FIRST – Fire strategies for unmanned island ferries

Concluding report

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Content

1 Preface

This document presents the project "Fire strategies for unmanned island ferries" and gathers the main findings. Based on these findings, an approach to designing the fire safety strategies for such ships is proposed.

The full extent of the project work is detailed in a set of annexes presented at the end of this document. The reader is directed there for further information and details.

The project was led by the Danish Institute of Fire and Security Technology (DBI) and had FORCE Technology, Molslinjen A/S, and JJohannesson ApS as project partners.

The project partners wish to thank *The Danish Maritime Fund* for generously supporting the project.

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2 Project introduction

2.1 Scope

This project is concerned with exploring the implications of autonomy in the context of fire safety on board small passenger ferries. When the topic of autonomy is debated, discussions focus on technical considerations such as situational awareness, connectivity, or communication; legal considerations to adapt current laws to the new situation autonomous shipping would create; safety considerations such as piracy, hacking, or collision avoidance. There is little to no consideration of the issues relating to fire safety.
Fire may not be the primary technical challenge to develop autonomy for ships; it may however prove to be a major challenge to enable the implementation of this technology. Fire remains one of the most feared issues on board ships, threatening crew, passengers, and cargo.

In the context of small domestic ferry routes, there can be strong economical competition and large operational costs, making the use of autonomous ships an interesting potentiality. The main challenge becomes providing the right level of fire safety to the passengers when limited number of crew is present on board.
As a result, the project will focus on the two main tracks of technical aspects and human factors. The human factors part of the study provides the settings and design constraint around the operation of the ship. The technical part integrates the data from the human factor part in order to design a fire safety strategy optimised for the given operational model of the ship.

This ultimately translates into suggestions for a fire safety strategy suited to a ferry designed for autonomous operation.

The project is based on an actual ferry design provided by Molslinjen A/S and Jjohannesson ApS. This design is Sønderho II, the replacement ferry for Sønderho, currently in service between Esbjerg and the island of Fanø in Jutland.
For this specific ferry and given existing operational and technological constraints, it was hypothesised that an achievable level of autonomy would be to have one crew member on board holding the position of Master.

2.2 Objectives

The objectives of the projects are to:

- Highlight the challenges and investigate the meaning of fire safety in the context of small autonomous passenger ferries
- Propose a fire safety strategy adapted to the level of autonomy decided for the given ship
- Review existing technology usable for fire safety on board small autonomous ferries and the market actors providing this technology
- Investigate challenges related to human factors for small autonomous passenger ferries

2.3 Limitations

The project is framed by the specific requirements relating to the design of the ferry Sønderho II for which details will be provided in Section 3. As a result, some of the findings and recommendations may not be extendable to other projects.

The project is dependent on the level of knowledge available at this point in time. New data is created in the course of the work, but additional work on specific issues is necessary. This concerns scientific work, approval procedure with flag state authorities, or technology development.

Some of the findings should be taken as suggestions or indicators of certain trends, rather than actual scientific evidence. Specific items are highlighted in the body of the report.

Legal considerations related to the technology and implementation of the technology discussed herein are not included in this study. Similarly, no cost-related study was performed. This project explores only technical feasibility.

2.4 Structure

The project consists of three main parts.

The first part is a review of available technology for application in the context of fire safety on board autonomous ships, existing projects concerned with autonomy for ships, and an overview of guidelines and regulations. It is reported in Appendix 1.

The second part is focussed on human factors. It consists of a field study, desk research, and an empirical case study investigating the personality of the Master. It aims at exploring the implications of autonomy on passengers, their relation to the fire safety strategy, and the requirements placed on the Master. The study is presented in Appendix 2.

The third part concerns the fire safety strategy as such. It consists of a hazard identification, a risk analysis, and the associated fire safety design of the ship following a performance-based philosophy. It explores the roles allocated to the Master and to the ship as a system with respect to fire safety. It promotes a strategy of early detection and quick action. The study highlights the necessary technology to achieve the safety objectives. The study is presented in Appendix 3.

2.5 Project team

The project team consisted of:

- Ship owner
- Naval architect
- Human factors specialists and psychologists
- Anthropologist
- Fire safety engineers

3 Base design – Sønderho II

This section presents the base design of the ship and the ferry service associated with its operation.

3.1 Ferry service to the island of Fanø

The Danish island of Fanø is located 1.3 nautical mile (nm) of the mainland of Denmark close to Esbjerg, the fifth largest city in Denmark. The island has a population of 3345 inhabitants, and it is situated in the UNESCO World Heritage Site Wadden Sea. The island is a popular place for recreation tourism, and in the summer high season the population increases by a factor 10. With an ever-increasing public interest for the unique nature and speciose wildlife of the island and the Wadden Sea area, the island is popular for recreational visits. The sensitive area surrounding the island is a protected nature reserve under Natura 2000.

The ferry company Molslinjen A/S operates the ferry service, under the local brand Fanølinjen. Being the only ferry service to the island of Fanø and therefore an indispensable backbone of local transport infrastructure, the route has more than 30,000 departures annually, carrying more than 1.75 million passengers, 390,000 cars, and 11,000 busses and trucks. Currently the ferry service is operated by 3 vessels, i.e. 2 RoPax ferries (M/F Meja and M/F Fenja with max. 395 pax and 35 cars each) and 1 passenger ferry (M/B Sønderho, 163pax). The route has a distance of approx. 1.33 nm for a crossing time of 12 minutes and a harbour stay of 8 minutes. The ferry service has a public service obligation of providing an overnight emergency service to the island.

