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Guidelines for crew-centered fire safety design

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Abstract

Although fire management operations would stand to gain from technologies and working environments designed with closer consideration to crew needs, such practice remains rare in ship newbuild projects. In response to this, LASH FIRE researchers have been engaging with shipping companies, design firms and systems suppliers to investigate how current approaches to fire safety design could be augmented by human-centered design methods.

This report presents the development of design guidance for fire safety installations on the ship's bridge. It is aimed at the design team within a shipping company engaging in a newbuild project and reflects the same human-centered practices applied in previous LASH FIRE WP07 research. Development of the guidance had three main objectives. The first was to supply shipping companies with methods allowing them to describe and communicate crew needs. The second was to introduce a more systemic perspective on fire safety than what is normally considered in newbuild projects. The third was to provide guidance that is simple enough for any shipping company to apply them, the only demand being that they are willing to invite operational competence into the company-internal ship design process. Data used to inform the design of guidance was produced using qualitative methods, such as workshops, stakeholder interviews and feedback sessions. Investigations and development of materials set out from a user-centered perspective and followed an action-research approach, i.e. where researchers actively engage with organizations, propose new actions, and study the outcomes. This was made possible due to the close contact and collaboration with a Swedish shipping company engaged in a ship newbuild project. Data was also obtained from previous studies on the ship design process (D07.1, D07.2) and applied design research (D07.6). Guidance is provided on design process integration, i.e. how stakeholders within a shipping company can work to identify crew needs, formulate design requirements and communicate those requirements, both internally and externally. The guidance also summarizes the knowledge developed in LASH FIRE and previous projects around activities and design factors relevant for fire management on the bridge.

The guidance in its present shape has been positively received by the case study organizations. When moving on, some key points of interest are the appropriate level of detail in supporting materials, how to make outputs compatible with existing project structures, how these outputs are received by external stakeholders, and what adjustments might be necessary to make guidance applicable for other environments than the bridge. It has also been noted that within one of the case study organizations, discussing crew needs related to fire safety has also spawned an interest in human-centered design applications to other crew activities. This could provide us with the opportunity to investigate how the proposed design guidance scales when applied to a larger set of problems, a situation that would probably require an even greater emphasis on process simplicity.

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Involved partners

No.	Short name	Full name of Partner	Name and contact info of persons involved
01	RISE	Research Institutes of Sweden	Staffan Bram staffan.bram@ri.se Julia Burgén Julia.burgen@ri.se

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Contents

1 Executive summary

1.1 Problem definition

Although fire management operations would stand to gain from technologies and working environments designed with crew needs as a top priority, such practice remains rare in ship newbuild projects. In response to this, LASH FIRE researchers have been engaging with shipping companies, design firms and systems suppliers to investigate how current approaches to fire safety design could be augmented by human-centered design methods.

1.2 Method

This report presents the development of design guidance for fire safety installations on the ship's bridge. It is aimed at the design team within a shipping company engaging in a newbuild project and reflects the same human-centered practices applied in previous LASH FIRE WP07 research. Development of the guidance had three main objectives. The first was to supply shipping companies with methods allowing them to describe and communicate crew needs. The second was to introduce a more systemic perspective on fire safety than what is normally considered in newbuild projects. The third was to provide guidance that is simple enough for any shipping company to apply them, the only demand being that they are willing to invite operational competence into the company-internal ship design process. Data used to inform the design of guidance was produced using qualitative methods, such as workshops, stakeholder interviews and feedback sessions. Investigations and development of materials followed an action-research approach, i.e. where researchers actively engage with organizations, propose new actions, and study the outcomes. This was made possible due to the close contact and collaboration with a Swedish shipping company engaged in a ship newbuild project. Data was also obtained from previous studies on the ship design process (Bram, 2020; Bram, 2022) and applied design research (Steinke, 2022).

1.3 Results and achievements

Guidance is provided on design process integration, i.e. how stakeholders within a shipping company can work to identify crew needs, formulate design requirements and communicate those requirements, both internally and externally. The guidance also summarizes the knowledge developed in LASH FIRE and previous projects around activities and design factors relevant for fire management on the bridge. The value of the materials produced is twofold. First, our guidance fills an under-developed niche by targeting the shipping company, where previously existing design guidance mainly targets design firms and suppliers. Second, there is no previously existing guidance that explicitly supports development of fire safety design, which is an area that demands special consideration.

The objectives of task T07.4 were to develop a methodology for the design of fire detection system interfaces, incorporating results from Tasks T07.2 and T07.3 by:

1. Establishment of technical boundary conditions and specifications of alarm system interface

2. Development of user requirements to be regarded in the design guidelines; input from T05.5

3. Development of design guidelines, process and methods for fire detection interface design

The objectives concerning technical boundary conditions and interface specifications have been fulfilled in the design research associated with the development of the Digital Fire Central (D07.6). All objectives relevant for the development of design guidance have been achieved.

1.4 Contribution to LASH FIRE objectives

The design guidance presented in this report contributes to LASH FIRE Objective 4, "*LASH FIRE will propose new regulations and guidelines founded on common positions by drawing upon global research and experience and by facilitating international cooperation*".

The guidance also fulfils the Action 7-A objective "*Re-design and develop guidelines for improved fire detection system interface design, promoting intuitive operations and quick decision-making.*".

1.5 Exploitation

Design guidance has been written and edited for direct use by industry stakeholders, with the shipping company as the primary target organization. Guidance has been written to provide a low threshold for application, suggesting simple work methods and forms of requirements management. Stakeholder feedback has, however, suggested that the guidance may also be of use for other stakeholders, such as design firms or equipment manufacturers. These stakeholders could, for example, apply the guidance in communication with customers (e.g. shipping companies) or to support continuous development of their products. The guidance documentation will be made available on-line at the DiVA portal, thus ensuring accessibility after the end of the project.

2 List of symbols and abbreviations

DFC	Digital fire central
ECR	Engine Control Room
HCD	Human-centered design
OOW	Officer-on-watch
Ro-pax	Roll-on roll-off passenger ferry

3 Introduction

Main author of the chapter: Staffan Bram, RISE

Throughout the LASH FIRE project, researchers have been exploring how Human-Centered Design (HCD) methods can be leveraged in the development of onboard fire safety installations, in order to provide the crew with the best possible support as they work to understand and manage a fire in the roro space. Part of this work has led to the development of Digital Fire Central (DFC) prototype, a digital interface implemented on a large touch-screen, providing the fire chief with all the information and controls needed for monitoring and controlling a fire event. The DFC rests on several iterations of development, combining ethnographic studies (such as onboard drill observations) with end-user interviews and scenario-based testing (Steinke et al., 2022).

But while the DFC has served to demonstrate good design practice and the benefits made possible by combining Human-Centered Design (HCD) methods with state-of-the-art technologies, any real improvements in the domain of maritime fire safety will depend on a broad and consistent uptake of new design approaches amongst the industry's stakeholders. To that end, LASH FIRE researchers have also been engaging with shipping companies, design firms and systems suppliers, to investigate how current approaches to fire safety design could be augmented in a way that pays greater respect to the practical activities and needs of the onboard firefighting organization. The foundations of this work were lain at the beginning of the project (Bram et al., 2020), in the form of stakeholder, process and barrier analyses, aiming to demonstrate both possibilities and obstacles in ship design process innovation.

This report presents the development of design guidance for fire safety installations on the ship's bridge. It is aimed at the design team within a shipping company engaging in a newbuild project and reflects the same human-centered practices applied in previous LASH FIRE WP07 research. Development of the guidance had three main objectives. The first was to supply shipping companies with methods allowing them to describe and communicate crew needs. The second was to introduce a more systemic perspective on fire safety than what is normally considered in newbuild projects. The third was to provide guidance that is simple enough for any shipping company to apply them, the only demand being that they are willing to invite operational competence into the company-internal ship design process. Guidance is provided on design process integration, i.e. how stakeholders within a shipping company can work to identify and describe crew needs, formulate design requirements, and communicate those requirements both internally and externally. The guidance also summarizes the knowledge developed in LASH FIRE and previous projects around activities and design factors relevant for fire management on the bridge. The guidance documentation itself can be found in Appendix B, but to ensure the best reading experience and the most recent version, it is recommended to be downloaded from here: http://ri.diva-portal.org/smash/record.jsf?pid=diva2:1751612 This report describes the development of the first version of design guidance. Materials will continue to evolve as the case studies that inform their design progress further.

Throughout the LASH FIRE project, a large amount of ethnographic studies have been carried out investigating crew activities and interactions in the fire management process (Bram et al., 2022). Data from these studies provided grounds for contextualization of the design requirements, such as suggestions of crew goals and tasks to consider, and practical working conditions that may affect their performance.

4 Method

The design guidance is developed based on previous LASH FIRE experiences, literature and stakeholder interactions within the current scope. The creation of guidelines was an iterative process where the concept was adjusted primarily based on stakeholder interactions.

4.1 Scope of design task

Based on the design process analysis performed in D07.1 and later discussions with industry stakeholders, sharing their experiences from past newbuild projects, the decision was made to center the development of design guidance around the activities and needs of shipping companies.

First, there seems to be few mechanisms that would motivate design firms, suppliers or shipyards to volunteer human-centered design practices. Whether or not these actors try to cater for crew needs commonly seems to depend on the shipping company's interests and priorities. In addition, the shipping company will have easy access to crewmembers for needs elicitation and feedback on designs.

Second, we have observed several shipping companies where newbuild practices appear to be quite flexible and where stakeholders representing crew interests (such as Chief Engineers or Masters) can actively influence design decisions. In some of these organizations there have been attempts (albeit limited) in the past to take in crew perspectives on design, sometimes with demonstrably positive outcomes. On the other hand, it is not uncommon that involvement from operations in newbuild projects only extends to the participation of a few, senior officers. We regard this as an opportunity to extend and amplify such shipping company practices and suggest new working methods that can produce more consistent outputs.

Even though development focused on the shipping company as an agent in the newbuild process, however, this work was also highly concerned with stakeholder interaction. Crew demands can only be transformed into functional designs if they are recorded systematically and communicated effectively to design project partners. For that reason, development also included interactions with a supplier of fire safety systems and panels, and a special interest was given to interactions between the shipping company and firms responsible for different aspects of ship design (i.e. a design firm responsible for ship design, and an architect firm responsible for interior design).

Development of design guidance primarily hinged on the collaboration with a Swedish shipping company that, at the beginning of our work, was in the early phase of a passenger ferry newbuild project. The opportunity to experiment with alternative practices within an ongoing design project caused us to select and Action Research approach (Willis & Edwards, 2014), which was deemed to be highly compatible with the overarching human-centered design perspective applied to guidance development. New working practices and forms of interactions could be drafted, tested and analyzed iteratively, allowing us to observe whether they stood the test in a real design project environment.

A main ambition with the study was to find a good balance between concrete, applied design guidance and guidance that would make it possible for the shipping company to investigate, formulate and pursue design demands on their own. This approach was chosen in order to equip the shipping company with capabilities that extend beyond the scope of the LASH FIRE project (i.e. fire safety). Therefore, even though the guidance produced in this study focus on aspects of fire safety (and bridge design in particular), the methods and structures suggested could be used in the design of any onboard environment or artefact.

4.2 Analysis of existing design guidelines

This is not the first attempt to provide the shipping industry with design guidelines and an analysis of existing guidelines and regulations were carried out. Those that were considered during the analysis of existing guidelines are:

a) Guidance or regulations with the purpose of enhancing ergonomics and usability of onboard systems or products.
b) Accessible for the industry, meaning that it is not a scientific publication and that it is open-source or easily accessible on other ways.

