, p. 122) claims that after decades of panic research, it is now assumed that panic is social and affiliate behaviour in the situations when the risk of death or injury is high, as opposed to Quaratelli (1954) who manifested panic to be asocial collective behaviour. In the study cases it was found that crowds formed in the assembly points and staircases.

According to the findings, people fought and shoved each other for places in lifeboat. This might be due to a threat to physical safety when evacuation is delayed. Even though it is rare that people take physical contact to each other, excluding extreme crowd disasters, situations can get out of control due to spontaneous behaviour in response to the perceived threat (Beverley, 2005). Instead, any collective mass panic or flight was not found and more over, mass panic, where people are trampled over by others is relatively rare (Beveley, 2005; Quaratelli, 2001;). Also no mass egress from a closed space was reported, it is nevertheless likely that such situations did and will occur.

One of factors that causes panic, is the lack of leadership and moreover, inadequate leadership skills. Similarly to maritime accidents, it was stated in an empirical study on air passengers' perception about the safety that the *flight-crew leadership is important for controlling panic* (Chang et al., 2008, p. 1465). According to the findings, typical causes and consequences were incomplete information, prolonged waiting time and inability to make decisions leading to situations where ”third party information” became a significant source of information guiding people. However, even in the worst circumstances, there is a place for natural leaders to take charge, if professional leadership is on an unsatisfactory level or does not exist at all. This kind of informal system is called, according to Beverley, (2005) ”emergency organisation” which rapidly develops among those affected. Natural leaders arise in such circumstances with efficient response, helping others to survive (Beverley 2005).

In the light of evidence collected from the studies, prolonged waiting affected passengers in a way that they gathered for instance in staircases waiting to be rescued. People have tendency to gather in large places in group context (Aquirre, 2005). In case of sudden changes in circumstances, e.g. flooding, increased listing or fire spreading, it may result in uncontrolled panic. In such circumstances, having people already blocking the escape routes for themselves by gathering in staircases, the situation is hazardous. Staircases as a safety feature are important escape routes to assembly stations. According to (Ahola et al., 2014) studying passengers' safety perception onboard expressed concern over staircases being trammeled in the evacuation. When developing regulations in the future, it is necessary to consider in operational as well as in functional sense, how this affects the passengers.

The term ”panic” was widely used in data at least as diversity relating meaning of panic. Panic was characterised as aimless, irrelevant movement, yelling, pushing and rushing or paralysing behaviour. Perhaps, the usage of the term stems from everyday speech to describe irrational behaviour with groundless fear in a threatening situation. Further, in the crisis situation basically any irrational behaviour is called panic, and thus widespread diversity of panic can have multiple meanings and conditions that generates the phenomenon (Quarantellli, 2001).

In the future the definition of panic should be sharpened to avoid any misuse of the term. Irrational or aimless behaviour are not such patterns of behaviour that meet requirements of the definition. Still more detailed knowledge is needed on people's (passengers) behaviour to define the occurrence of panic or stress due to an accident. Proceeding on a more detailed level, focus should be directed to questions of emotion, information processing and judgements, as well as activities during an accident. Consequently, those issues are important to understand in order to prevent panicky behaviour among the passengers.

6.4 Ship architecture in an emergency

Based on the analysis, large open places became dangerous while the ship was listing and the lack of safety appliances (such as guardrails) in these particular spaces complicated the proceeding across the space. In addition, due to listing the staircase handrails pulled away by extreme use and forces. In terms of safety, architecture and safety appliances have a significant meaning since the environment's purpose is also to guide passengers, facilitate their activities and ensure their safety in the evacuation. For instance, guardrails have significant and very practical value for passengers. Passengers ranked guardrails as the most important safety feature in the ship (Ahola et al., 2014). Estonia accident highlighted some architectural factors although those improvements in the regulations were more technical. However, it can be considered that enforcing the lower section of bulkheads in corridor segments in order to have possibility to continue walking even if the ship is listing benefits the passengers. Furthermore, escape routes must be kept free during the voyage. Amendments of regulations were approved in 1997 in SOLAS 1974, II-2/28-1 (JAIC). However, the usability of guardrails was not under consideration at that time, even if it has crucial role for survival of an individual.

Lifejackets that were used in the Estonia accident by passengers were refused to be distributed by the crew during the evacuation. Although improper, this can be considered an isolated case. Failure of complying the rules is ineffective and dangerous in terms of safety. Safety appliances around the ship are the most visible factors to passengers and therefore, the condition and functionality should be reliable but their availability is of an equally high importance. Easy access to the safety appliances evokes a feeling of security in passengers (Ahola et al. 2014). Furthermore, it reduces the probability of unnecessary injuries or even casualties in the rescue phase, if passengers wear life jackets.