3.2 Description of the new ferry

General layout

The ferry is to operate as a passenger day ferry for the transportation of passengers, ambulance, bicycles etc. in domestic national traffic on the route between Esbjerg and Fanø. The Danish authorities define this operation as sea area category D.

The ferry will have a capacity of 155 persons (150 passengers and 5 crew members). An open deck will be available for the ambulance service and/or bicycles. For the sake of the present study, it will be assumed that the crew is reduced to only 1 Master. The fire safety strategy will be designed accordingly.

The ferry is designed as battery driven with electrical motors, without any exhaust or other discharge other than sewage to ashore. The design choices ensure minimum usage of electrical power: LED lights for lighting, electrical automatic door where needed, heat pump for heating or cooling purposes etc.

The stem is shaped so that the land ramps in Esbjerg or Fanø fit the vessel enabling the ambulance to be driven in and out. The open deck is 10 m long and approx. 3,5 m wide and arranged as a flexible deck for both ambulance and/or bicycle parking. Bow operation is electrical.

The wheelhouse sits on top of the accommodation spaces and is lifted up to provide the navigator with nearly 360° view.

The Ferry is arranged with 3 decks:

- Deck no.1 Tanktop: extends to collision bulkhead forward, comprises machinery and electrical spaces, tanks and void spaces.
- Deck no.2 Main Deck: area for passenger accommodation, open deck fore and aft.
- Deck no.3 Open deck: for passengers and wheelhouse.

The hull includes integrated tanks for freshwater, sewage, and dry tanks.

Machinery spaces
The propulsion machinery is electrically driven, with energy supplied by the battery system. Shore connection will enable vessel charging during harbour stay. One Azimuth thruster and one bow propeller make the propulsion system. They are both controlled by variable speed drive.

Passenger spaces
The passenger facilities are located on the main deck with open deck areas fore and aft and on top of the passenger cabin. Access in through the land-based ramp in the two harbours. The vessel provides public space for all passengers including seating arrangement for approx. 75 passengers. The public spaces also include two restrooms and one restroom accessible to wheelchair users.
The interior of the ferry is designed for the intended shuttle service based on combined seating and standing arrangement for the passengers, laid out for easy maintenance and easy cleaning. The interior will be furnished in accordance with contemporary Scandinavian/north European ferry style standard.

Crew spaces
The crew space is located in the wheelhouse.

Safety
Assembly stations for passengers including entrance for MES evacuation systems is located within the passenger saloon.

Environmental footprint
The vessel is designed with high energy efficiency and low environmental footprint.

4 Summary of project findings

This section presents the main findings of the project. The details are available in the relevant appendixes.

4.1 Background study

This section summarises the findings from Appendix 1.

The concept of autonomy is very much a question of definition. Autonomy does not necessarily mean unmanned – you can have autonomous vessels that are crewed. Autonomy can refer to the entire ship, but also to certain specific processes or under certain operational conditions.

There are currently several definitions of autonomy from various class societies, scholars, authorities (including the IMO). All these definitions are different, however, what they have in common in that autonomy has various levels and can apply to various system and operating conditions (see first paragraph).

The concept of manning will change with the development and implantation of autonomous seafaring; either with reduced crew sizes, periodically unmanned bridge, remote operations, and shore control centers.

Training and educational requirements for shore-control personal is currently unknown and under debate within the industry. It will probably in the early state of implementation not differ much from current standards, however, with the introduction of more software based solutions this might be subject to change over time.

There are currently no international rules specifically governing autonomous marine vessels. The IMO has started a drafting exercise and is currently working on this. It is, however, unlikely that any new rules or changes to current rules will happen within a decade.

Passenger ships operating solely within Danish territorial waters will have to abide by the DMA's Declaration D. This declaration does not specifically address autonomous seafaring, however, when operating solely within territorial waters, vessels does not need to comply with IMO rules. Consequently, the general tendency within the industry is to test various forms of autonomous operation within territorial waters under their current rules. Additionally, it is the position of the DMA and many actors in the industry that there is room within the current ISM codes to operate with various degrees of autonomy.

In anticipation of autonomous ship designs, class societies have formalised guidelines that describe necessary steps or principles to follow in order to get such designs approved. The guidelines deal with issues like navigation, structural integrity, and most of the all how to ensure safe operation when certain processes are "automated". The guidelines all vary to some degree; however, they all share the common traits of autonomy being defined in degrees or levels, and being applicable to certain procedures or operating conditions.

There are several major developers and suppliers of autonomous systems. Kongsberg is one of the marked leaders within the category being involved in several high profile projects, including the Yara Birkeland. Likewise, Rolls-Royce and Wärtsilä has both invested heavily within the field and has tested autonomous system on full-scale vessels to various degrees.

The state of the technology is rapidly changing and is constantly under development. While this development and maturing of the technology is necessary, it is the position of the DMA that safe seafaring with autonomous is actually plausible within the right operating conditions and use-scenarios at the current state.

Generally, the DMA is positive towards the development and operation of autonomous vessels within Danish waters. Although there are no specific Danish rules governing and guiding the development of such vessels, it is possible to operate under declaration D with the right approval from the DMA.

Due to the current state of the rules and regulations concerning autonomous vessels, it is likely that most of projects in the near future experimenting with autonomy will be concentrated in strictly national waters.