The guidelines and regulations considered in this analysis is not a complete mapping. The analysis aimed to answer the questions listed below.

- Who is the intended reader?
- What is the scope?
- What is the shape of the guidelines? I.e. concrete advice, measures and limit values, collection of methods or instructive?
- What is the overall structure? I.e. read from start to finish or free-standing reference materials to apply in uncertain situations.

4.3 Ship design stakeholder and process analyses

Analyses of stakeholders and activities in the newbuild process built on previous results from D07.1, but aimed to achieve a higher level of detail that would provide better grounds for the development of design guidance. Data collection was performed through interactions with two ropax shipping companies and one equipment manufacturer. All major interactions are presented in Table 1.

Table 1. Major stakeholder interactions

Activity	Involved
Workshop 1 - walkthrough of the design process, common interactions, issues	Shipping Company 1
Workshop 2 – calibration of workshop 1 outcomes	Shipping Company 1
Workshop 3 - demonstration of design guidance draft and feedback	Shipping Company 1
Workshop 4 – Presentation of design guidance concept and discussions of design project interactions	Manufacturer
Workshop 5 – Continued discussion, design project interactions and stakeholder influence	Manufacturer
Testing of partial design guidance draft	Shipping Company 2
Interview – Ship design process	Design firm

The stakeholder analysis followed the same method as presented in LASH FIRE D07.1 (Bram et al., 2020), focusing on the influence, interest and interactions of stakeholders. In this iteration, our access to a working newbuild project organization also allowed us look more in detail at stakeholders internal to the involved organizations and their interactions. The new data was used to adjust the stakeholder mapping created in D07.1 and to inform the design process investigation.

Results from early stakeholder interviews suggested that apart from the effects that organizational structures such as processes and routines have on project outcomes, project developments also seemed to be influenced by the interests of individuals, and the way they acted to promote these interests in design project transactions. This made us sensitive to the social underpinnings of the design process (particularly the fact that different departments within the studied organization seemed to be associated with different levels of credibility and influence), something that led us to apply an organizational theory perspective in data collection and analysis. The theory of Institutional Work was chosen as a framework, due to its focus on micro-level organizational transactions and the way that it takes in both influence from organizational structure and the practices (or *agency*) *of* individuals. Institutional work is described as the practices that individuals or groups employ to create, maintain or disrupt institutions, and builds on the notion that such work is embedded – it is both affected by, and affects, the organizational structures where it takes place (Lawrence et al., 2010). Using this theory, we searched for concrete examples of agency in accounts and observations of project stakeholder interactions, trying to assess what lies behind both successful and less successful institutional work. We also included Critical Theory in our theoretical framework, in order to cast light on situations that communicate an imbalance between the interacting parties. Critical Theory emphasizes the context of interaction and examines how individuals may become excluded from organizational decision-making through the influence of internal ideologies, power relations, communication patterns and through limited access to internal fora (Deetz, 2005). In Critical Theory (e.g. Habermas) it has been noted that 'technical rationality' will often dominate over 'practical reasoning' in organizational discourse, a pattern that may be relevant for the ship design process, where the needs and experiences of operational personnel must be reconciled with streamlined processes and business interests. These types of social dynamics could affect the uptake and effectiveness of design guidance, and it was therefore important for us to be sensitive to the social relationships and interaction patterns between key stakeholders.

5 Results

Main author of the chapter: Julia Burgén, RISE

Development of the design guidance presented in this report set out from the same principles as the guidance itself advocates – that artefacts used to improve onboard work should be closely adapted to the needs of their users, and to the context where they are applied. The results section describes the rationale behind design guidance characteristics, including a review of existing human-centered design guidance, data from investigations in ongoing newbuild projects, insights from previous design process innovation research, and a review of potential obstacles to human-centered design practices. These sources together made it possible to construct design demands for our end product. The current version of design guidance documentation can be found in Appendix B, but to ensure the best reading experience and the most recent version, it is recommended to be downloaded from here: http://ri.diva-portal.org/smash/record.jsf?pid=diva2:1751612

5.1 Previous LASH FIRE work

Throughout the LASH FIRE project, a large amount of ethnographic studies have been carried out investigating crew activities and interactions in the fire management process (Bram et al., 2022). Data from these studies provided grounds for contextualization of the design requirements, such as suggestions of crew goals and tasks to consider and practical working conditions that may affect the crew's performance.

A more applied study was the LASH FIRE work development and testing of a fire management interface (Steinke et al., 2022). The interface did not only contain alarm-related functions, but also controls for countermeasures. The DFC was the fourth iteration within LASH FIRE and it was designed based on the feedback on previous iterations as well as other LASH FIRE findings. The team members who developed the DFC were experienced in applying user-centered methods and paid much attention to user experience and usability.

The main objective of the DFC was to provide crew with information that will help them fight the fire effectively. By studying the outcome of the development and testing of the DFC, experiences were extracted that could benefit the development of design guidance.

Fire panels of the mimic-type can show detectors on a fire plan or ship outline, as opposed to text-based panels where the location must be interpreted from the alarm message itself. In the DFC heat and smoke were visualized as grey and red areas on a fire plan with three levels of darkness, depending on the smoke concentration and heat levels. In tests, all participants could immediately understand the location of the fire by looking at the smoke and heat visualizations. However, the tested case only included a situation where smoke and heat maps were not affected by wind or ventilation. The DFC also included a timeline where it was possible to scroll back in time and compare past heat and smoke maps with current. This can give indication about which direction the fire is spreading. The timeline also included intensity graphs (trend curves) which were based on the number of new detections and heat/smoke levels increasing. Possibilities of systems integration were included in the guidance materials.

In post-test interviews, trust in the DFC information was discussed. Participants said that they would be a bit reluctant to put too much trust in the presented information. This concerned both heat and smoke maps, where all that is *really* known is the temperature in certain spots, as well as trends and predictions. Comments suggested that the system would have to be transparent and show how the information was derived. One participant said: *'The more parameters I have that work independently, the more trust I have in the system. But I would never give myself into trusting the* *system. That is how we are taught. In the end it is about what you see.'*. Based on this, the issue of trust was included in the guidance's design principles.

As with many other onboard systems, contextual factors must also be accounted for when designing a system. Some examples of factors that were not evaluated in the DFC tests were using the touch screen with greasy or dirty hands and using the system in heavy seas. One participant also discussed whether the DFC and having all controls and information at hand might decrease communication and the spread of important information between different locations. On the other hand, it was also expressed that the DFC made it really quick to provide the fire team with information, as you would not have to gather information from many different systems. When designing interfaces that play a part in collaborative work, such as dealing with a fire, it is important that the system supports sharing information orally and that visually represented information is accompanied by measurements and spatial references that are useful on-scene. Aspects of collaboration across the ship were included in the structure of design guidance.

5.2 Existing design guidance

The current work is not the first attempt to increase the impact of human-centered design in the maritime context. However, an observation from our review of published design guidance is that such materials are far fewer than the available research. In this review, the aim was both to identify important gaps to fill, and to understand more about the apparent practice-research gap associated with maritime human-centered design guidance. Selected design guidance that fulfils the profile explained in section 4.2 are presented in Table 2.

*Table 2. Summary of analyzed design guidance. * Item only available in Swedish, **Item not open access*

Guideline * Item only available in Swedish ** Item not open access	Intended reader	Scope	Guidelines style
A Best Practice Guide for Ship Designers (Lloyd's Register Marine, 2014b) & **A Best Practice Guide for Equipment Manufacturers** (Lloyd's Register Marine, 2014a)	Ship designers & equipment manufacturers respectively	Informs three distinct types of use: *Overview or getting started*, *Implementation of human element management* and *Assessment/review of best practice*	Collection of processes (sorted into different areas). Processes are described through purpose, outcome, activities and references to additional resources or methods which can be used in the activities.
Granskning av ritningar ur ett arbetsmiljöperspektiv. Translated title: **Drawing review from a work environment perspective** (Österman, 2013)	Anyone involved in different types of ship design review work	Specifically focuses on reviewing drawings from a work environment perspective	Provides the reader with guidance and templates to favour work environment-focused drawings review, a user-centered approach.
Guidance notes on the application of ergonomics to marine systems (American Bureau of Shipping, 2018)	Ship or equipment designers	Introduces ergonomic principles and criteria to consider during design	Contains concrete advice and design principles for controls, displays, alarms, labelling, graphics among other areas.
Human factors in the maritime domain (Grech et al., 2008) **	A maritime audience (e.g. seafarers, maritime administrations, classification societies, research institutes and students)	Provides an overview of human factors within the maritime domain	Explains theory and aspects to consider within *communication and teamwork*, *technology interaction* and *organization, society and culture*, among other areas.
MSC/Circ.982 Guidelines on ergonomic criteria for bridge equipment and layout	Ship or equipment designers	Assists designers in realising a sufficient ergonomic design of the bridge (improving the reliability and efficiency of navigation)	Contains ergonomic requirements for the bridge layout, work environment, workstation layout, alarms, information display and interactive control

Guideline * Item only available in Swedish ** Item not open access	Intended reader	Scope	Guidelines style
(International Maritime Organization, 2000)			
SN.1/Circ.265 Guidelines on the application of SOLAS regulation V/15 to INS, IBS and bridge design (International Maritime Organization, 2007)	Designers and system integrators designing and installing INS and IBS	The purpose of this document is to identify the needs of the bridge team and the pilot and the BRM principles that should be considered in the design and arrangement of INS, IBS and for bridge design for the installation of INS and IBS on the bridge.	Contains functional requirements relevant for INS and IBS systems
MSC.1/Circ.1512 Guideline on Software Quality Assurance and Human-Centred Design for e-navigation (International Maritime Organization, 2015)	Stakeholders involved in design of e-navigation systems (e.g. equipment designers, system integrators, maritime authorities, shipbuilders, shipowners, ship operators, VTS and Rescue Coordination Centers)	A guideline on how to ensure trustworthiness and user need fulfilment of e-navigation systems, through using Software Quality Assurance and Human-Centered Design.	Describes HCD activities that are carried out throughout the life cycle of a product. Usability testing is given a large emphasis. For other aspects, such as the activity *Identify user requirements,* guidance is provided on what to accomplish and not how to get there.
Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems (International Organization for Standardization, 2019)**	Those responsible for planning and control of projects in interactive system development	Provides requirements and recommendations for user-centered design activities in a development process for interactive systems. Contains further references to additional standards containing method descriptions and design guidance	Explains design activities and what they should include, but little guidance on how to carry out each activity.

Based on the scope for this task, Österman (2013) stands out as an interesting example. Österman's handbook is written in Swedish and provides guidance on reviewing drawings from a work environment perspective. The tone is quite popular-scientific and the book also stands out in terms of layout from the other reviewed documents. A hypothesis for the present work is that the willingness to use Design Guidance is heavily dependent on the material being easily approachable – primarily in terms of language, length of texts and the possibility to quickly get an overview. Such goals can also be fulfilled through a well thought-out layout. This hypothesis is supported by experiences from previous LASH FIRE work, such as the development of guides for remote video-based work studies (Bram et al., 2022). Grech and Lutzhoft (2016) also studied HCD in the maritime industry and tested using an HCD framework. It was said that use of simple and concise language as well as avoiding technical and academic language, could reduce the risk of inaccurate interpretation of the usability guidelines. The following was pointed out by Costa et al. (2017) who studied HCD application within a maritime design firm:

"ISO 9241-210:2010, although perceived by the Design Team to give HCD more credibility and to make it "less fuzzy", was at the same time considered a "boring and cumbersome" read that should have its core information extracted."