In evacuation analysis, escape planning complies with the model which does not consider passengers passing through a large space (IMO, 2007). For instance, models propose escape routes from large space (restaurant) to stairs and further to assembly points in the daytime cases. However, according to evidence it is quite usual that the passengers' movement is directed through public areas, such as lobbies or restaurants when, for instance, moving across the ship from one side to the other. Even if from the design perspective it is not considerably natural, efficient or a desired choice to design a escape passages through large spaces, it is likely that passengers in the ship evacuation do proceed through them in order to get to the assembly station.

The latest guideline for evacuation, Safe Return to Port suggests that ”the ship is the best lifeboat.” The work for updating safety regulations of passenger ships started already in 2000. The cruise industry expressed their concern regarding controlled evacuation of large amounts of passengers, especially concerning the difficulties faced with evacuating passengers with disabilities (Germanishe Lloyds). However, there are perspectives that highlight keeping people onboard for as long as possible. According to the operational perspective of Savolainen (2015), to prevent unnecessary casualties or injuries due to ship motion in rescue state at sea, the best practice is to hold passengers in safe circumstances onboard, and assembling them to large open spaces for easier and more effective control.

In accordance to (SRtP) regulation 21.5.1.1 functional requirements are presented for safe areas to passengers. It determines that safe areas are preferably to be arranged in the accommodation spaces or public places. Furthermore, sizing of these safe areas should be based on the time needed for safe return to port operation (Germanishe Lloyds p. 25). However, selection of areas for safe areas may be based on scenario type and environmental conditions. In operational sense, it can then be assumed that safe areas may have to be established in public places, for instance in case of spreading fire in accommodation area.

Large open spaces surely have to be safety critical in the sense that fire and water spread more easily in these spaces (Ahola et al., 2014). In such case, if the scenario is escalating quickly e.g. with increasing heeling angle, flooding or smoke and toxic fumes spread fast through open spaces, likely causing the crowd to panic. This situation highlights crowdmanagement which has to be very efficient and escape routes should be kept untrammelled.

6.5 Accident investigation

The main objective of maritime accident investigation is to prevent accidents from happening similarly in the future. Investigation relays on international regulation adopted in MSC-MEPC.3/Circ.2. Investigations focus mainly on finding causes and consequences of accidents from a technical perspective. Therefore many improvements in ship safety concern technical system safety rather than comprehensively distinguishing multidisciplinary aspects. Describing the approach to investigation as a top-down process, only recently has the focus been directed towards organisation behaviour, when after the Costa accident attention was paid to crew members' activities, training and safety culture. However, not much attention has been paid to the passengers' survival from an accident. This observation is supported by the fact that accident reports where passenger pertain to as an integrated part of investigation is rather limited. However, not all implementation and follow-up of recommendations as part of the investigation concern only technical safety improvements. For instance, the crew neglecting safety drills arose in discussion after the Costa Concordia accident. Requirement for musters for newly embarked passengers prior to departure entered into force in 2015, three years after the accident (amendments: SOLAS regulation III/19). The highlight the necessity to learn from past accidents, It would be convenient to study how these changes actually affect passengers' perception of safety.

All accident reports examined for this study included either hearing passengers as witnesses or interviewing them by surveys afterwards to collect evidence to support in analysing causes and consequences of the accident. Yet passengers' perception, activities interaction with environment and each other or emotions are in subordinate role in the investigation. Thus, the behaviour of passengers during the emergency are very little known. Formal accident investigation might not be enough to prevent accidents from happening similarly in the future. Hence, Lesson Learned is the knowledge or understanding acquired by real experiences. In fields where risks are high, such as the military, learning from the past failures or successes has become a significant framework for collecting, storing or disseminating and reusing experimental knowledge (Weber et al., 2001). Rather than provide recommendation it offers guidance through the different levels of organisation (Weber, et al., 2001). Le

Coze, (2013) stated that learning from accidents is still young and scattered in high-risk industries. Furthermore, he recommended using cross-disciplinary perspective as a method. In other words, combining psychological, sociological or managerial sciences in empirical studies is a way to increase the level of knowledge and learning from accidents (Le Coze, 2013).

Also in maritime field, the reason for limited amount of research data available from real accident in the passenger perspective is related to the inability to integrate multiple dimensions of disciplines. This considers knowledge on individual and social levels, which seems to have an important role in accidents but is yet missing from investigations. The best practice in order to learn from the accident is to focus on real life incidents. By using different methods, such as post-analysis from real accidents with integrating multiple perspectives such as social and psychological sciences into research throughout the organisational levels increases understanding on what really happens during accidents and which factors, for instance, actually reduce the efficiency of evacuation performance. Furthermore, post-analysis from accident is the only way to collect real accident data and gain insight to people's behaviour during an emergency, thus being an opportunity which should not be missed.

7. Discussion and conclusion

7.1 Overview of research outcomes

Research revealed that in emergency (1) people trust more in their own perceptions and intuition than given instructions by the crew. (2) Human behavior is guided by instinctual urge to get away from the danger, while rational thinking needed in way finding is secondary. (3) Furthermore, if there’s a lack in safety instructions people tend to follow each others, which often results in crowding in places that should be untrammeled in order to ensure efficient evacuation. (4) Accident investigation should be integrating multidisciplinary perspective for increasing understanding about passengers’ behavior during an accident. Evacuation analysis is in need of a tool with which to study findings such as these that are closely linked to human behaviour. The following chapter proposes a solution for a more flexible and comprehensive research tool.