To operate with some level of autonomy under the current rules, the approval process is highly dependent on operational conditions and specific parameters of the given route. Therefore, decisions regarding technical solutions, design, operations, and manning etc. should all be based on these parameters.

To obtain approval for any vessel, regardless of the technology used, equivalent safety must be documented according to the existing rules. This can be mitigated through 1) alternative design, or 2) operational changes. Alternative design is to prove and document that the design is as safe, or safer as a traditional vessel with full crew. Alternatively, operational changes can be made to mitigate concrete use-cases and thereby enable use of autonomy for specific roles or in specific use-cases.

Regardless of a given use-case and autonomy level for a given vessel, there must always be a designated responsible master. This means that if the vessel operates under full autonomy, a shore-based control must be ready and available to take control of the ship and be legally responsible for safe navigation. A designated person ashore will not be sufficient in case of a vessel operating under full autonomy.

The DMA was positive towards the notion of having stewards on board ferries operating under some form of autonomy. Alternatively, the concept of super users (users with special training) is also currently viewed as a possibility for certain use-scenarios and operating conditions.

4.2 Human factors

This section summarises the findings from Appendix 2.

The Master's personality: the optimal profile for (semi-) autonomous ferries
As presented in Appendix 2, our personality greatly influences the way we perform our job and in the case of a master holding a safety critical job it is important to be aware of just how his or her personality (and mental abilities) could influence the performance. We recommend using the assessment tool provided by Hogan Assessment, including The Hogan Personality Inventory, Development Survey and the Safety Report. This test battery identifies a person's strengths and shortcoming with respect to safety related competencies using research-based correlations between these (individual levels of) competencies and the risk of being involved in incidents and accidents when holding a safety critical job. Also, the battery aims to predict a probable pattern of reaction from the master with respect to what is known as either a fight, flight or freeze reaction to eg. very stressful situations.

On top of the personality assessment, we also recommend assessing the master with an additional tool, the APRO+ test, which generally aims to predict the level of training needed by the tested person, when he or she needs to adapt to new knowledge, new technologies and new procedures. The APRO+ also measures the person's correctness-priority which shows whether the person places correctness over speed or the other way around, when solving tasks/performing the job.
Psychological assessment in this context aims to predict the performance of a person in a safety critical job, using correlations and/or comparisons with norm groups etc. Of course, these predictions are based on probabilities, hence not "bullet-proof". However, as described in the heading further below, both the Hogan personality-based results and results from the APRO+ mental ability test, can be very useful when tailoring training and further education into a safety critical job.

One thing is training and further education of an already employed master. Another is recruiting new masters. Assessment tools alone cannot solely provide an answer to the question of which profile to hire, but as shown in appendix 2 the recommended tools could very well provide useful input to decision makers, when it comes to identifying which candidates have optimal (safety) profiles as a starting point.
Familiarity with appendix 2 will supply the reader with details, but it summarises an optimal profile like this:

- Personalities with scores on the Hogan Safety report in the yellow/green areas. However, a few red scores should not be a criterion for exclusion. The person might be well aware of his or her possible shortcomings and might also be very good at compensating for them.
- If the candidate reveals one of the mentioned derailer patterns (flight, fight or freeze), the fight pattern seems to be the least problematic. The fight pattern indicates readiness to act, which might not be the case with a freeze pattern. The flight pattern could mean communication – say, with passengers in a critical situation – is slow or even absent.
- The mental abilities should preferably be as high as possible; however the most likely applicant has an average level of mental abilities which can easily suffice. In any case, it is relevant to look at scores (aka probable abilities) within the different sub-tests managed, checking for extreme (low) scores, which indicates cognitive or perceptual shortcomings. Also, it is recommendable that a candidate's correctness-priority is in favor of correctness over working speed, due to the safety critical nature of the job.

The optimal training of the master based on the safety profile
The best outcome of a personality assessment is concrete consultancy of what to do about the results. The recommended assessment tools use personality as a central factor in predicting safety behavior, however, personalities are not easily changed. However, the right training can provide the person in question with the right tools to compensate for shortcomings. Personal safety profiles provide a picture of the master's strengths and possible shortcomings when performing the safety critical job. A job that might involve periods of extreme mental workload, important and complex decisions and prioritisation in relation to safety and compliance with procedures. Instead of a "one size fits all" model, we recommend a tailormade type of training, based on the person's safety profile. The safety profile can be seen as the "diagnosis", the training as the "treatment". Focus in this "diagnosis-treatment" regime is the psychology of the individual master. The master should therefore be supervised by experienced psychologists with considerable and practical knowledge of the work on board a ship. The training must include concrete techniques and strategies for the master to use in order to compensate for his/her individual challenges and possible shortcomings as indicated in the safety profiles and its identifications of the master's levels of safety competencies. As a proposal, appendix 2 outlines a specific course with the objectives listed below:

Objectives of the course
At the end of the course, the master must be able to:

- Identify relevant issues in relation to psychological profiles
- Identify relevant psychological patterns of behaviour in him-/herself and others
- Choose relevant techniques and strategies and apply them with the desired effect in the actual situations

in relation to situations in the daily operations.

The master must also have gained a basic knowledge of:

- The correlation between personal profile, behaviour and safety
- Causes of varying performance and behaviour in each person over time
- Causes of different persons' differences in performance

Recommendations based on the field study among passengers
Appendix 2 also presents on field study among passengers onboard the current ferry crossing Esbjerg-Fanø. The purpose was two-fold:

- Collecting information about the perception of safety and attitudes towards safety among the passengers using semi-structured interviews.
- Collecting data as supporting information concerning the visual attention towards safety signs and safety information among the passengers. Data collection was done wiht eye-tracking recordings.