Another aspect worth pointing out from Österman's guide is that the way it is anchored in a ship design process is consistent with our own approach to guidance, in that it is intended for reviewers within the shipping company. As described further in section 6.4.1, the Design Guidance developed here targets the shipping company and specifically the operator. This differs from other types of guidance listed, which target ship and equipment designers.

It is difficult to strike a balance between keeping text short and providing enough information and in some of the collected resources, the authors seemingly have attempted to be brief, sometimes possibly at the expense of being informative. In our present work, the approach is that texts should be kept short, undemanding to read, and still follow a clear structure that helps the reader to determine what is relevant for them to read or not.

5.3 Revised stakeholder analysis

A stakeholder analysis for the ship design process was performed at an early stage in LASH FIRE, aiming to identify important stakeholder characteristics and interactions that could help to define an approach to the introduction of human-centered methods in fire safety design. In the present work, this analysis was revised and complemented with more detailed data coming from interactions with participants in ongoing newbuild projects, where the explicit purpose was to find ways of augmenting or adding practices in the design process. As described further in section 5.4.1, the operator was selected as the user of design guidance, which resulted in some discarded stakeholders. The stakeholders are presented in Annex A. Compared to the analysis presented in D07.1, the main revisions are:

Redefinition of roles

- The technical department and the operator are still represented as different stakeholders, but it was found that the lines between the two are blurry. New investigations showed that in some organizations, the role of the operator may include the role of the technical department
- The shipping company's finance department was added, as they keep track of the design project budget and thus may influence design decisions that affect project cost

- The shipping company's commercial/customer department was added, since their interests (adapting the ship's design to enhance the passenger experience) may directly influence the ship's interior design and possibly compete with demands from the operational side
- Site team was removed, given that the focus of the present work is on early-stage design activities, while the site team is active during the actual building of the ship
- The fire safety consultant was removed because the inclusion of such competence appears to be an exception and mostly occurs when design solutions in some way challenge existing rules or regulations
- The insurance company was removed, for the same reason that the Site team was excluded.

Other

- Stakeholder relations were revised
- The goals were revised and rephrased to mirror the scope of the task.

5.4 Design demands for development of guidance

A central goal for the development of design guidance was to adapt it to the needs and working circumstances of its end users, and to make sure that it could realistically be applied by the people normally engaging in ship newbuild projects, despite all the potential obstacles and limitations that have previously been identified (Bram et al., 2020). This section describes the rationale for various design decisions in the development of guidance that shaped its final form.

5.4.1 Design guidance end users

The stakeholder analysis led to the identification of the shipping company as the main user of the design guidance developed, in particular, the person or group that works to specify fire safety requirements. In the case study (Shipping company 1) that contributed the most to context and end-user studies, this agent belonged to the stakeholder Operator. The decision to select the shipping company as the main receiver had several reasons.

Firstly, stakeholder interviews provided examples of past newbuild projects where engaged individuals within the shipping company had affected design decisions in ways that promoted crew working conditions. Such observations suggest that the shipping company has a real potential to influence design outcomes, provided that they express their requirements clearly and review design drafts based on those requirements. This conception is supported by results from interviews with design firm and manufacturer representatives as well as previous research (Costa et al., 2017). When the shipping company clearly communicates their needs and requirements, this provides richer information for the design firm, and may also come to balance the priorities of other stakeholders. One such example is the shipyard, who normally focuses on minimizing costs and, for example, may not screen equipment options based on user requirements.

Secondly, a hypothesis is that shipping company design team members have one great advantage when it comes to implementing human-centered design processes, which is their good access to end users (i.e. ship crews).

Thirdly, data from workshops and interviews suggest that decisions made in the shipping company design team are sometimes influenced by social dynamics such as power imbalances between stakeholder representatives. Previous findings (see D07.1) have shown that the extent to which crew needs are considered in design is often down to chance. If a design team member with operational experience and a high level of influence happens to be included, there is a greater chance that crew perspectives are included in design specification and review. Other related observations were made in workshops with shipping company 1. Here, the Commercial department responsible for the passenger experience had developed a highly structured approach to identifying and communicating passenger requirements, including demographics and passenger personas. This approach could not be matched by representatives for the Operations department, who did not follow any structured approach for identifying and presenting crew requirements, and thus, the interests of Commercial often came to dominate design discussions in the design team. An interesting aspect of this observation is that while Operations mainly interact with the design firm, on subjects such as layouts and placement of equipment, Commercial's counterpart is an architect firm responsible for interior design. According to one interviewee, interior design decisions will sometimes have consequences for the work of the crew. For example, the placing of walls and passages may affect common workflows, and there had been experiences where interior design installations had been discovered to obstruct maintenance tasks. Despite this, Operations had no interaction with the design firm, and Operations and Commercial were described to act in "stovepipes" (i.e. in isolation from each other) when dealing with design decisions. These observations resulted in the hypothesis that there is unrealized potential in project engagement from operational personnel, and Operations could be empowered by design and communication methods that, to a larger extent, measure up to the approaches of other stakeholders.

A caveat to these ideas that has been mentioned in previous research (Costa et al., 2017) is that the working circumstances of HCD researchers in projects such as LASH FIRE are quite different from those of design team members in actual ship design projects. The intense user interaction that is possible in research projects may be difficult to replicate in an industry project environment, where design team members need to balance their project involvement against their normal work duties. For this reason, efforts were made to provide a low threshold for the use of our guidance, with simple methods and a large component of advice based on research findings. Still, enabling a design team member to make use of the guidance work require an acceptance within the design project organization.

5.4.2 Process integration

Several workshop and interview participants agree in their statements that if any inputs that center on crew requirements are to have an effect on design project outcomes they need to be described and communicated early in the design process, something that is also confirmed by previous research (e.g. Costa, 2017; de Vries, 2017). According to one interviewee, it is not uncommon that the first opportunity for crewmembers to review the ship's design occurs very late, sometimes just before delivery, and any design changes made at that stage will be associated with very high costs. When discussing the revised design process map with interviewees from a ship design firm, their belief was that crew requirements should be part of the concept design stage, before contracting a shipyard (see figure 1 for a design process map based on workshop and interview data). This will allow the design firm developing the concept design to translate such requirements into technical requirements, that can then be forwarded to basic design and be used in review of drawings as well as selection of equipment.

For these reasons, the design guidance presented here focuses on shipping company activities at the stage where the design concept is developed, but before a contract is established with a shipyard. While it is important to make sure that requirements made during this early stage are carried on into basic and detailed design, the proposed structure for creating and managing requirements should also be applicable there, for example, when more developed designs are reviewed.

The guidance also places a heavy emphasis on stakeholder interaction, meaning that the different steps in the process should produce results that are fit for communication, either internally (e.g. to forward crew requests in the design team) or externally (for communicating requirements to the design firm).

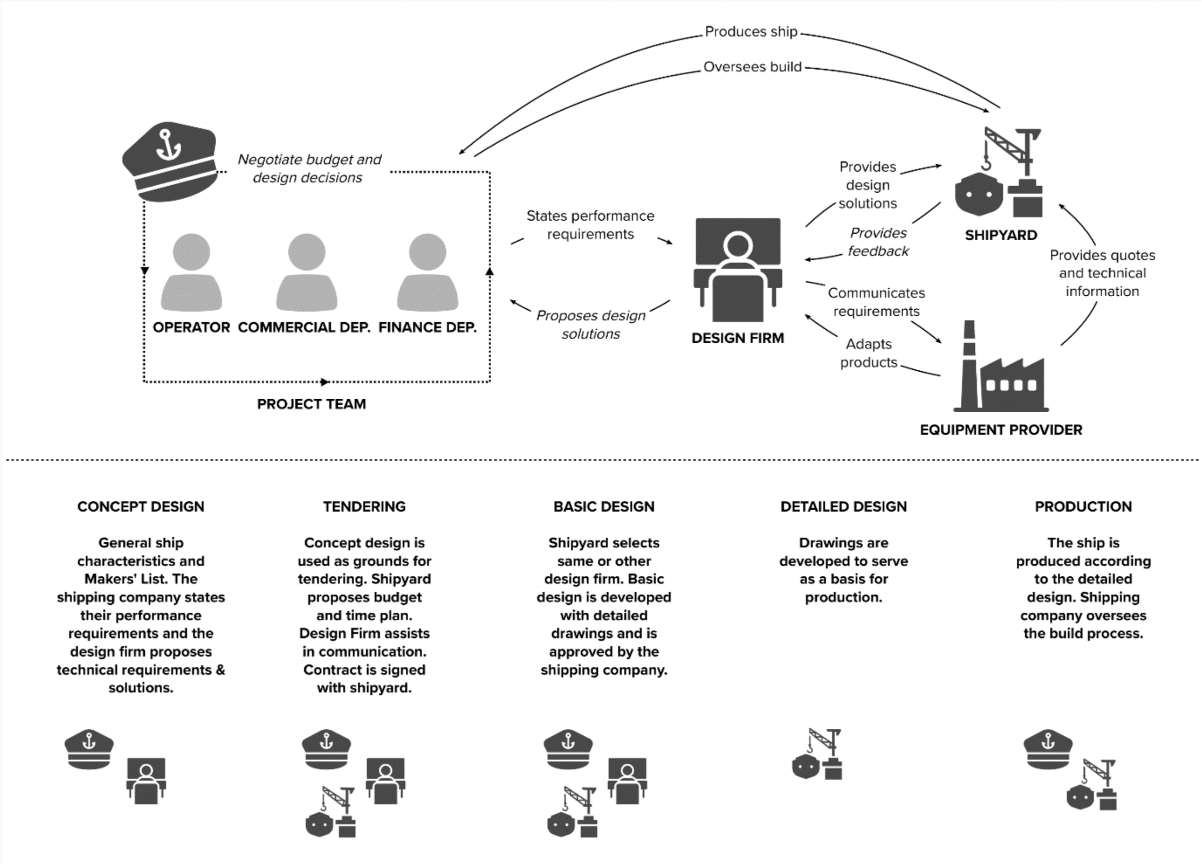

Figure 1 – Process phases and interactions between the shipping company, design firm, equipment provider and shipyard

Four activities were chosen to represent the main structure of design guidance, as they were found to correspond to existing activities performed by the shipping company during the design concept development phase – 1) investigating crew activities 2) definition of design requirements 3) communication and 4) review of design drafts (see figure 2 below). The design concepts behind these activities are described in the following chapter.

Correspondents to these activities can be found in most HCD guidelines (see for example the 11 step process proposed by Gaspar (2019) whom in turn makes reference to ABS guidance), but the process has been trimmed down to a few essential tasks in order to lower the threshold for application, and provides more detailed guidance connected to the task of fire incident leadership (exemplified by bridge design for fire management). Rather than propose a catch-all and elaborate process, the decision was made to attempt a minimalist approach, and then expand if end-user feedback indicates that it is required.

5.4.3 Design guidance contents

The following sections describe considerations and decisions made in the design of guidance activities. Version 1 of the design guideline can be found in Annex B.