7.2 Recommendation for Virtual reality as a research tool

This section proposes an idea of using virtual reality as a research method for interaction of passengers and the environment and collecting data from human behaviour in order to develop evacuation analysis towards reality.

Virtual reality (VR) is a technology which claims to provide the "ultimate" interface between humans and computerised applications based on real-time, three-dimensional graphical worlds. To clarify the elements of Virtual reality (VR) or virtual environment, the term ”virtual” means a technique in which a specific world is imaginary. ”Reality” in turn enables a person to enter into that specific world experiencing it as if it was real. There are several advantages in using simulation and game in illustrating interconnected processes within complex systems. It offers a possibility to create a logical system that provides realism and enables rapid responses to user inputs.

Simulation and game environments focus learning not simply on the knowing of facts and ideas (Jackson, 2004). Utilisation of game development industry principles, processes and techniques for creating and training environment for analysis, prediction modelling, evaluations and education enables new forms of knowledge interaction previously unavailable within the normal curricula. Game's virtual reality and environment visualisation becomes a dynamic and active process experimentation and experience.

Virtual reality has been applied in several domains: surgical simulations in medicine, sports, entertainment, military, built environments, economics and transportation. Engineering and social sciences have successfully utilised virtual reality in improving safety issues, learning processes and design architecture.

For example, the military has historically used virtual environments and simulation in "war games" as far back as the 1950s in order to improve high-risk occupational training. The virtual war teaches the soldiers to prepare for a real combat situation. It teaches ways to deal with unexpected events when it is vitally important for them to understand how to react in dangerous settings where any decision might mean the difference between life and death. It develops an understanding on how to behave in and deal with unexpected events. As virtual reality is used as a safe training tool for soldiers, it also provides teachers and researchers with immediate responses and data on human behaviour. Safety issues in military and in the naval domain have this in common: the need for information on human behaviour and action, decision making process as well as perception in an unexpected situation.

It is possible to use the game as a research tool, instead of only focusing on using the game for learning purposes. In general, design scientists produce and apply local knowledge for unique circumstances to create effective artefacts. Design science is made up of constructing artefacts for special purposes and for assessing their effect under well-defined circumstances of use (Klabbers, 2006). A basic question that needs to be addressed is how well does the artefact perform, considering the specifications for the design, including the goals to be achieved? Problem settings point out that design science is issue driven. It addresses human needs, conquers bottlenecks and capitalises on opportunities. Implementing games in social systems to raise the level of awareness, to practice skills and also to produce knowledge, are interventions to enhance change (Noy et al., 2006).

Virtual reality is used in maritime domain for training the crew, for instance for purposes of ship navigation. Operational perspective supports developing training effort and educational performance as well as complex operation management (Buzzing, 2013). In addition, several software tools simulating human behaviour in emergency situations in maritime domain use virtual environment as a platform. However, in order to test current theories and models of human information processing, decision-making, interaction with environment as well as emotional models VR could be used to elaborate and extend knowledge (Noy et al., 2006). Problem structure and problem-solving processes can be investigated, interpreted and further applied for design purposes, even regulative processes. Simulation and game environment enables new forms by swinging interaction from passive to active which means an active learning process (Jackson, 2004). Learning is a comprehensive experience since a person in virtual reality is immersed within an environment, concept or a system. Furthermore, in virtual reality the process can be either sped up to view longitudinal outcomes or slowed down for incremental progression. Longitudinal outcome means the natural course of life or disorder in which a group of subjects are observed over a period of time and is especially beneficial when studying the risk factors of human life. Since time and place can be manipulated in virtual reality it is a suitable research tool for analysing already occurred accidents, thus gaining advance in lesson learned possibilities because the environment and events can be manipulated safely (Jackson, 2004).

Human as an active operator needs to be set on the premise, unlike current agent-based modelling which does not highlight user participation. Some argue that the VR is only seen as a framework for maintaining traditional practices and still ignores human factors and cognitive processes as perceptual issues (Johnson et al., 2010). Comprehensive use of virtual reality for investigating human behaviour in non-emergency and emergency situations is missing. However, many studies (Jackson, 2004; Klabbers, 2006, Noy et al., 2006) in multiple fields have investigated the usage of virtual reality and found that VR is an effective empirical research framework considering human perception and cognition. The doubts regarding whether the results of human perception and action in virtual reality can be applied and transferred in natural environment is probably justified. However, this particular question concerns also other investigated topics such as learning and training. For instance, is training effective in virtual environment? Further, is the first officer ready to navigate a ship after being trained just within a virtual ship? Gaining the best outcome, training both in natural and virtual environment brings the best benefits. Similarly, for research purposes, at least some of the experiments would be conducted in a natural environment and when a consistency is reached in the results, it will be verified for by both environments (Van Veen et al., 1998).