The field study provided notable clues as to how some passengers might react e.g. in emergencies and from observing the visual attention among a small sample of passengers, it became relevant to suggest a way of informing the passengers about safety, shown in the table below concerning pre-ride.

The main conclusions and recommendations from the field study:

- Generally, passengers seem not to pay much attention to safety signs and safety equipment, probably due to "not worrying" about their own safety on "this short crossing". The apparent disinterest should be kept in mind when designing attempts to control passenger behaviour in case of emergencies (such as signs and PA announcements). Procedures must not rely on safety competencies among passengers alone, since these are likely not to be adequate.
- The overall attitude among the passengers towards an (future) unmanned ferry was the same as with the current ferry: No significant resistance based on safety concerns towards using such a ferry, mainly "because the crossing time is so short and the shallow water" at the crossing
- Most of the passengers clearly expected some sort of direct communication line with people on land. A call button to be used in case of fire, etc. We recommend this call-button feature installed with a direct line to professionals familiar with the specific ferry and all of its features, including the safety equipment.
- Some passengers (of all ages) demonstrated some concerning attitude when it comes to an imagined scenario where smoke and even fire occurs on an unmanned ferry. They simply consider jumping overboard. Of course, this imagined reaction might be quite different in a real-life situation. However, the passengers seemed confident that they would be able swim ashore – a confidence we do not share. We recommend different precautions to prevent the situation of man over board on top of a fire or another emergency:
    - To deliver safety information specifically addressing this identified tendency among passengers, urging people not to jump overboard even though it might be "their instinct" to do so.

- Provide passengers with a clearly visible safe escape in the form of a life raft (even though the life raft is not strictly necessary from an evacuation perspective – the ferry being "its own life raft")

- We noticed that that very few of the interviewed passengers spontaneously mentioned that in the case of an emergency, they would try to help other passengers in need of assistance. Of course, had we asked people if they would help someone in need, they would probably answer yes – but it was not an imagined behaviour they spontaneously brought up themselves. We therefore recommend mitigating this issue as part of the ferry's general safety information and through PA announcements like: "in the unlikely event of an emergency, please make sure to help children, elderly, disabled and injured fellow passengers in need of assistance".
- Based on our observations on site and the supportive information obtained via eye-tracking, we conclude that passengers do not pay much attention to safety signs or safety equipment (partly due to the general notion of feeling safe onboard and partly due to embarkment activities like parking the bike, finding a seat, etc.). This leads us to recommend an additional strategy to signs onboard following the task of providing safety information to passengers: The strategy of using the pre-ride to prepare passengers for safety onboard. The recommendations given in appendix 2 are summarised in Table 1.

Table 1 – Summary of recommendations for the pre-ride as given in Appendix 2

Phase of travel	Recommendation
Arrival at terminal	Upon arrival at the terminal, passengers should be primed with "safety thinking" through signs and directions. For example: The use of different path ways through the terminal area for passengers with prepaid tickets and passengers who need to buy tickets.
Waiting	While waiting at the terminal (area), passengers should be primed with "safety thinking" through information and announcements, e.g. PA-messages like "never leave your belongings unattended", and "in the unlikely event of an emergency, please make sure to help children, elderly, disabled and injured fellow passengers in need of assistance". Waiting time could also be used to give relevant safety information to the passengers e.g. by video (looping) or PA-announcements (repeating) explaining what to do in case of an emergency on board, how to deal with it and how to alarm the master or land station. Further, the waiting area can be arranged with a pre-boarding area, which opens e.g. 5 minutes before departure. This has no real practical purpose, but it will exercise passengers' timing of actions and conformity (acting as a group rather than individuals).
Boarding	Passengers should be primed with "safety thinking" during boarding. A boarding sequence could be applied like in commercial flights: First disabled and travellers with small children, then passengers with bikes and last all other passengers. A boarding sequence like this might even improve the efficiency of boarding, but the most important point is that passengers are prepared for conformity and timing of actions. Passengers can also be primed with "safety thinking" during boarding by placing safety equipment such as fire extinguishers and lifebuoys close to the boarding ramp, where they are clearly visible for passengers boarding.
On board	Safety information as required by regulation should be maintained, but we have pointed out the need for additional information on for example man over board (MOB) alarm button or emergency phone.

4.3 Fire safety strategy

This section summarises the findings from Appendix 3.

Fire safety objectives
The fire safety objectives to fulfil are listed in the table below.

Table 2 – Fire safety objectives for the present fire safety strategy

ID#	Objective
1	Reduce the risk to life caused by fire
2	Reduce the risk of damage caused by fire to the ship, its cargo and the environment
3	Contain, control and suppress fire and explosion in the compartment of origin
4	Provide adequate and readily accessible means of escape for passengers and crew
5	Make the ship its own best lifeboat

Fire safety design process

The design process for the fire safety strategy followed a Hazard and Operability procedure out of which fire scenarios are treated in a deterministic way. Mitigation solutions are developed in a performance-based thinking, on the basis that all the scenarios are equally likely to occur. This deterministic approach was chosen due to the lack of data and historic perspective to create a probabilistic description of the scenarios.

The performance based approach advocates for a closer position to "holistic" design by seeing the ship as an integrated system, and by including human factors in the design.