Figure 2 - Design process overview

5.4.3.1 Investigate crew activities

The first step of this process is to gather data on how the environment at hand (in this case, the bridge and its fire management resources) is used during a fire scenario. In order to balance the often-reported fact that ship design tends to revolve around technical issues and specifications, the decision was made to focus this step on the crew's practical activities when discovering and engaging a fire on board. By focusing on activities, which by their nature will often involve interactions with several systems, people and resources, the ambition was to lead design team members into thinking more holistically about fire safety design. An additional hypothesis was that bringing crew activities to the forefront would help maintain a focus on realizing operational goals in the event of fire – that it is the combined performance of the crew and its working environment that will lead to positive outcomes. Finally, it was hypothesized that having an activity-centered approach might compensate for a lack of ship operational experience within the design firm, and make it easier for the shipping company to convey what the designed environment will actually be used for. It has been noted in previous research that when stakeholders work to uncover experiences from previous designs (e.g. by looking at old drawings and specifications), it is simple to assess "how things are", but not necessarily as easy to understand "how things work" (Gernez, 2019).

For this stage, the decision was made to supply the design guidance users with an overarching goal structure for fire incident leadership, consisting of five main goals and related tasks distilled from previous LASH FIRE research – *Detect, Confirm, Assess, Communicate and Respond*. Each goal is accompanied with a brief description of tasks that are relevant for the fire case. The suggested goals were reviewed during a shipping company workshop and found workable, although the guidance clearly encourages the user to modify this structure according to their own context. It can be noted that Assess and Communicate are more abstract goals that do not represent distinct phases in the fire management process as the other items, but it was found that these goals were tied to important tasks and needs that could not be logically sorted under any one phase.

When the user feels satisfied with the description of activities, these are populated with crew tasks. This step was again included to maintain a focus within the design team on operational conditions and outcomes, i.e. that design should not only satisfy technical requirements, but should also help the crew to achieve their operational goals.

Both this data and all other information produced under the continuation of the process are entered into a simple Excel worksheet. Even though more elaborate systems for hosting user data are available, the ambition here was to use a platform that is accessible to all.

Environment	Goal	Task	System	Hazard	Requirement	Comment
Bridge	Detect	Perceive alarm	Fire alarm system	Alarm missed	Alarm signal is clearly audible.	
Bridge	Detect	Interpret alarm message	Fire alarm system	Alarm misunderstood: location, faulty/real	Alarm message conveys location of detector in a way that is recognizable to crewmembers. Message includes drencher zone, heat/smoke level.	
Bridge	Assess	Assess heat spread	Fire alarm system	A rise of heat / spread of fire is missed	Clear presentation of changed detector state, e.g. additional detections, rise/decline in temperature.	
Bridge	Assess	Assess smoke spread	Fire alarm system	Smoke density and/or spread is underestimated, smoke spread is mistaken for fire spread	Clear presentation of changed detector state, e.g. additional detections, rise/decline in smoke concentration. Ability to review smoke concentration in relation to heat measurements.	
Bridge	Assess	Control for dangerous goods	DG information	DG information is missed or insufficient	Information on Dangerous Goods must be kept in a way that is easy to access and understand in a crisis situation.	

Figure 3 - Example of requirements worksheet

5.4.3.2 Define design requirements

This step begins with the identification of hazards that may undermine crew tasks. The ambition behind including this step was to offer alternative ways of approaching requirements – supporting positive outcomes vs preventing negative outcomes. It was also hypothesized that hazards connected to fire management activities might be an effective way of communicating around design priorities, which is described further in section 6.4.3.3. Next, goals and their associated tasks are compared to *design principles* supplied in the design guidance documentation. With the help of these principles, the users of the guidance should try to describe what requirements on the working environment and its resources could help realize their goals, i.e. make successful work more likely.

The design principles have two main sources, where principles more specifically associated with the maritime context have been derived from LASH FIRE research, while those concerning general usability issues have been informed by Nielsen's usability heuristics (Nielsen, 1994). The principles are generic in nature instead of prescribing bridge design solutions in detail. The reason for that is to make the guidance applicable to different design contexts, e.g. both to lower and higher-budget projects where very different design solutions may be possible. By focusing the shipping company's requirements on work-oriented issues, this also leaves room for dialogue with the design firm and allows them to translate shipping company requirements into technical requirements.

A structure with three categories is proposed for sorting requirements – Usability, Layout and Collaboration. These categories were chosen to represent different levels of design consideration, from the characteristics of individual system interfaces and other resources, to the workflows and properties of the overall bridge environment, on to the interfaces between the bridge and other groups engaged in fire response (such as the engine control room and the fire groups). The last category, collaboration, was included in order to direct the reader's attention to joint performance in the ship safety organization, and to think of the consequences of bridge design decisions for other important agents in the fire management process.

5.4.3.3 ***Communicate*** *with internal and external stakeholders*

When developing this guidance, communication with external stakeholders such as the design firm or equipment suppliers was perceived as being more technical and straightforward. There is no need to convince these stakeholders of anything – instead, it is hypothesized that this communication is mostly a matter of conveying (or simply sharing) the inventory of requirements made in the accompanying work sheet. Therefore, the section on communication with designers and suppliers was kept short.

Instead, guidance on communication centers on interactions within the shipping company. Based on feedback from interviewees and workshop participants, this is where competing interests and budget limitations may cause crew interests to be overshadowed. Communication is grounded in materials from the requirements worksheet. For example, it is hypothesized that for some audiences, hazards associated with poor design may be good argument for HCD, while in budget-oriented discussions, benefits may be more appropriate. A LASH FIRE example on how crew-centered solutions can be shown to be cost effective is also provided.

The importance of communicating the realities of operational work was stressed for both internal and external communication, because in both cases, the counterpart may be in need of more knowledge about operational work (Österman et al., 2016).

5.4.3.4 ***Review*** *design drafts*

Interviews concerning common practice in newbuild projects suggested that as such a project progresses, more and more detailed design considerations can be made. For that reason, guidance on design review was split into two parts. The first part applies to layout review, because draft layout drawings are often available early in a newbuild project. The second part applies to the review of installations such as systems and equipment – considerations that will be made after a shipyard has been contracted for continued development. The basic approach for these review instances is to refer back to the materials that the guidance user has developed in the accompanying worksheet. It was also an ambition to encourage the user to engage in more active or physical forms of review, paying close respect to the practicalities of fire management work tasks. A few simple suggestions of such methods are provided.

5.5 Obstacles to fire safety system design improvement

When describing obstacles to fire safety system design improvement, three major topics will be described – room for interpretation, considering the context and costs.

5.5.1 Room for interpretation

It may be very difficult for a person who is not used to thinking in terms of usability to identify and communicate such requirements. *'The fire alarm panel should be easy to use'*, leaves room for interpretation and cannot guarantee efficiency, effectiveness and satisfaction. Two main issues with leaving room for interpretation are:

a) Requirements might be wrongly interpreted unconsciously because the *reason* of the requirement is not understood. For instance, *'The status of X must be clearly communicated'* can be interpreted as something that can be visualized through the use of red and green colours. Red and green signal 'correct' and 'wrong' and it is possible that a user interprets this differently depending on what is considered to be the normal state (fire or no fire).

b) Requirements might be consciously interpreted in certain ways to favour a specific (e.g. cheaper) solution. For instance, the above mentioned example of '*easy to use'* can be argued by anybody if the requirement is not specified further.

To address these issues, the guidelines encourage the reader to include hazards (if requirement is ignored) and explanatory comments. To address the issue with potential conscious interpretations, the design guidance stresses that operational personnel should be part of design review, since they can represent people that have no economic incitement connected to particular solutions.

5.5.2 Considering the context

In previous LASH FIRE studies, we have discovered that as ship equipment is exchanged, added and adjusted over time, things such as consistency in naming between systems and environments may start to drift. This is addressed through the activity point of view. When the requirements are set, the reader is not encouraged to look at everything system-by-system, but rather focus on accomplishment of the activity. That way, systems, environments and other contextual factors are studied more as a whole. By focusing on activities rather than individual technical components or technical systems, the wider context is also brought into consideration, even over time.

5.5.3 Cost

Cost aspects cannot be overlooked, and specific design solutions can be judged to be 'too expensive'. However, it is worth pointing out that the Digital Fire Central presented in section 6.1 was judged to be cost-effective for ro-pax, ro-ro and vehicle carriers in terms of Net Cost of Adverting a Fatality, i.e., saving cargo, ship and life, in newbuild projects (De Carvalho & Lewandowski, 2023), an example that is also included in the guidance documentation.

One of the most important factors when it comes to cost minimization, according to our interviewees, is to introduce crew needs as early as possible in newbuild discussions. This is reflected in the developed design guidance, which has a clear focus on early design project activities and interactions. Furthermore, the cost aspect is addressed by not specifically recommending any costly solutions, instead focusing on harmonizing information and systems. Efficient workflows and easy access to information and controls can be accomplished through integrated systems, but to some extent it can also be achieved with separate systems where attention has been paid to aspects such as co-location of resources and cross-system harmonization (e.g. of terms and language used).

5.6 Summary of design hypotheses

The following is a summary of the design hypotheses made before and during the development of design guidance. To the extent that hypotheses could be answered, this is also commented under each heading.

1. **Target group**

The shipping company design team is a relevant target group for design guidance given that their requirements will set the level of expectation on other stakeholders (such as the design firm), and because of their good access to end users (i.e. ship crews) – *Confirmed through stakeholder interviews.*

2. **Stakeholder interactions**

2a. Social aspects of communication (e.g. influence of hierarchies and argumentation strategies) are mostly relevant for interactions within the shipping company, where discussions about competing design goals may occur – *Partly confirmed through stakeholder interviews, where social factors where only mentioned in relation to interactions internal to the shipping company.*

2b. Providing design guidance that represents crew needs in relation to fire safety may strengthen the position and arguments of operational personnel in relation to other shipping company stakeholders, such as commercial and finance – *No possibility to confirm within the timeframe of the task.*

2c. In stakeholder interactions where safety is regarded as a prioritized design goal, emphasizing hazards associated with poor design may be good argument for HCD, while in budget-oriented discussions, emphasizing the benefits of good design (e.g. efficiency) may be more appropriate – *No possibility to confirm within the timeframe of the task.*

2d. In communication with the design firm, there should be an emphasis on conveying operational knowledge and experience, which design firm agents may often lack. – *Confirmed through stakeholder interviews.*

3. **Design of guidance**

The willingness to use Design Guidance is heavily dependent on the material being perceived to have a low threshold for application – primarily in terms of language, length of texts and the possibility to quickly get an overview – *Partly confirmed through end-user feedback.*

4. **Structure of guidance**

4a. Using crew fire management activities as the basis for requirements identification may steer the design team's focus away from purely technical considerations and emphasize the fact that it is the combined performance of the crew, its working environments and equipment that leads to positive outcomes in a fire scenario, thus promoting a more holistic approach to fire safety design – *Partly confirmed. End-user feedback provided that an activity-centered approach will accentuate crew needs that do not emerge as easily when basing discussions on required technical installations, but there was no opportunity to assess the consequences of the approach for design team discussions*.