Theses outcomes have put weight on the importance of understanding human cognitive behaviour in purpose-driven ship environment. Individual’s way finding in complex environment, social environment in emergency or external environmental circumstances surely are affecting human behaviour and effective answers for these complex environmental issues are still being sought. Maybe physical modelling in some of these challenges affecting human mental behaviour which is then reflected on the physical behaviour cannot be solved by traditional design manners or in field experiments.

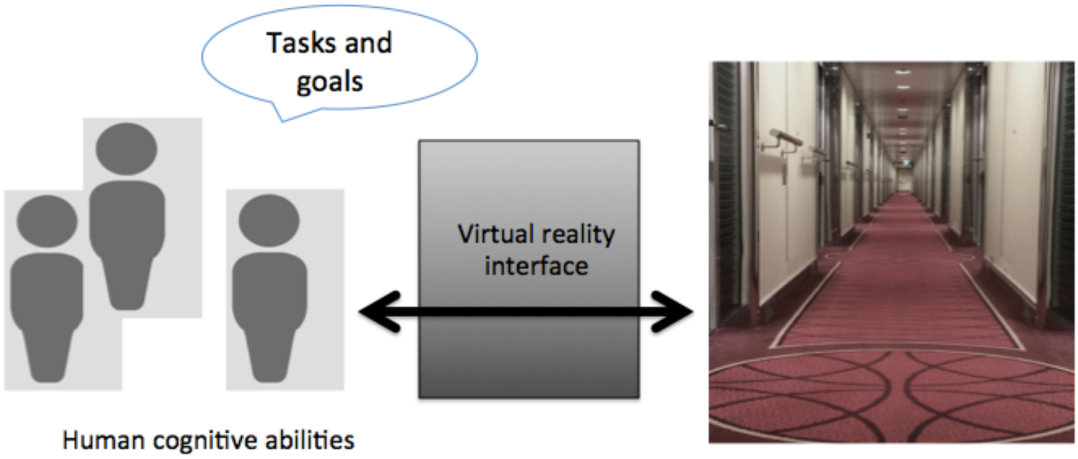

Figure 22 Propositional virtual reality framework

Figure 22 illustrates the outline recommendation as a framework for investigating human cognitive processes in virtual reality in emergency or non-emergency situation. Humans are set at the centre of the framework, because passengers work as active users conducting goal oriented tasks. Similarly, as in reality, humans are interacting with the environment and the human goal oriented mindset makes decisions and actions for proceeding towards a final goal.

Virtual reality here is functioning as a interface tool enabling humans to conduct different tasks. Virtual reality is online spaces functioning as a replica of physical ship spaces and as an extension of the ship environment. Interaction does not happen merely between the environment and the user, but VR enables also constructing social dimensions. Even though the user would sit alone in front of a computer, a social environment can be exposed with different levels of social interaction either with other players or with game agents (Noy et al., 2006). Social theories are dependent upon the field and the objectives of a research. For instance, group presence in an evacuation where passengers make decisions and judgments are not solely related to individual behaviour (Noy et al., 2006). Thus, it is worth testing how information influences a group's decision-making and activities (movement). Individuals have limited attention to the world which they perceive and interpret at once resulting in a situation in which our expectations and knowledge overrule the information that is actually available from the stimulus (Jackson, 2004). Even though human perception has cognitive limitations due to culture, past experiences and interpretations of the perceived space or objects, humans still do actively perceive their environment instead of just taking ”snapshots” of the environment, since they are driven by an individual’s desire to arrive at precise decisions. Therefore, VR provides a technology of rich visualisations which is balanced with realism (Johnson, et al, 2010). Furthermore, in virtual reality a precise control over the present stimulus is possible. In addition, VR technology enables users to navigate in the virtual environment, manipulate objects and get feedback from the environment. For testing purposes it is possible to record time and measure distances needed in design or for evaluation purposes.

In technology, virtual reality is used in the design process to enable engineers to view artefacts in 3D and gain a greater understanding on how systems work. This also helps them spot any flaws or potential risks before implementation. Design team can observe their work within a safe environment and make changes if necessary. Taking advantage of these capabilities virtual reality offer in identifying human actions in evacuation process seems very reasonable.

Following hypotheses have been made:

Advantages of using virtual reality game in a ship environment:

- Examine the ways in which passengers perceive the environment around them and how these perceptions are utilised in information processing and decision making.

- Widen the understanding of human behaviour in stressful situations, such as evacuation, and provide valuable and more detailed data for improving usability issues and promoting safety.

The basic idea of the serious game in passenger ship environment is simple. In "Virtual Reality Ship" game, the players move around the ship as cruise passengers executing various specific tasks. For example, the player would have to navigate from a cabin on the 7th deck to the nearest assembly point on the 8th deck. This task could be completed in various situations - under normal conditions, in case of a fire, while the ship is flooding, or any number of other instabilities. Human behaviour in stressful situations may change radically from one scenario to other.