Seeing the ship as a system means that solutions for a given room should find their place within the overall design, without conflicting with choices made elsewhere. This also means that the design attempts to maximise the unicity of technical solutions, and designs the interfaces between rooms and interactions between rooms and systems so as to maximise the level of safety.

The fire safety engineering team chose to follow a room-by-room approach to produce, paradoxically, a holistic fire safety strategy. The intention is that a room-by-room approach will identify necessary fire protection for each individual room, and at the same time highlight common themes between rooms to unify the solutions at the scale of the ship. Moreover, incompatibilities between individual room solutions can then surface and be treated accordingly.

The proposed approach has the advantage to address specific fire scenarios. It highlights necessary measures to protect a given room, as well as common themes between rooms which leads to a ship-wide protection solution, hence the reference to the term "holistic". The systematic approach makes the method function as an iterative process from a total ship perspective, in which the "holistic" design choices are refined and validated.

The main drawback of this method is its extensiveness, making it time-consuming. The process is also repetitive at times, boredom becoming an actual risk so issues could be overlooked.

In general, it was found a very useful, insightful method leading the team to ask highly relevant questions. The fire safety strategy was laid down this way and believed to be valid. Fire safety engineering calculations were performed on the basis of the strategy, illustrating some of its premises and their viability. Though heavy, this process is considered as useful and relevant.

Fire safety strategy

As a result of this work, the fire safety strategy laid out consists of the following points:

- The roles of the Master and the ship are split. The ship is considered as a member of the team it forms with the Master, and as such the ship has a defined roles with functions it has to perform. The actions of the team and the relationship between the team members promotes the achievement of the fire safety objectives.
    - The roles are split so that the Master is responsible for the passengers, the communication with them, their obedience to directions, the communication to shore, the coordination of rescue, and he retains the decision power at all times. The Master is responsible for the decision to evacuate the ship, and for the organisation of the evacuation.
    - The ship has the role of handling fire-related tasks. It means that it takes care of detection, detection confirmation, active firefighting, initiation of return to port procedure, sending distress signal, monitoring the fire situation and reporting it to the Master. This way the Master retains the possibility to handle the situation with the passengers and shore.
- The Master and the ship are part of a team, creating a synergy and a thereby a safety system which can check itself, increasing redundancy.
- Early detection is a critical parameter, and is coupled with early suppression.

- Fast decision making by automating actions. Speed and efficiency are possible by the use of computerised systems, decreasing time-to-action dramatically (e.g. detection confirmation, firefighting…). This maximises the chance to control the fire an contain it to the compartment of origin.
- Keeping passengers on board to avoid potentially risky evacuation, leading to the use of two muster stations and two evacuation zones, should it be necessary.
- High level of redundancy of fire safety systems
- Fire safety design integrates the operational setup of the ship and accounts for passenger behaviour (e.g. use of fire rated glass to separate the two fire zones, or the discussion on the use of MES to avoid MOB situations).

Engineering passive protection

A case exercise of fire safety engineering was provided to illustrate the technical possibility to keep passengers on board the ship at all times. The most dangerous fire scenario was estimated to be a fully developed battery fire in the below deck spaces.

The first step of the engineering exercise aimed at calculating the temperatures which could be expected from such a fire, according to various ventilation conditions in the battery room. The second step of the engineering exercise evaluated whether a standard A60 deck solution would be sufficient to provide a liveable environment to the passengers situated on the deck above. If this could be achieved, the principle of safe return to port would be ensured since the ship is fitted with two battery rooms (e.g. sailing capability assumed functional) and evacuation would be unnecessary.

The engineering exercise turned out positively, showing that in most cases the standard A60 deck could provide the right environment for the passengers to stay on board. Indeed in most ventilation cases the temperatures were not exceeding 40 °C on the unexposed side of the deck for the entire duration of the fire. Certain ventilation cases, corresponding to having a door open, lead to temperatures above 120 °C on the unexposed side of the deck. The takeout being that doors should be kept closed at all times. These results also showed the irrelevance of the ISO 834 curve used for testing purposes when it turns to real-life designs. Limitations of the calculations should be emphasised, as discussed in Appendix 3.

4.4 "Holistic" perspective

4.4.1 "Holistic" perspective on fire safety

This perspective could be based on the description of a socio-technical system with both human and technical components:

> *"During the 1960s a number of social scientists at the Tavistock Institute in London formed the idea that organizations could be described as sociotechnical systems. Furnham (1997) describes sociotechnical systems as "a set of interrelated elements that functions as a unit for a specific purpose" (p. 74). It is obvious that organizations in the maritime domain are consistent with the sociotechnical systems perspective. As described in previous sections a maritime organization could be the ship owner or shipping company and a part of the organization could be a specific ship. It should also be obvious that ships can be analyzed as a combination of technology (the vessel, engine, equipment, instruments, etc.) and a social system (the crew, their culture, norms, habits, custom, practices, etc.). If we use the idea about sociotechnical systems as an approach for the analysis of maritime accidents and safety, we could talk about system error rather than organizational or human error. If we are able to define the "set of interrelated elements" in the sociotechnical system, and thereby build a model of the system, we would have a useful tool for the analysis of maritime accidents, incidents, or safety-related issues, a tool that would be more precise than the general and all-encompassing human error term". (Grech, Horberry & Koester 2008, p. 19-20)*

> *"The sociotechnical system model advocates a more holistic systematic approach rather than a piecemeal, fragmented approach for dealing with relationships among various elements that form a system". (op.cit., p. 20)*

This system is illustrated in a socio-technical system model called the SEPTIGON-model:

> *"We argue that the sociotechnical system model is a systematic approach for viewing human factors; it indicates how various factors interact to influence system performance. By managing these factors we can strive to ensure that the system as a whole operates within a safe boundary". (Grech, Horberry & Koester 2008, p. 23-24)*

> *"The sociotechnical system model. The model is also called "The Septigon Model." Septigon refers to Society and Culture, Physical Environment, Practice, Technology, Individual, Group and Organizational Environment Network. Septigon is also the name of a shape with seven sides — the outline of the model". (op.cit., p. 21)*

The SEPTIGON-model comprises seven main domains:

- Individual
- Processes (this domain was called "Practice" in early versions of the model)
- Technology
- Group
- Physical environment
- Organizational environment
- Society and culture

Definitions for these elements originate from Rizzo and Save (1999) and the ECCAIRS Human Factors classification system (Grech, Horberry & Koester 2008).

The SEPTIGON-model is illustrated in figure 1:

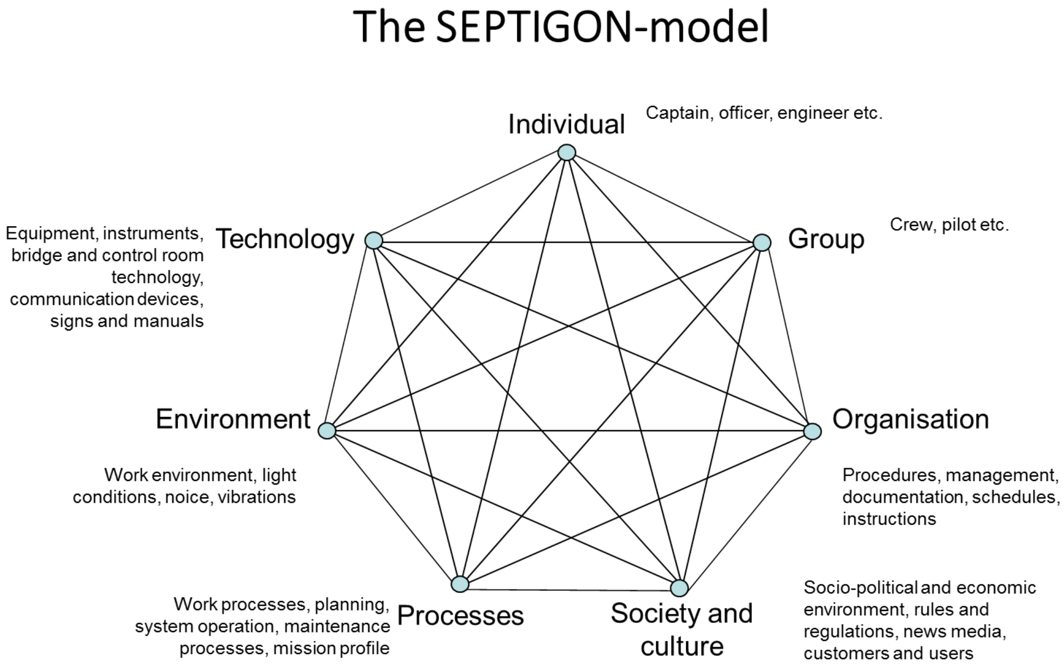

Figure 1: The SEPTIGON-model (Grech, Horberry & Koester 2008). Septigon refers to Society and Culture, Physical Environment, Processes, Technology, Individual, Group and Organizational Environment Network. Septigon is also the name of a shape with seven sides — the outline of the model. The SEPTIGON-model consists of seven internally connected elements, and the base point is the individual in the top of the model. The connections in the model or system symbolize the different interactions between the elements and how these interactions are always influenced by other interactions within the system.

The philosophy behind a holistic approach to fire safety is based on the assumption, that fires occur in complex settings with both human and technical components, and that fire safety therefore should be accomplished from a broad perspective on how different components of the system each individually as well as in interaction could contribute to the overall safety of the entire system. This approach is different from non-holistic approaches focusing only on for example technical solutions.

> *"Historically, humans have developed a divisional approach to solve problems, rather than a more holistic systematic approach. This is reasonable enough as dividing a problem into smaller parts can make it simpler and hence easier to solve. Does it really? Vicente (2004) argues that this "reductionist strategic approach" that has been adopted for centuries by humans has "led directly to our troubles with technology." Vincente mainly attributes this to the fact that scientific knowledge has been divided into two broad groups: the first is the technological sciences, and the second the human sciences. This has created a situation in which most people would be biased toward their own discipline and are usually induced to make the assumption that anything beyond their realm of understanding can be safely ignored. Hence, a situation has arisen where engineers and designers tend to focus only on the technical aspects of design adopting, as Vicente argues, a "mechanistic" view, while the human sciences group tend to focus mainly on people, adopting what he describes as a more "humanistic" view". (Grech, Horberry & Koester 2008, p. 19)*

The holistic approach to fire safety is based on The SEPTIGON-model can best illustrated with two examples. The first example illustrates how safety can be obtained through design when looking at the interaction between individual and technology in a broad and complex context. The second example illustrates how the holistic perspective can support the design of an intervention when interaction between the individual passenger and the technology is not obvious or intuitive.