4b. Having an activity-centered approach might compensate for a lack of ship operational experience within the design firm, and make it easier for the shipping company to convey what the designed environment will actually be used for – *Partly confirmed through design firm and manufacturer interviews, but there was no opportunity to observe the consequences for actual design firm interactions within the timeframe of the task.*

4c. Distinguishing ship-wide collaboration as its own layer of design issues may raise awareness about the need for human-centered design interventions in other environments than the bridge. – *Confirmed through stakeholder interaction, where stakeholders easily strayed into discussing needs associated with every-day crew activities.*

5. **Level of guidance**

Different design projects may call for different levels of detail with regards to stated design requirements. For example, it is hypothesized that the contextualized design principles offered in the guidance documentation, coupled with rich descriptions of crew tasks and associated hazards, might be enough to drive design discussions between the stakeholders. – *No possibility to confirm with the timeframe of the task.*

6 Discussion

Main author of the chapter: Staffan Bram, RISE

Development of the design guidance presented in this report had two main drivers. The first was to supply shipping companies with methods allowing them to describe and communicate crew needs. The second was to provide guidance that is simple enough for any shipping company to apply them, the only demand being that they are willing to invite operational competence into the company-internal ship design process. As reported in previous LASH FIRE work (Bram et al., 2020), there are many potential obstacles to the application of human-centered methods in newbuild projects. Shipping company management that are unwilling to spend resources on the investigation and satisfaction of crew needs, design firms that lack methods for matching those needs with technical requirements, and shipyards that shy away from ship adaptations that go beyond standard designs and preferred suppliers can all come in the way of human-centered improvements of fire safety design. Even though this is true, the bulk of existing research targets these other stakeholders, and we maintain that the actions and attitudes of the shipping company has a large potential impact on design outcomes. First, when the shipping company articulates crew needs related to fire safety at an early stage, many design choices emerge that have little impact on the total project budget. Second, if shipping companies explicitly request design solutions that are well adapted to the practical needs of the crew, that could create business incentives amongst design firms and suppliers to steer their offerings towards more crew-centered practices and products.

When writing this guidance, the ambition was to encourage a more systemic perspective on fire safety than the normal considerations within this domain – Fire safety installations is often approach from a technical point of view, where the main aim is to fulfil technical performance (such as sprinkler coverage and capacity). In reality, fire management is a process that requires coordination among several different groups on board, fulfilling many different functions, applying many types of technologies. These technologies must fulfil the needs of the immediate user, like the Officer of the Watch (OOW) reading out fire alarm messages, but some of them must also support collaboration amongst crewmembers, such as information that needs to be communicated between the bridge, the Engine Control Room (ECR) and the fire groups. The layered approach that was taken in design guidance (separating issues of *usability*, *layout* and *collaboration*) is intended to make the user of guidance more sensitive to systemic nature of fire management and not only consider human-machine interaction, but also the way design can support joint efforts within the whole safety organization. Another rationale for separating usability and layout was to provide a better match for the order in which these topics are considered in design projects, where at an early stage, mostly layouts may be up for discussion. That said, whenever ontologies like these are introduced, there is room for confusion. For example, it may very well be that aspects of usability and layout play a large role for collaboration. In the guidance, the *collaboration* category is mostly described in terms of how resources and information available at the bridge might need to be reproduced in other locations across the ship. The intention was to extend the perspective on fire incident leadership to include other resources that could offload the fire chief and support decision-making. It was also hypothesized that bringing in collaborative topics might raise awareness about the need for human-centered design interventions in other environments than the bridge, although this hypothesis remains to be tested.

Design guidance was developed in collaboration with two shipping companies, and confirmation of design hypotheses was sought to the extent that their respective projects allowed. If a shipping company were to start applying the guidance systematically, several topics would have to be investigated. First, the guidance was intended to raise awareness of design issues concerning environments, systems and other resources that may affect the performance of the safety organization in a fire scenario. For that reason, the examples and supporting materials of the guide are largely centered on fire safety issues. However, conversations during shipping company workshops easily strayed into other needs of crew-centered design, such as the way layouts affect workflows and work tasks belonging to day-to-day crew responsibilities. The process and methods suggested in the guidance were meant to be generic, and it should be possible to apply them to any work-oriented design problem. However, a lack of concrete examples could make application more difficult. In general, there is a balance to be struck between offering detailed guidance and encouraging the shipping company to make its own investigations into crew needs. In our guidance we attempted to take a middle path between the specific and the generic. On the one hand, it was feared that too detailed guidance would prevent the shipping company from making its own inquiries around crew experiences and feedback. On the other hand, it was expected that the operator might struggle to apply the guidance if the materials (e.g. design principles) were too abstract. The practical applicability of design guidance will be continuously assessed (and materials revised) as the case studies within Shipping Company 1 and 2 progress and the results will be included in the later publication of official LASH FIRE guidance.

Another issue that might arise if an ambitious shipping company was to start applying human-centered design guidelines on a larger scale, is that of the quantity and complexity of requirements. Simply mapping out crew requirements in fire safety design for other relevant environments (such as the ECR, drencher room, fire stations, drencher room and roro spaces) could already be expected to generate a massive amount of materials. We wanted to suggest a system for managing requirements that would be available to any shipping company and thus went for a simple Microsoft Excel workbook, where different onboard environments are represented on different sheets, but managing requirements could still come to imply a lot of effort on behalf of the design team. This issue borders on two other topics – first, what level of requirements is suitable for communication with the design firm and suppliers, and second, how guidance could be applied with different levels of ambition. On the first topic, it was mentioned during interviews that one of the most important goals when the shipping company interacts with the design firm should be to convey a realistic image of operational tasks, and the conditions that may affect the crew's work. It should then be within the design firm's expertise to produce design solutions (or at an early stage, technical requirements) that satisfy crew needs. From that perspective, it may be questioned what level of detail the shipping company should strive for when defining their requirements. For example, it could be hypothesized that the contextualized design principles offered in the guidance documentation, coupled with rich descriptions of crew tasks and associated hazards, might be enough to drive design discussions between the stakeholders. Again, further investigations will be performed as the case studies progress. In either way, these options around requirements definition and communication could also be used as different levels of ambition, where applying the simpler approach could be a first step for a shipping company with little experience or a very limited budget.

On a final note, the shipping industry is currently going through a period of rapid change driven by technological advances such as automation and remote operation. These are developments that are also relevant for fire safety, both in the sense that automated fire safety functions (e.g. fire monitors) are becoming available, suddenly demanding that topics such as human-automation interaction are also considered in fire safety design, and that the work tasks of the crew is likely to shift over time, thus changing the characteristics of the envisioned end-user of onboard fire safety systems and equipment. Upholding fire safety in this changed landscape, and designing for effective interventions, will likely demand that new perspectives are applied to crew-centered fire safety design guidance.

7 Conclusion

Main author of the chapter: Staffan Bram, RISE

Data from our inquiries confirmed prior findings (Bram et al., 2020) which suggest that passenger ferry fire safety installations are rarely designed and assessed according to crew needs. While some advancements have been made to promote human-centered design in shipbuilding (International Maritime Organization, 2015), fire safety is one area where such practices still need to be established. Stakeholder feedback also confirmed one of the main hypotheses for our work, namely that there is a need for guidance specifically targeting the shipping company, to complement existing guidelines directed towards other stakeholders, and that providing shipping company guidance may create incentives among those other stakeholders to offer more crew-centered practices and products. Two newbuild case studies within two separate organizations are currently active and will inform the continued development of design guidance. In these organizations, no prior methods existed for identifying, recording and communicating crew needs in newbuild projects. Based on the outcomes of these studies, the decision was also made to focus guidance on the earliest phases of the newbuild process. At this stage, the organizations involved had the time needed to investigate their fire management practices and formulate overarching requirements that could then be communicated with the design firm before producing the basic design.

While the ambition with our work was to encourage shipping companies to be active in identifying their own needs and requirements, given that the involved organizations had no prior experience of human-centered methods, guidance also needed to have a low threshold for application. The decision was made to keep guidance simple and brief, and to present it in a way that would be perceived as approachable. In addition, while the documentation includes a process and methods for needs and requirements investigation, it also includes supporting materials (such as design principles) that more explicitly target the main objective of the task – design of fire safety installations on the ship's bridge.

Operational fire safety management is a process that demands effective interaction between several working groups on board, and the ambition was to reflect this in the proposed methods. To this end, guidance was structured according to three layers: layout (bridge movements and interactions), usability (system interface properties) and collaboration (interactions between the bridge and other working groups). This division was also intended to match a pattern observed in the case studies – that different stages in the design process allow for different levels of design consideration, where layout design is the first step of concept evolution.

The guidance in its present shape has been positively received by the case study organizations, although development will continue as we keep interacting with the corresponding newbuild projects. In future development, some key points of interest are the appropriate level of detail in supporting materials, how to make outputs compatible with existing project structures, how these outputs are received by external stakeholders, and what adjustments might be necessary to make guidance applicable for other environments than the bridge. It has also been noted that within one of these organizations, discussing crew needs related to fire safety has also spawned an interest in human-centered design applications to other crew activities. This could provide us with the opportunity to investigate how the proposed design guidance scales when applied to a larger set of problems, a situation that would probably require an even greater emphasis on process simplicity.

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10 ANNEXES

10.1 ANNEX A – Design guidance stakeholders

Table 3. Design guidance stakeholders

Stakeholder	**Roles**	**Goals** (fire safety influenced)	**Influence**	**Knowledge**	**Resources**	**Design guidance needs/use**
Owner	Future owner of the ship. Approves inquiry specification and building specification.	Needs to **fulfil market niche and avoid property perishing** in order to **ensure long-term profitability**	Strong: budget	Experience of newbuild projects, market, operations and management, from a business perspective	Production/market analyses from existing lines, market research	
Tech. dep.*	Responsible for fire safety	Needs to **specify fire safety requirements** in order to **achieve fire safety**	Large/medium: large influence on fire safety question, but likely limited by budget	Specialist competence		
Operator* May include the roles of tech. Dep.	Will operate the ship	Needs to **monitor practical usability in design** in order to **ensure safe and efficient operations**	Partial: through development participation	Operative experience, technical knowledge, route knowledge	Company contacts	Guidance in communicating needs effectively
Design firm	Designs the ship, from general to detailed characteristics. Issues inquiry specification.	Needs **usable and reasonable requirements** in order to **fulfil the requirements.**	Partial, works according to design specification	Naval architecture, system design, propulsion, production of 3D-models and drawings.	Design specifications drawings, models	Understanding the underlaying purpose of the requirements can make it easier for the design firm to meet the requirements.
Finance dep.	Review purchases, choice of suppliers	Needs to **follow up that purchases are economically sound** in order to **make sure that the project falls within budget.**	Strong: budget		Responsible for budget	

Commercial/ customer dep.	Conducts market surveys, societal trends, future needs. Guide ship interior design.	Needs to **describe passenger needs** in order to **maximize profitability (passenger spendings)**	Partial	Trends and passenger data	Strong communication skills, passenger focus	
Crew	Will run the ship and is end users of fire safety systems. Design input - experience and opinions.	Needs **a workable, efficient and comfortable workplace** in order to **stay safe**	Weak: may have little representation in project team, may enter late in the process (after delivery)	Operational knowledge about shipboard activities and technologies	Product manuals, procedures	One purpose of the design guidance is to benefit the crew.
Shipyard	Builds and commissions the ship. Issues the building specification.	Needs **usable and reasonable *requirements*** in order to **fulfil the requirements.**	Strong: influence over project expenditures, design, selection of design/equipment	Technical competence, class negotiation		That the requirements that are set are usable - that they understand what is meant (and why)
Equipment supplier	Supplies shipboard systems or equipment	Needs **usable and reasonable *requirements*** in order to **deliver systems according to specifications**	Weak/medium: supplies product according to shipyard/suggests product based on budget	Specialist technical competence		
Classification society	Controls ship design and construction, issues classification	Needs to **know what is installed and how** in order to **verify that class rules and regulations are fulfilled.**	Negotiate with shipyard over interpretation of class rules. Classification society interpretations may also be used in internal budget negotiations.	Technical and operational knowledge.	Regulations, class guidelines and notations.	