Virtual reality can be built based on ideas, facts, qualitative and quantitative research data. Creating a virtual ship should be based on reality, in order to get results that are representative and valid in practice. Visualisation of the environment is generated from an existing ship structure and architecture in detail. Subjective perspective of a passenger should be used as a basis and utilise data from personal safety issues of cruise passengers: which artefacts do people consider safe and which are the issues they have concerns about. Age and gender of passengers must be identified in order to generate an authentic population. The users' individual tasks in the game are based on the scenarios defined in IMO guidelines in passenger ship evacuation, but can be adapted to be more detailed. Using data from previous microscopic simulations available from naval domain, flow rates, flow densities, walking speed, time usage in ship evacuation process gives physical basis for human behaviour. For closing this chapter, figure 23 summarises the main benefits, challenges and opportunities of virtual reality.

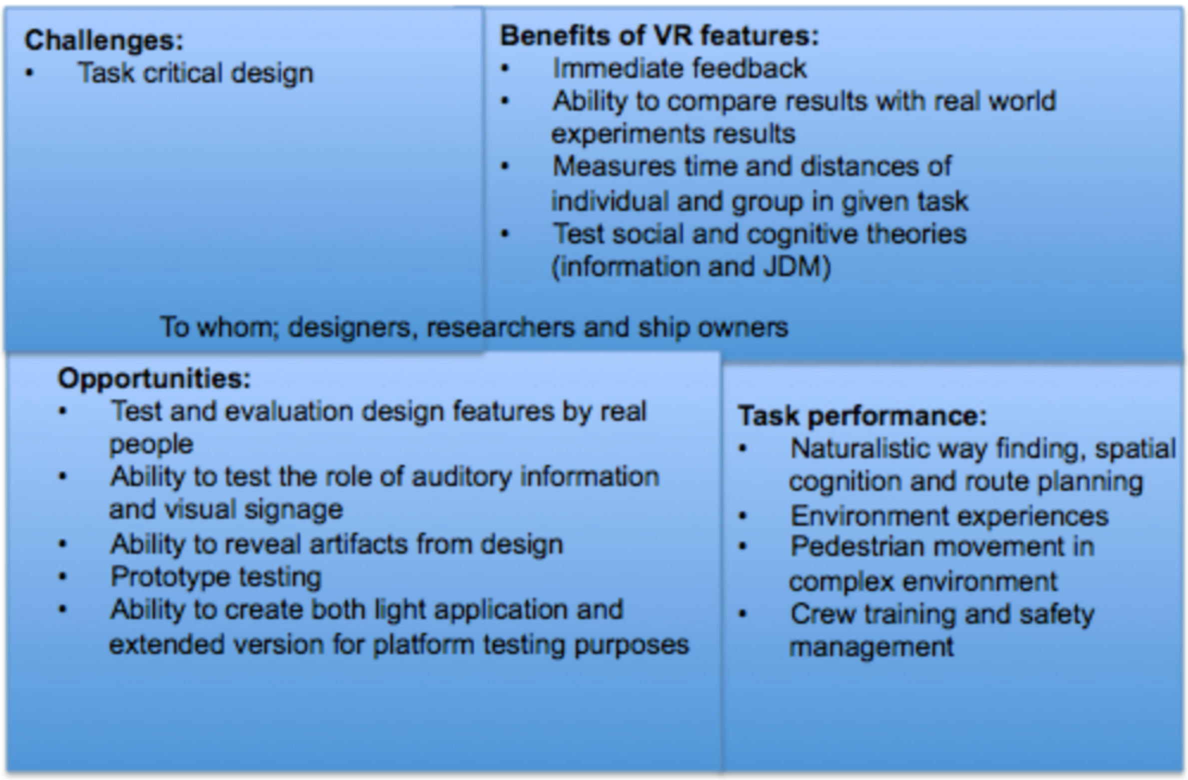

Figure 23 Summary of pros and cons of virtual reality

7.3 Conclusion

The purpose of this theses was to study human-environment interaction during evacuation from the passengers' perspective. The results from the study give us insight to human behaviour affecting the evacuation process, which can be used to develop evacuation analysis that is more corresponding to reality. However, rather than providing detailed information about human behaviour in all its aspects, the theses emphasises certain factors in human behaviour which are crucial for surviving from accident and that is why further study questions are proposed. Current evacuation modelling does not take these factors into account. Human behaviour studies in evacuation situations focus primarily on improving and validating existing evacuation models in respect of human physical abilities, mainly excluding psychological aspects out of scope.

More reliable data on passengers behaviour in this respect need to be collected. Thus, proposals of using virtual reality as a research tool in multidisciplinary perspective are provided here. It would benefit engineers in design, the classification society and ship owners.

In conclusion, a future study could examine how and which factors influence a person's ability to make good decisions during an emergency on a more detailed level. The concepts of time pressure, information flow, stress and panic are necessary to include in the context of human-environment research in maritime accidents. Learning more how passenger perceive and act in ship environment in an emergency increases safety in the evacuation and enables to improve knowledge towards reality.