4.4.2 Example 1 – use of the life rafts as escape routes

The use of life rafts as escape route to prevent passengers from jumping over board into the water

Evidence from on board interviews with passengers show, that some passengers in case of fire on board will jump over board into the water in the belief that they will be able to swim away from the burning ferry to a safe place: to the shore or to shallow water from where they can walk to shore. The result of this would be an even more unsafe situation including "man over board". The rescue effort would therefore – apart from the burning ferry – also include the rescue of passengers swimming in the water. Different precautions could be taken to prevent the situation of man over board on top of a fire on board. One is to give instructions to passengers on not to jump over board e.g. by explaining the dangers of doing so. Another one is to provide them with a safe escape in the form of a life raft even though the life raft is not strictly necessary from an evacuation perspective (the ferry being "its own life raft"). This can be illustrated using The SEPTIGON-model (see figure 2) where the individual is the passenger showing irrational behaviour during a fire on board the ferry. The technology is in this case the life raft providing a safe escape and alternative from jumping over board in the water. The situation is thereby changed from unsafe (man over board) to safe through the interaction between technology (life raft) and individual (the passenger showing irrational behaviour), where the life raft by its presence is nudging the passenger to use the life raft as way of escape rather jumping into the water.

The use of the life raft for this purpose should be seen in context: The physical environment will have an influence on how attractive the life raft options is perceived by the passenger. The life raft will probably be perceived as a more attractive alternative to jumping into the water in a cold and stormy weather and in the dark at night than in the warm and sunny summer. The use of the life raft would probably require an action by somebody else than the passenger activating the life raft – e.g. the master on board the ferry, the group in The SEPTIGON-model. The action of the master would most probably be based on a procedure made by the organisation. And the activation of the life raft can be considered as a process with some steps. The general perception of risk and safety, the use of a life raft, fire on board a ferry, the perception of dangers related to jumping into the water among passengers is most probably formed through influence and experience from society and culture e.g. through media reports on accidents and fires and passenger behaviour in emergency. You could even say that passengers' evaluation of their own swimming skills when jumping over board depends on society and culture and for example traditions of teaching swimming in schools and national tradition on going swimming at the beach.

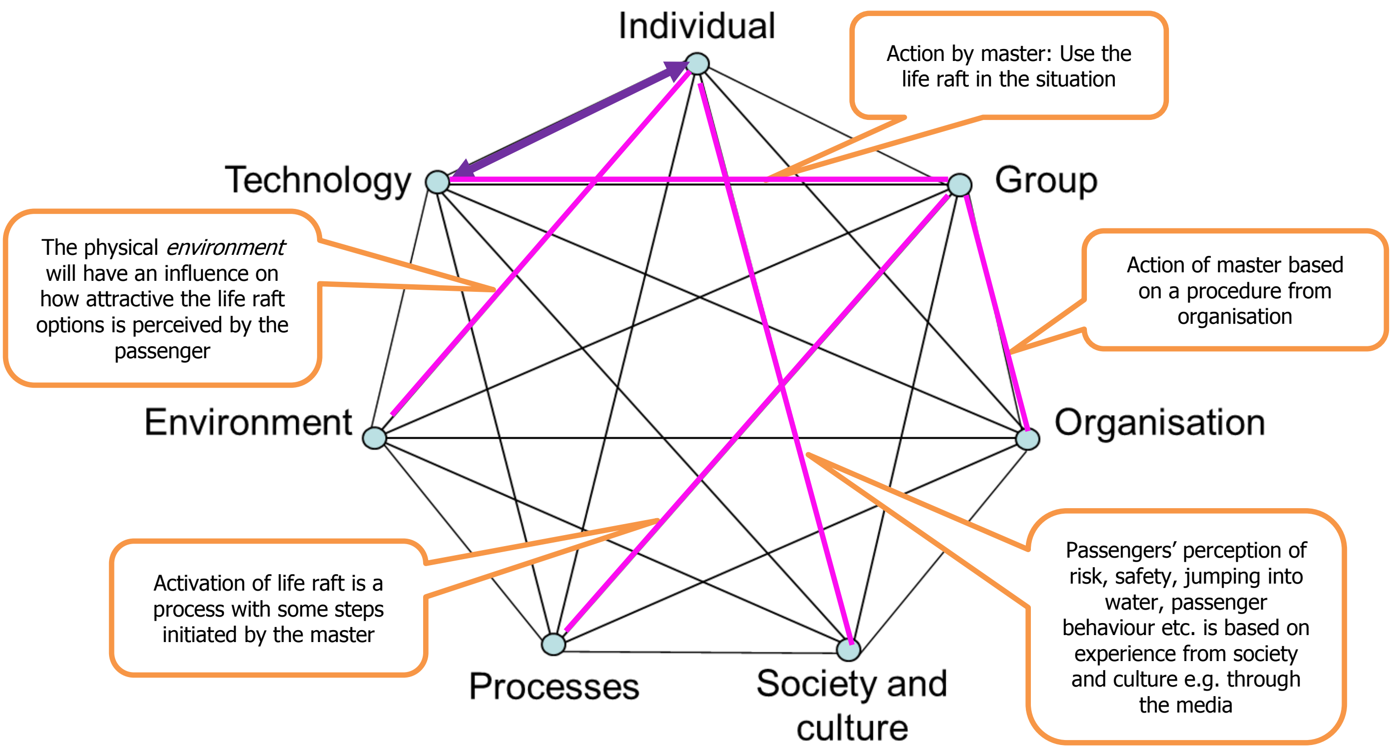

Figure 2: Holistic approach. The individual is the passenger showing irrational behaviour during a fire on board the ferry. The technology is in this case the life raft providing a safe escape and alternative from jumping over board in the water. The situation is thereby changed from unsafe (man over board) to safe through the interaction between technology (life raft) and individual (the passenger showing irrational behaviour).