10.2 ANNEX B – Guidelines for crew-centered fire safety design

This appendix contains the developed guidelines. For best reading experience and the most recent version, please download the pdf from: http://ri.diva-portal.org/smash/record.jsf?pid=diva2:1751612. The related working file can also be downloaded from here.

LASH FIRE GUIDELINES

Guidelines for crew-centered fire safety design

DEVELOPED FOR SHIP OPERATORS

Version 01 - 2023

LASH FIRE GUIDELINES - Guidelines for crew-centered fire safety design

Staffan Bram and Julia Burgén, RISE Research Institutes of Sweden, 2023

Introduction

Paying respect to the crew's practical needs during fire safety design will translate into effective action when a fire occurs. This guide is intended to help the shipping company fulfil that goal in a ship newbuild project.

Representing crew needs in fire safety design

Managing an onboard fire is a time sensitive process where smooth action and collaboration amongst the crew is key to good outcomes. These actions and interactions, however, are heavily influenced by ship design. Information that is difficult to collect, systems that create confusion and disturbances in the bridge environment are all factors that may lead to delays, and ultimately, to an aggravated fire scenario.

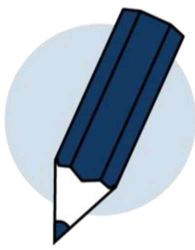
Fire safety design is often treated as a purely technical issue, with a focus on technical performance and rule compliance. But when a fire occurs, gaining control requires correct and timely actions from the crew. Providing the crew with the right tools for this job – purposefully designing onboard environments, systems and tools according to their needs – is an underused and powerful approach to fire safety. This guide sets out from an activity-centered perspective, that is, a strong emphasis on what the crew needs *to do* in the event of fire, and how those actions can be supported. The purpose of this guide is to show how such an approach can be applied in the early phases of a ship newbuild project.

INVESTIGATE

For the environment at hand, investigate crew activities in a fire scenario. Describe general goals and tasks for those activities.

DEFINE

Identify hazards associated with the tasks. Compare tasks, the related hazards and design principles and define design requirements. How can the crew be helped to accomplish the goals through the design of layouts, systems, resources and tools for collaboration.

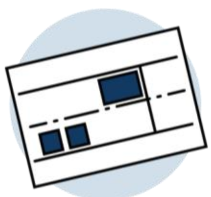


COMMUNICATE

Communicate with project stakeholders:
Internally, to advance crew interests in the project;
Externally, communicating design requirements to the design firm or suppliers.

REVIEW

Review design drafts or supplier products and the materials produced in the process.



Who is this guide for?

The intended user of this guide is a member of the newbuild design team within a shipping company, responsible for fire safety issues. In a situation where no such representation exists, the guidance could also be used by a crew member (such as a designated fire chief) to create materials for communication with their land organization.

What does the guide contain?

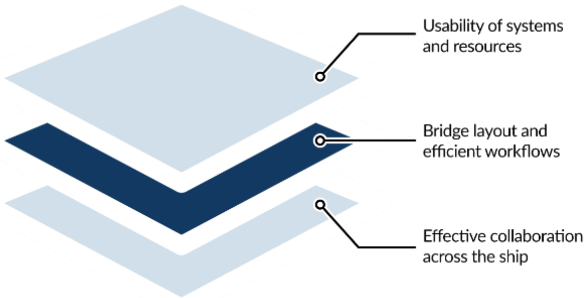
The guidance in this document covers the early phases of a newbuild project, where crew needs can still be taken care of in a cost-effective manner. Guidance is exemplified through a case of bridge design for fire safety - the bridge working stations and installations used to detect, monitor and coordinate the response to a fire scenario (the Safety Center).

When using the guide, you will be taken through a process of **four steps** - investigating crew tasks, transforming that information into design requirements, communicating with design process stakeholders, and reviewing design and equipment proposals. An outline of these steps is also presented on the previous page.

The guide includes an Excel worksheet where you keep track of your progress. Besides working as a suggestion of how to structure your design requirements, it also contains information that can be used a starting point for specifying bridge fire safety systems.

Examples of applying the guide

The examples provided for the different steps of the process build on a real case study on bridge design. This case was developed together with a Swedish shipping company during a newbuild project, and even though the outcomes from that case may not be relevant in other newbuild contexts, they may still serve as an inspiration.



Layers in fire safety design

When investigating the design of an environment where the crew will be active during a fire incident, it is good to think in terms of layers, going from low-level to high-level design issues. Throughout this guide, three general layers will be used to structure activities and outputs from the process:

1. **Systems and resources** should be effective and easy to use, both when used in isolation and in combination with each other.
2. **Layouts** should support common workflows and interaction between members of the crew.
3. **Collaboration** should be supported between the designed environment and groups in other locations on board.

The purpose of using this layered approach is to encourage discussions around fire safety design that go beyond individual systems and detailed design issues (such as graphical design). Effective fire management depends on close collaboration between many crewmembers, fulfilling many different functions. Supporting that collaboration is just as important as providing systems and resources that are easy to use.

Environment	Goal	Task	System	Hazard	Requirement	Comment

Contents

Keeping track of information

When working with design requirements you will be producing a lot of information that needs to be managed in a structured way. If you already have a way of managing requirements, we recommend that you stick to that structure. In this guide we propose a simple Microsoft Excel sheet for keeping track of information associated with tasks and requirements. The table has the following columns:

a) **Environment** (such as bridge or ECR), to allow filtering of requirements per environment

b) **Goal** represents what should be achieved with an activity, and is primarily used to help with mapping out work tasks

c) **Task** descriptions help to make sure that design proposals match what the crew actually needs to do in a fire scenario

d) **System**, to allow filtering of requirements per individual systems

e) **Hazard** is included as a tool for communication, and to give the designer more context for the requirement

f) **Requirement** is the design requirement communicated to the design firm or suppliers

g) **Comment** is the place for any additional information that may be relevant

The purpose of this structure is to present the requirements so that a design firm, shipyard or supplier also understands the reasons for requirements. Another purpose is to provide grounds for the review of design drafts and suggested products.

EXAMPLE – DESIGN REQUIREMENT DATABASE

Environment	Goal	Task	System	Hazard	Requirement	Comment
Bridge	Detect	Perceive alarm	Fire alarm system	Alarm missed	Alarm signal is clearly audible.	
Bridge	Detect	Interpret alarm message	Fire alarm system	Alarm misunderstood: location, faulty/real	Alarm message conveys location of detector in a way that is recognizable to crewmembers. Message includes drencher zone, heat/smoke level.	
Bridge	Assess	Assess heat spread	Fire alarm system	A rise in heat / spread of fire is missed	Clear presentation of changed detector state, e.g. additional detections, rise/decline in temperature.	
Bridge	Assess	Assess smoke spread	Fire alarm system	Smoke density and/or spread is underestimated, smoke spread is mistaken for fire spread	Clear presentation of changed detector state, e.g. additional detections, rise/decline in smoke concentration. Ability to review smoke concentration in relation to heat measurements.	
Bridge	Assess	Control for dangerous goods	DG information	DG information is missed or insufficient	Information on Dangerous Goods must be kept in a way that is easy to access and understand in a crisis situation.	

Investigate crew activities

Fire management builds on cooperation amongst the crew and involves the use of many different technologies. To maximize performance, this system of people and technologies must be designed for smooth interaction. The starting point of the design process is to map out the goals and tasks associated with fire management.

By investigating what crewmembers actually *need to do* when managing a fire, we can specify requirements that ensure that systems and environments fulfil their purposes. Onboard working environments, systems and resources should be designed to support the crew, and the first step in the development of design requirements is to create a truthful picture of their work.

This chapter presents a workflow for determining the goals and tasks associated with on-board fire management in a specific environment. Descriptions of goals and tasks may fulfil several purposes in the newbuild process. For example, while design requirements can become quite detailed, you should return to these work descriptions when design drafts are reviewed, to see whether a proposed design allows the crew to perform their activities successfully.

When crew activities are investigated, information can come from many different sources, such as crewmember interviews, system walkthroughs, workshops and drill debriefings. At the end of this chapter, a few such methods are described.

EXAMPLE – POSSIBLE CONSEQUENCES OF A PURELY TECHNICAL FOCUS

Even though a fire safety system is approved and has the right technical capacity, there is still no guarantee that it will be put to effective use in a fire incident. For example, consider the 2014 fire on the Norman Atlantic. When this passenger ferry was sailing in the Adriatic sea, a fire broke out in the roro space on deck 4. The crew was alerted to this fact by a fire alarm received at the bridge. However, because of the confusing placement and labelling of valves in the drencher operating room, the drencher system was activated on the wrong deck. This demonstrates that if the practical activities surrounding drencher activation are not considered during design, the performance of those activities may be undermined.

Map out goals and tasks

The starting point of the process is to develop a realistic image of the fire management activities performed by the crew in a certain environment. This chapter exemplifies how core *goals* in bridge activities, often performed by the fire chief, can be broken down into *tasks*. For any other environment, some goals and tasks may be similar, while others will need to be added or removed.

Goal: a desired result of fire management activities

Task: something that the crew needs to do in order to accomplish the goal

When

Mapping out goals and tasks is the starting point of crew-centered activities in a newbuild project, but this type of work could also be done proactively, well before a new project has started. Once the mapping is done, the materials can provide a head start when a newbuild project begins. Making the details of work visible like this may also serve other purposes, for example, to discover improvement possibilities on an existing ship, to structure training, or to review work procedures.

How

For the present case, five basic goals are considered:

- **Detection** of the fire
- **Confirmation** of the fire and its location
- **Assessment** of the fire's intensity and spread
- **Coordination** amongst the crew, both on and off the bridge
- **Extinguishment** of the fire using fixed systems and manual interventions

The purpose of starting with a small number of goals is simply to make task identification more manageable. These goals were chosen because to a large extent, they represent the most common phases of fire management.

When the core goals have been decided, the next step is to review each goal and think of underlying *tasks*. A task is simply anything that the crew needs to do in the studied environment in order to accomplish the goal. Some tasks are concrete (like manual work tasks) and other may be more abstract (like assessment or information sharing). In the box below, a few examples of tasks are given for the goals *Detection* and *Assessment*.

Tips & tricks

Make sure that the persons involved in goal and task identification have relevant experience of operational work. Even if you are a senior officer with a long work experience, it is easy to forget the details of everyday activities when you do not perform them regularly. It is good practice to involve currently operational personnel in the analysis.

EXAMPLE – TASKS RELEVANT FOR FIRE DETECTION

Goal	*Tasks*
Detection	- Perceive the alarm
	- Interpret the alarm message
Assessment	- Assess heat spread
	- Assess smoke spread
	- Control for dangerous goods
	- Assess external factors (e.g. weather, other traffic, external aid)

Fill out the worksheet:

Goals and tasks can be added to column B and C in the worksheet. You can already start tagging systems (in column D) or add comments (in column G) that you think may be useful later on.

Interviewing users

Conducting interviews is one way of identifying crew needs. Being able to quote crew experiences can be a powerful way of communicating the importance of design requirements.

When

A good time to use interviews is when you need concrete examples from operations about positive and negative experiences of fire safety installations. Such experiences can provide shortcuts when defining requirements.

How

Interviews can be performed either locally or remotely. In cases where on-line interviews is the only option, video streaming can be used for task or equipment demonstrations. If the interview is centered around fire safety systems, however, it is advisable to carry out the interview onboard, making it easier to review and discuss existing installations.