8. References

Literature:

Accident Investigation Report of Ms Sally Albatross,1994. [Online] Available at: <http://www.onnettomuustutkinta.fi>. [Accessed 13.1.2015].

Ahola, M; Murto P; Kujala P; Pitkänen, J. 2014. Perceiving Safety In Passenger Ships - User Studies in an authentic environment. Safety Science, Vol. 70. pp. 222-232.

Aguirre, B.E. 2005. Emergency Evacuations Panic and Social Psychology. Psychiatry: Interpersonal and Biological Processes, Vol. 68:2. pp.121-129.

Baum, M.W.1989. Quantitative Prediction and Molar Description of the Environment. The Association for Behaviour Analyst, Vol. 12. pp.167-176.

Beverley, R. 2005. Crowds and other Collectives. Complexities of Human Behaviors in Mass Emergencies. Psychiatry: Interpersonal and biological processes, Vol. 68:2. pp. 115-120.

Brown, R; Galea, E.R; Deere, S; Lazaros, F. 2012. IMO INF Paper Summary. Response Time Data for Large Passenger Ferries and Cruise Ships.

Beverley, R. 2005. Crowds and other collectives. Complexities of human behaviors in mass emergencies. Psychiatry: Interpersonal and biological processes, Vol. 68:2. pp. 115-120.

Bruzzone A.G; Massei, M; Solis, A.O; Poggi, S; Bartolucci, C; Capponi, L.D. 2013. Serious Games as Enablers for Training and Education on Operations on Ships and Off-Shore Platforms. Proceedings of the 2013 Summer Computer Simulation Conference Article No. 36. Society for modeling & Simulation international. ISBN 978-1-62748-276-9.

Chang, Y-H and Liao, M-Y. 2008. Air Passenger Perception on Exit Row Seating and Flight Safety Education. Safety Science, Vol. 46:10. pp. 1459-1468.

Chen, J.L and Stanney, K.M. 1999. A Theoretical Model of Way Finding in Virtual Reality, Proposed Strategies for Navigation Aiding. Department of industrial engineering,Vol. 8:6. pp. 675-685.

Cacciabue, P.C. 2001. Human Error Risk Management for Engineering Systems: A methodology for Design, Safety Assessment, Accident Investigation and Training. Reliability Engineering and System Safety, Vol. 83. pp. 229-240.

Choo, F. 1995. Auditors' Judgement Performance Under Stress: A test of the Predicted Relationship by Three Theoretical Models. Journal of Accounting, Auditing and Finance, Vol.10:3. pp. 611-640.

Committee on Transportation and Infrastructure, U.S. Government. A Review of Cruise Ship Safety and Lesson Learned from Costa Concordia Accident. 2012. [Online] Available at: <http://www.gpo.gov/fdsys/browse/ committee.action?chamber=house&committee=transportation>. [Accessed 13.1.2015].

Colledge, R.G. 1992. Place Recognition and Way Finding: Making Sense of Space. Geoforum, Vol. 23:3. pp.199-214.

Corbin, J and Strauss A. 2008. Basics of Qualitative Research. 3rd edition. SAGE publication Inc. ISBN 9781452230153.

"Cruise Industry Overview 2013: State of the Cruise Industry" Florida-Caribbean Cruise Association (FFCA), 2013. [Online] Available at: <https://f-cca.com>. [Accessed 23.5.2015].

Deere S.J; Galea E.R; Lawrence P.J. 2009. A Systematic Methodology to Assess the Impact of Human Factors in Ship Design. Applied Mathematical Modelling, Vol. 33. pp.867-883.

Eysenck, M.W and Keane, M. 2010. Cognitive psychology. A student handbook. 6th edition. Psychology Press. ISBN 978-1-84169-539-6.

Elo, S and Kyngäs, H. 2008. The Qualitative Content Analysis Process. Journal of advanced nursing, Vol. 62:1. pp.107-115.

Evans, G and Stecker, R. 2004. Motivational Consequences of Environmental Stress. Journal of Environmental Psychology, Vol. 24. pp.143–165.

Forman, J and Damschroder, L. 2008. Qualitative Content Analysis. Empirical Methods for Bioethics: A primer Advances in Bioethics, Vol. 11. pp. 39-62.

Full Technical Accident Investigation Report of C/s Costa Concordia. 2012. [Online] Available at: <http://www.emsa.europa.eu>. [Accessed 13.1.2015].

Galea, E.R; Brown, R.C; Filippidis, L; Deere, S. 2011. Collection of Evacuation Data from Large Passenger Vessels at Sea. 5th International Conference on Pedestrian and Evacuation Dynamics, Maryland, USA.

Galea, R; Deere S; Brown, R; Filipinos, L. 2013. An Experimental Validation of an Evacuation Model using Data Sets Generated from two Large Passenger Ship. Journal of ship research, Vol. 57:3. pp.155-170.