4.4.3 Example 2 – the use of fire rated glass doors and passengers reaction

The use of fire rated glass doors and passengers' reaction if they can see flames though the door

The scenario in example 2 is that there is a fire on the car deck on the ferry and that passengers are evacuated to the passenger cabin/lounge and protected from the fire by fire rated glass doors. It is not obvious or intuitive from the design of these protecting glass doors alone, that they are good enough to protect passengers from the fire. It is therefore conceivable that passengers will perceive the situation as unsafe (not protected) when it is in fact safe (protected). The effect of the fire rated glass door (technology) cannot alone be based on intuitive perception of the design and should therefore be accompanied by information to passengers as a supplement. This information can be given through a combination of signs and verbal information through the passenger announcement system. See figure 3 for illustration: The individual is the passenger perceiving the glass door as non-protective and therefore the situation as unsafe. In fact, the glass door protects passengers from fire, but it does not appear intuitively from the design alone (glass is perceived as fragile as an experience from society and culture). Therefore, information about the effect of the glass door should be given to passengers as a supplement from the master (group), and this should be described in emergency procedures (from the organisation).

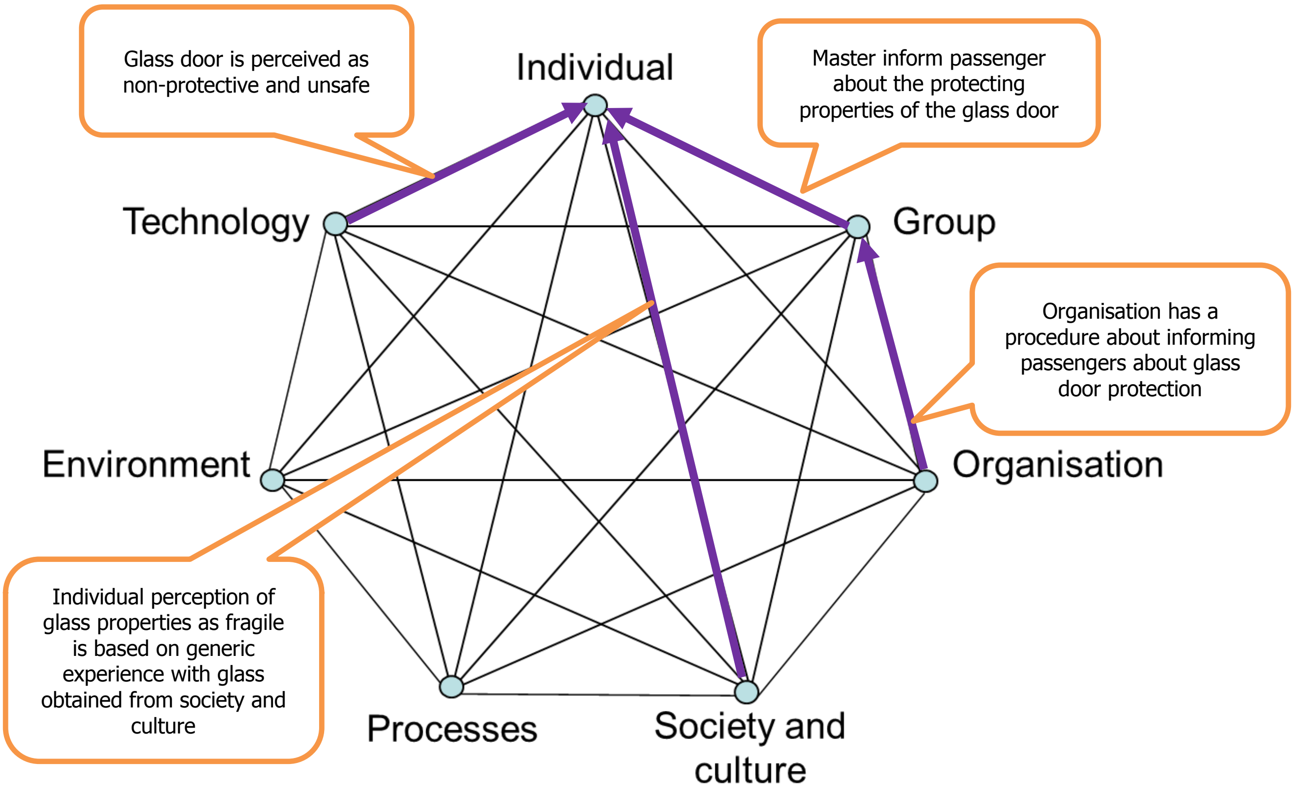

Figure 3: Holistic approach to the perception of safety. The individual is the passenger perceiving the glass door as non-protective and therefore the situation as unsafe. In fact, the glass door protects passengers from fire, but it does not appear intuitively from the design alone (glass is perceived as fragile as an experience from society and culture). Therefore, information about the effect of the glass door should be given to passengers as a supplement from the master (group), and this should be described in emergency procedures (from the organisation).

Source:

Grech, M.R., Horberry, T.J. & Koester, T. (2008). Human Factors in the Maritime Domain. Boca Raton, FL: CRC Press.

5 List of appendixes

The work summarised in this concluding document is detailed in the following appendices.

Appendix 1 – Background study
Appendix 2 – Human factors
Appendix 3 – Holistic fire safety strategy for small autonomous ferries