Preparations for interviews include:

a) Deciding the goal with the interview.

b) Preparing an interview guide. This could include specific questions, but also only discussion topics. See the next page for an example. Include your interview goal and a couple of neutral probes.

c) Planning for how to collect the data. The benefit of recording an interview is that you can re-listen if you are uncertain of what was really said, but transcribing an interview can also be very time-consuming. A good option is to make notes during the interview and record as a back-up.

d) Informing interviewees on what their participation means, for example how the collected data will be used, and whether their participation is anonymous.

After the interview there are many ways of processing the data. One suggestion is to go through your notes and sort findings under activity goals (see the previous chapter). It is likely that you see some requirements forming already. If you use the worksheet, you can start trying to enter these requirements, or just add them as comments for now and return to them in the next step.

Tips & tricks

The purpose of your interview is not necessarily to review a specific system, so if interviewee talks about something they like or dislike, follow up with questions on *why that is*. For instance, say that you hear that systems with physical buttons are much better than those with on-screen buttons. Follow-up questions can then show that the person thinks so because the on-screen buttons in the currently installed system are hidden behind a menu and therefore inaccessible. In this example, the user need could be that buttons for specific actions must always be visible, but not necessarily physical buttons.

When interviewing, it is important to give participants enough time to gather their thoughts. Do not move on to the next topic too quickly. If you stay silent, the person will likely continue talking about the subject.

OTHER WAYS TO ENGAGE WITH USERS

There are many other methods that can be used to collect data and insights from the crew. Some example are:

- **System walkthrough:** Let a user demonstrate and explain existing systems for you. Pay attention to crew-made notes or instructions attached to systems – these can be an indicator of shortcomings in systems or interfaces.
- **Fire drill debriefing:** arrange a systems-oriented fire drill debriefing. Inform crewmembers before the drill that you will spend some time after to discuss fire-related systems and ask them to pay attention to pains and frustrations related to systems during the drill.
- **Collaborative mapping session:** Crewmembers can be invited to carry out the methods suggested in this guide, such as mapping or creating requirements.

Example – interview guide

This is an example showing how an interview guide can be structured. The example is created for an imagined interview with a fire chief.

In this example we have chosen to focus on topics and question formats that suite a free-flowing and flexible interview. You can also construct specific questions beforehand if you prefer that. No matter what you prefer – do not forget to ask follow-up questions!

Interview goal

What are important factors to consider when selecting fire alarm panel?

Introduction

- Welcome
- Purpose of interview: To learn about your experiences of fire panels and ideas for improvement
- Conditions (anonymity, handling of data etc.)
- Warm-up questions (if needed, e.g. role, years on the ship, previous workplaces)

Alarm system walkthrough

- Receiving alarm(s)
- Alarm interpretation
- Assessing intensity and spread
- Silencing alarms
- Relaying information to others

Success factors and frustrations

- What works well?
- What things frustrate you?
- What improvements could be made?

Wrap-up

- Thank you and goodbye

Question openings

- Tell me about…
- Can you describe…
- Can you show me how you…

Follow-up questions

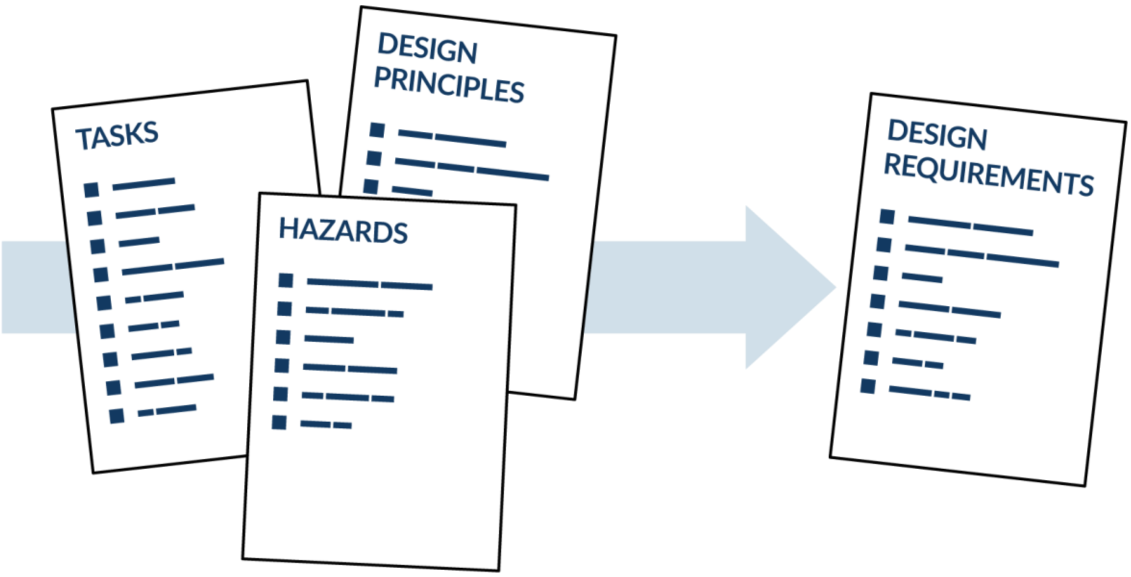
- Do you have an example?
- Why is that?
- Could you explain further?
- Did this procedure/system ever fail?
- What would be the consequences if..?

Define requirements

When you define design requirements, you investigate the connection between practical work tasks and the environments, systems and tools that should support them. These requirements will be used for communication with the design firm and suppliers.

After the previous step of investigating operational goals and tasks, you now have a good foundation for defining design requirements. But stating requirements can sometimes be difficult. To that end, the guide provides two approaches. First, you will think of *hazards* that may appear due to poorly designed or implemented systems – considering what the design of environments, systems and other resources should safeguard against. Second, the guide provides a set of *design principles* that can help you see how different properties of the working environment can be made to support task performance. These principles reflect the same layered approach as the previous steps, going from the detailed properties of individual interfaces, to requirements for layout and integration, and on to requirements for interaction between bridge personnel and other work groups. You will feed the results of this process into the worksheet, and the materials can later be used for internal and external communication.

A natural starting point when discussing newbuilds or design improvements is often negative operational experiences from past or present workplaces. This kind of input can be of great value for the continued process, so when they appear, make sure to note them in the worksheet, even if you are not yet ready to process them.



Hazards

Discussing hazards related to the tasks involved in fire management has several purposes. Firstly, it may be a good way of bringing operational experience into the formation of design requirements. Talking about potential pitfalls in fire management activities, and the causes behind those pitfalls, can make it easier to see how work is affected by the design of environments, systems and equipment. Secondly, the fact that hazards exist but can be mitigated through crew-centered design may also be a strong argument in internal newbuild project discussions, and support operations as they communicate their demands. Thirdly, information about potential hazards provides the designer with more context for a particular requirement.

The hazards we are focusing on here are those that can be mitigated with improved design solutions, but whether that is the case may not always be obvious. It is better to make note of as many conceivable hazards as possible and remove irrelevant ones later, when you set the requirements.

How

When documenting hazards in the worksheet, only the hazard itself will be noted, but for use in project argumentation, it may be warranted to dig a bit deeper. Below is an example of how a hazard related to fire detection can be explored.

Task: Interpret the alarm message

Hazard: Location of detection is misunderstood

Causes: Information in the alarm message is difficult to interpret

Consequences: Response to the fire is delayed

Requirements

When setting the design requirements, you will make use of the materials you have developed in the previous steps. Requirements should be firmly rooted in the goals and tasks related to the working environment and they should counter potential hazards, but they should also live up to good practice for systems usability, layouts and crew collaboration. For the latter purpose, this guide provides a set of design principles that have been developed based on research experience and general usability principles. You will find these principles on the next page.

How

When discussing requirements for a specific task, the following series of questions can be one way of uncovering relevant information:

- *What environments, systems, tools or other resources are associated with the task?*
- *What characterizes good performance of the task and how can such performance be supported?*
- *What are hazards are associated with the task and how may those hazards be prevented?*
- *Can any of the design principles be applied to promote good performance, or to prevent hazards?*

Requirements need to be concrete enough so that the design firm can match them with solutions, and so that the shipping company design team can use them for design review. At the same time, they should not be over-specific. Very detailed requirements (for example, based on individual experience and preferences) may overshadow innovative design solutions that could have provided better answers to operational needs.

Fill out the worksheet:

Hazards and requirements are added to columns E and F in the worksheet.

Design principles

This set of design principles can help you see how properties of the working environment relate to task performance. The principles are based on insights from fire management studies on ropax ships. It is likely that different principles will be relevant at different stages of design development.

You will also find the design principles in a separate sheet in the worksheet, so that you can edit the list according to your needs.

Usability

- Text-based information is clear and informative
- Graphics replace text where appropriate
- Graphics (e.g. GA) contain only relevant information
- Safety systems are easy to read and control
- A consistent naming practice is applied in all systems and documents
- Clutter (e.g. paper handling) is minimized
- It should be possible to assess the source and validity of information, especially information that has been aggregated from different sources

Layout & integration

- There is room for parallel activities
- Disturbances between work groups are minimized
- The placement and layout of workstations enables collaboration between work groups (e.g. evacuation and OOW)
- Panels and controls are placed in a way that promotes an efficient workflow
- Resources that must be used together are placed together – consider integrating information and controls for different systems where it benefits efficiency and effectiveness
- It is possible to quickly get an overview of all system statuses

Collaboration

- Information sharing with other parties (e.g. ECR and fire groups) is supported
- Systems provide information that is easy to communicate to others
- Events and developments in other working groups are easy to monitor
- Work delegation is supported, e.g. to relieve the fire chief

Communicate with stakeholders

Getting design requirements across to other project parties is vital to ensure that crew-centered design goals are met. This communication must be clear and relevant for the receiver.

Design requirements will need to be communicated to different stakeholders, both internal to the shipping company and externally, primarily to the design firm. Different stakeholders – and different goals of communication – will require different approaches. In one forum, the objective may be to gain understanding and acceptance for crew needs. In another, the objective may be to supply enough information to guide design decisions.

The main emphasis of this chapter is on how to champion crew requirements internally, within the shipping company. Because ship design may involve trade-offs between competing needs and cost minimization is often sought, it is important to be able to frame crew needs in a way that communicates well to stakeholders without operational experience. Doing so requires that the communicator presents a compelling narrative, describing the realities of performing an activity, how the performance of that activity may affect fire safety outcomes, and potential hazards connected to design solutions.

EXAMPLE – COMMUNICATING CREW REQUIREMENTS INTERNALLY

DESIGN TOPIC - Supporting response coordination on the bridge

GOAL:

Communication - Clear and undisturbed communication must be possible with personnel both on and off the bridge.

WHY?

A noisy bridge environment makes it difficult to communicate

DESIGN CONSIDERATIONS:

Layout: Disturbances between work groups must be minimized

Layout: The placement and layout of workstations must enable collaboration between work groups (e.g. evacuation and OOW)

Usability: Sound signals from different systems must be harmonized so that co-occuring signals do not cause disturbance

Communicating internally

Getting acceptance for crew requirements may be a lot easier if they are systematically presented. This is both a matter of conveying the real working circumstances of the crew during fire management, and the consequences of not living up to their needs. The target groups for this communication will not always have knowledge about onboard fire safety, which makes it important to adapt the contents to them.

How

Different audiences may require you to focus on different types of information. When addressing safety aspect of design, it may be good to put an emphasis on hazards, but to gain acceptance for investments, direct and indirect benefits of crew-centered solutions may be equally important. In early design discussions, it may be good to focus on environments where crew needs in connection to fire safety may compete with design considerations of other stakeholders, such as those representing the passenger experience.