Germanishe Lloyds, (GL): Preliminary Guidelines for Safe Return to Port Capability of Passenger Ships. 2009. [Online] Available at: <http://www.gl-group.com/infoServices/rules/pdfs/gl_vi-11-2_e.pdf>. [Accessed 1.2.2015].

Gigerenzer, G and Gaissmaier, W. 2011. Heuristic Decision Making. Annu. Rev. Psychol., Vol. 62. pp. 451-482. [Online] Available at: <psych.annualreviews.org>.

Ginnis, A.I; Kostas, K.V; Politis, C.G; Kaklis, P.D. 2010. VELOS: A VR Platform for Ship-Evacuation Analysis. Computer-Aided Design, Vol. 42. pp.1045-1058.

Gärling,T. 1998. The Role of Cognitive Maps in Spatial Decision. Journal of Environmental Psychology, Vol. 9. pp. 269-278.

Ha, S; Ku, N-K; Roh, M-I; Lee, K-Y. 2012. Cell-based Evacuation Simulation Considering Human Behavior. Ocean Engineering, Vol. 53. pp.138-152.

HSVA Report No. 1663. Research Study on the Sinking Sequence and Evacuation of the *MV Estonia*- Final Report. Hamburg, May, 5, 2008. [Online] Available at: < https://www.hsva.de>. [Accessed 13.1.2015].

Hebling, D; Farkas, I; Tama's V. 2000. Simulation Dynamic Features of Escape Panic. Nature, Vol. 407. Macmillan magazines Ltd.

Hongtae, K; Park, J-H; Lee, D; Yang,Y-S. 2004. Establishing the Methodologies for Human Evacuation Simulation in Marine Accidents. Computers and Industrial Engineering, Vol. 46. pp. 725-740.

Hsieh, H-F and Shannon, S.E. 2005. Three Approaches to Qualitative Content Analysis. Qualitative Health Research, Vol. 15. pp.1277-1288.

IMO, Resolution A.849(20): Code For The Investigation Of Marine Casualties and Incidents. Adopted on December 1997.

IMO, Circular MSC.1/Circ.1238: Guidelines for Evacuation Analysis for new and Existing Passenger Ships. Adopted 30 oct 2007.

Jackson, M. 2004. Making Visible: Using Simulation and Game Environments Across Disciplines. On the Horizon, Vol.12:1. pp. 22-25.

Johnson, A; Thompson, E.M; Coventry, K.R. 2010. Human Perception, Virtual Reality and the Built Environment. 14th International Conference of Visualization. pp. 604-609.

JAIC, Full Maritime Investigation Report MV Estonia, 1994. [Online] Available at: <http://www.onnettomuustutkinta.fi>. [Accessed 13.1.2015].

Klabbers, J.H.G. 2006. A framework for Artifact Assessment and Theory Testing. Simulation Gaming, Vol. 37:155. [online] Available at:<http://sag.sagepub.com/content/37/2/155>.

Kaplan, S.1983. A model of Person-Environment Compatibility. Environment and behavior, Vol. 15:3. pp. 311-332.

Lazarus, R.S and Folkman S. 1984. Stress, Appraisal and Coping. Springer Publishing Company. 456 p. ISBN 0-8261-4191-9.

Lee, D; Kim, H; Park, J-H; Park, B-J. 2003. The Current Status and Future Issues in Human Evacuation from Ships. Safety Science, Vol. 41. pp. 861-876.

LeCoze, J.C. 2013. What We Have Learned About Leaning from Accidents? Post-disasters reflection. Safety Science, Vol. 51. pp. 441-453.

Lerner, J.S; Ye, L; Valdesolo, P; Kassam, K.S. 2015. Emotion and Decision Making. Annu. Rev. Psychol., Vol. 66. pp. 799-823.

Loewenstein, G.F; Weber, E.U; Hsee, C.K; Welch, N. 2001. Risk as feeling. Psychological Bulletin, Vol. 127:2. pp. 267-286.

Løvås, G.G.1998. Theory and Methodology: Models of Way Finding in Emergency Evacuation. European Journal of Operational Research, Vol. 105. pp. 371-389.

Matthews, G; Davies, D.R; Westerman, S; Stammers, R.B. 2000. Human Performance, Cognition, Stress and Individual Differences. Psychology Press. ISBN 0-415-04406-5.

Meller, B.A; Schwartz, A; Cooke, D.J. 1998. Judgement and Decision Making. Annu. Rev. Psychol., Vol. 49. pp. 447-477.

Noy, R. D; Ravid, R; Ravid G. 2006.Testing Social Theories in Computer-Mediated Communication Through Gaming and Simulation. Simulation and Gaming, Vol. 37:174. [Online] Available at: <http://sag.sagepub.com/content/37/2/174>.

Nurmi, L. 2009. Kriisi, pelko, pakokauhu. Edita publishing Oy. ISBN 951-37-4364-0.

Oliveira A, 2007. A Discussion of the Rational and Psychological Decision-Making Theories and Models. The Search for a Cultural Ethical Decision-Making model. Electronic Journal of Business Ethics and Organization studies, Vol. 12:2. pp.12-16.

Ozel, F. 2001. Time pressure and stress as a factor during emergency egress. Safety Science, Vol. 38. pp. 95-107.

Park, H-J; Lee, D; Kim, H. 2003. Development of Evacuation Model for Human Safety in Maritime Casualty. Ocean Engineering, Vol. 31. pp.1537-1547.

Pachella, R.G. 1974. The Interpretation of Reaction Time in Information Processing Research. Technical report. No. 45.

Papanikolaou, A. 2009. Risk-Based Ship Design: Methods, Tools and Applications. Springer Science & Business Media. 376 p. ISBN 978-3-540-89041-6.

Patton, M.Q. 1990. Qualitative Research & Evaluation Methods. 3rd edition. SAGE publication Ltd. 538 p. ISBN 0-7619-1971-6.

Pires,T.T. 2005. An Approach for Modeling Human Cognitive Behavior in Evacuation Models. Fire Safety Journal, Vol. 40. pp. 177-189.

Quarantelli, E.L. 1954. The Nature of Panic. American journal of sociology, Vol. 60:3. pp. 267-275.

Quarantelli, E.L. 2001. The Sociology of Panic. Preliminary paper #283. Disaster Research Center. University of Delaware.

Salas, E and Driskell, J.E. 2013. Introduction: The study of Stress and Human Performance. Eds. Psychology Press.

Shaw, R. 2001. Don't Panic: Behavior in Major Incidents. Disaster prevention and management, An international journal, Vol. 10:1. pp. 5-10.

Shager, B. 2008. Human Error The Maritime Industry. How to Understand, Detect and Cope. Vinnova and Bengt Schager. 186 p. ISBN 978-633-2064-4.

Sherry, P. 1991. Person-Environment Fit and Accident Prediction. Journal of business and psychology, Vol. 5:3. pp. 411-416.

Sime, J.D.1983. Affiliative Behaviour During Escape to Building Exits. Journal of environmental psychology, Vol. 3. pp. 21-41.

Sime, J.D.1995. Crowd psychology and engineering. Safety Science, Vol. 21. pp.1-14.

Schwarz, N. 2000. Emotion, Cognition and Decision-Making. Cognition and Emotion, Vol. 14:4. pp. 433-440.

Tang, C-H; Wu, W-T; Lin, C-Y. 2009. Using Virtual Reality to Determine How Emergency Signs Facilitate Way-finding. Applied Ergonomics, Vol. 40. pp. 722- 730.

Tvesky, I.1977. Model of Crisis and Decision-Making. Administrative Science, Vol. 22:4. pp. 640-657.

UNCLOS: United Nations Convention on the Law of the Sea [Online] Available at: <https://www.un.org>.

Vanem, E and Skjong, R. 2006. Designing for Safety in Passenger Ships Utilizing Advanced Evacuation Analysis - A risk-Based Approach. Safety Science, Vol. 44. pp. 111-135.

Van Veen, A.H.C; Distler, H.D; Braun, S.J; Biilthoff, H.H. 1998. Navigating Through a Virtual City: Using Virtual Reality Technology to Study Human Action and Perception. Future Generation Computer Systems, Vol.14. pp. 231-242.

Vassalos, D. 2006. Passenger Ship Safety: Containing the Risk. Marine technology, Vol. 43:4. pp. 203-212.

Vassalos, D; Kim, H.S; Cristiansen G; Majumber, J. 2002. A Mesoscopic Model for Passenger Evacuation in a Virtual Ship-Sea Environment and Performance-Based Evaluation. In pedestian and evacuation dynamics. Springer Netherlands, pp. 369-391.

Wang, J. 2001. The Current Status and Future Aspects in Formal Ship Safety Assessment. Safety Science, Vol. 38:1. pp.19-30.

Wang, J; Zhang L; Shi,Q; Yang P; Hu, Z. 2015. Modeling and Simulation for Congestion Pedestrian Evacuation with Panic. Physical A., pp. 296-409.

Weber, R; Aha, D.W; Becerra-Fernandezc, I. 2001.Intelligent Lesson Learned System. Expert Systems with Applications, Vol. 17. pp- 17-34.

Yu-Hern, C; Meng-Yuan, L. 2008. Air Passengers Perception on Exit Row Seating and Flight Safety Education. Safety Science, Vol. 46. pp. 1459-1486.

Zeisel, J. 2006. Inquiry by Design: Environment/Behavior/Neuroscience in Architecture, Interiors, Landscape and Planning. Rev ed. W.W. Norton & Company Ltd. 288 p. ISBN 978-0-393-73184-2.

Interview:

Interview 1. Captain Savolainen, J. Commander; The West Finland Coast Guard District. 2015. Interviewed by Jonna Nevalainen. Place: Juhana Herttuan Puistokatu 21, 20100 Turku. 27.5.2015. Recorded in textual data form.