The materials that you have gathered in the worksheet provide many different approaches to communication. The example on the previous page shows a very condensed way of communicating a work goal, a hazard (explaining *why* it is important) and relevant design principles (expressed as design considerations). Try to think of a good narrative for your discussion, such as describing the way a certain task is carried out, and issues that may be encountered.

The example below shows how the cost-effectiveness of an integrated Digital Fire Central was assessed and confirmed in the LASH FIRE project. The argumentation behind this assessment may serve as an inspiration when costs related to different design or equipment options are discussed.

Communicating with designers & suppliers

The worksheet that you have developed is the main material used to structure communication with design firms and suppliers. We encourage you to share more than only the list of requirements per system. By including information such as tasks, hazards, and useful comments, you help your partners understand the case that they are designing for.

Remember that designers and suppliers are likely to have less experience than you when it comes to:

- The day-to-day work on a ship
- Ship fire organization
- Tasks that are carried out simultaneously or in relation to proposed designs
- Impact of onboard culture (e.g. blame-culture)

EXAMPLE – COSTS AND RISK REDUCTION

Within the LASH FIRE project, a prototype for a Digital Fire Central was developed. The prototype was implemented on a touch screen where all the information resources and system controls that might be needed for fire management were gathered into one single interface, providing a good overview and simple access to fire safety systems. The prototype was assessed for risk reduction according to the risk model developed in the project, and costs were assessed by experts in ship design and production.

Results placed the Digital Fire Central as one of the five most cost-effective solutions in terms of Net Cost of Adverting a Fatality. This means that for newbuild ropax, roro and vehicle carriers, the cost criterium of saving cargo, ship and life is far higher than the cost for purchasing, installing and maintaining such a system.

One reason for these results is that the solution belongs to a category of measures that affect the earliest phases of a fire incident, where the possibility of minimizing risks is the highest.

For more information, see the LASH FIRE Deliverable D04.6 Cost-effectiveness assessment report https://lashfire.eu/deliverables/

Review of design solutions

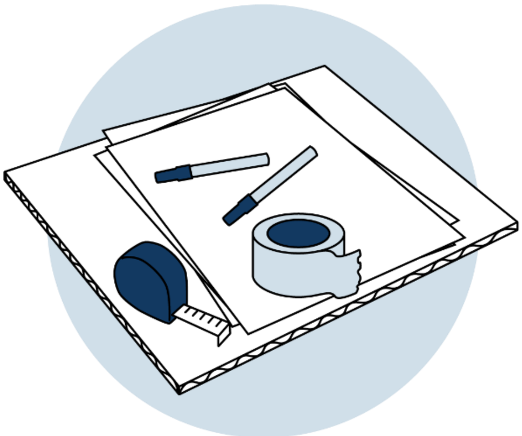
Shipping company representatives are rarely involved in actual design tasks, and therefore, reviewing design outcomes is a very important part of achieving crew-centered fire safety solutions.

Design solutions are reviewed iteratively throughout the newbuild process and as the project evolves, increasingly detailed assessments can be made. When performing these reviews, you will go back to the worksheet and your descriptions of crew tasks, hazards and requirements. But whether the review can be made successfully also depends on your review approach and whether you include people with the appropriate knowledge and background. This is an excellent opportunity to involve crewmembers with roles in the onboard safety organization.

The materials developed in the requirement worksheet can be used in several ways in design reviews. A review will often concern one specific onboard environment or system, so you can apply a filter in the requirement worksheet to bring out information relevant to the current topic. Some overarching review themes are:

- Does the design product support all of the crew tasks that are associated with it?
- Does the solution address the identified hazards?
- Does the solution live up to the relevant design principles?
- Does the solution satisfy the stated requirements?

This chapter provides guidance for two main iterations in the design process – first, reviews of ship layouts, and second, reviews of more detailed design solutions and product suggestions that appear as the project evolves.



DESIGN REVIEW
TOOLKIT

Review of layouts

When assessing layouts, it is important to make sure that the methods used allow the reviewer to gain a realistic understanding of work performance and circumstances in the envisioned environment.

There are clear limitations to review methods that only involve on-screen assessments, and even if 3D models are made available, it may still be difficult to properly assess aspects such as space requirements, room for movement, work positions or systems visibility. To complement these common approaches, you are encouraged to use methods where you experiment with the design in the real world. The box to the right gives a few examples of such methods.

- Use drawings or 3D-models to perform walkthroughs of crew tasks, simulating how the task would play out in the proposed environment. Assess if hazards, design principles and requirements can be accounted for.
- Use tape to create simple mockups of the workspace, where you can assess aspects such as distances, dimensions and line-of-sight.
- Visit an existing onboard environment and make observations (such as measures) for comparison.

Review of systems and equipment

It may often be difficult to assess and compare systems and equipment that, for example, are proposed by the shipyard, if the shipping company has no prior experience of the supplier's products. The shipyard can be expected to push for options that minimize cost and will normally not factor in values associated with practicality and ease of use.

Communicating design requirements (or simply the relevant design principles) before the tendering process may give the considered shipyards some indications of the shipping company's interests. As the process continues, you should make sure that the suppliers suggested by the shipyard can provide fair grounds for review, such as system or equipment demonstrations or references to ships where similar products have been installed, and where crewmembers can make real-life assessments.

It is important that contextual factors are not forgotten in the review, for example visibility, time of day, heavy seas or greasy hands. Experienced crewmembers are often good at coming up with varying conditions like these. Perhaps it is even possible to include in contracts that experienced (possibly handpicked) crewmembers should approve specific safety-critical systems.

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10.3 ANNEX C – Requirements worksheet

The table below is a filled-in example of the requirements worksheet used throughout the design guide. For the editable file and the most recent version, please download the excel file from: http://ri.diva-portal.org/smash/record.jsf?pid=diva2:1751612.

DESIGN GUIDANCE - REQUIREMENTS WORK SHEET						
ENVIRONMENT	**GOAL**	**TASK**	**SYSTEMS**	**HAZARDS**	**REQUIREMENTS**	**COMMENTS**
Bridge	Detect	Perceive alarm	Fire alarm system	Alarm missed	Alarm signal is clearly audible	
Bridge	Detect	Interpret alarm message	Fire alarm system	Alarm misunderstood: location, faulty/real	Alarm message conveys location of detector in a way that is recognizable to crewmembers Message includes drencher zone, heat/smoke level	Outside-systems resources such as documents should not be necessary to use in order to determine locations
Bridge	Assess	Control for dangerous goods	DG manifest	DG information is missed or insufficient	Provide information on Dangerous Goods in a way that is easy to access and understand in a crisis situation.	
Bridge	Assess	Integrate fire information	Bridge layout	Information is spread out across the bridge - interpretation is delayed, information requires double-checking	Quick and easy access to fire safety resources on the bridge (fire alarms, GA, DG, dampers, fire doors...) Ability to overview all relevant parameters from a single location.	
Bridge	Assess	Assess smoke spread	Fire alarm system	Smoke density and/or spread is underestimated, smoke spread is mistaken for fire spread	Clear presentation of changed detector state, e.g. additional detections, rise/decline in smoke concentration. Ability to review smoke concentration in relation to heat measurements.	Consider visual representations of heat and smoke

DESIGN GUIDANCE - REQUIREMENTS WORK SHEET

ENVIRONMENT	GOAL	TASK	SYSTEMS	HAZARDS	REQUIREMENTS	COMMENTS
Bridge	Assess	Assess heat spread	Fire alarm system	A rise of heat / spread of fire is missed	Clear presentation of changed detector state, e.g. additional detections, rise/decline in heat.	
Bridge	Assess	Assess external factors (operational state, weather conditions, seas, surrounding traffic, external aid)	External monitoring systems	Smoke drifts towards crew/pax, reduced visibility on deck	Ability to review external conditions data in relation to fire alarm system information.	
Bridge	Communicate	Sound internal fire alarm	Fire alarm controls	Fire alarm not activated	Visible feedback that fire alarm is activated	Audible fire alarm feedback is likely the alarm sounds from outside the bridge
Bridge	Communicate	Muster personnel	Muster list Radio	Delay, mustering takes a long time (e.g. long reaction time, night-time)	Keeping track of mustered personnel	Radio communication is likely sufficient
Bridge	Communicate	Provide information to fire group(s)	Fire plan Fire group data	Risk of personal injury and delays (e.g. due to wrong entry point), lack of oxygen tube supply, group unaware of DG	Close access to fire safety plan. Support for keeping track of fire group data (e.g. timing for smokedivers) or positioning.	Consider drag-and-drop or markup features on the fire plan to make notes of fire team locations
Bridge	Communicate	Receive feedback on firefighting outcomes	Fire group data Radio	Poor decision base for FF strategy	VHF/UHF with sufficient coverage in all locations.	
Bridge	Communicate	Communicate on bridge	Bridge layout	Noisy bridge environment, difficult to communicate	Placement of work stations allow for sufficient focus and efficient communication.	

DESIGN GUIDANCE - REQUIREMENTS WORK SHEET

ENVIRONMENT	GOAL	TASK	SYSTEMS	HAZARDS	REQUIREMENTS	COMMENTS
Bridge	Communicate	Communicate on bridge	All systems with audible alarm signals	Noisy bridge environment, difficult to communicate	All alarm signals relevant for an emergency scenario are harmonized and their combined noise is assessed.	
Bridge	Communicate	Issue PA announcements	Bridge layout	Noisy bridge environment, difficult to communicate	Placing of PA system to counter disturbance	
Bridge	Confirm	Consult CCTV	CCTV display	Insufficient coverage or quality of CCTV picture False sense of security if no smoke is visible	Possibility to review fire alarms and CCTV from same location.	
Bridge	Confirm	Communicate location	Fire alarm system Ship signage & markings	Runner goes to wrong location	Location description in alarm message matches namings and markings of on-board environments	
Bridge	Respond	Control fire doors	Fire door panel	Fire door malfunction missed (e.g. blocked door)	Panel placed in close conjunction to other fire safety systems. Panel conveys door status without risk of confusion.	E.g. color coding may not be interpreted in the same way by all.
Bridge	Respond	Control fire dampers	Fire damper panel	Automatic damper malfunction or closure of manual fire dampers is missed	Panel placed in close conjunction to other fire safety systems. Panel conveys damper operational state without risk of confusion.	

DESIGN GUIDANCE - REQUIREMENTS WORK SHEET

ENVIRONMENT	GOAL	TASK	SYSTEMS	HAZARDS	REQUIREMENTS	COMMENTS
Bridge	Respond	Control ventilation	Ventilation panel	The fire is supplied with oxygen Visibility for the fire group is limited	Access to ventilation controls close to other fire safety systems. Controls are intuitive and easy to use.	
Bridge	Respond	Determine drencher zone(s)	Drencher panel	Drencher activated in wrong zone(s)	Drencher zone(s) corresponding to incoming fire alarms should be easy to determine.	Consider integration into a graphical interface.
Bridge	Respond	Start pumps	Drencher panel	Pumps in manual mode, no water on deck	Pump status & controls available near other fire safety systems and clearly indicated.	
Bridge	Respond	Activate drencher	Drencher panel	Missed activation, worng section, feedback reqiured	N/A	Covered by task "Determine drencher zone(s)"
Bridge	Respond	Assess stability	Stability system	List due to water/debree buildup	Stability monitoring & controls avaliable close to fire safety systems.	