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Vessel TRIAGE: A method for assessing and communicating the safety status of vessels in maritime distress situations



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ABSTRACT

Efficient response to maritime incidents and accidents requires good communication processes and situation awareness by all involved parties, in particular between the Search and Rescue (SAR) response operators and the crew of the distressed vessel. In this paper, a method is proposed for enhancing the communication between the involved parties, by focusing on the safety status of the vessel. Borrowing ideas from well-established working methods in especially emergency medicine, the Vessel TRIAGE method has been established through a broad stakeholder consultation process. Its intended application is to assess and communicate whether a vessel can provide a safe environment for the people onboard. Using a set of threat factors and a four-level ship safety categorization, the method aims to establish a shared understanding of the nature of the distress situation, which in turn has implications for the operational focus of the SAR operators and vessel crew. An evaluation of the proposed method indicates a positive reception among various maritime stakeholders, suggesting that implementing the Vessel TRIAGE method in maritime SAR procedures may act as a useful tool to assist in the management of maritime distress situations.

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1. Introduction

Maritime accidents are rare occurrences with the potential to result in significant human casualty. Various studies have addressed maritime accidents, presenting statistical analyses in certain maritime areas (Aydogdu, 2014; Kujala et al., 2009; Kum and Sahin, 2015; Qu et al., 2012; Valdez Banda et al., 2015) or of specific vessel types (Mullai and Paulsson, 2011; Papanikolaou et al., 2014; Sonninen and Goerlandt, 2015; Wang et al., 2005; Yip et al., 2015). Research by Weng and Yang (2015) indicates that fatalities are highest for collisions, fires/explosions, contacts, groundings and sinking accidents, with contextual factors such as weather conditions and the sea area where the accident occurs also significantly affecting the fatality rates.

Apart from highlighting the need for research on and operational improvements for preventing accidents, these studies

support the need for efficient response to maritime incidents and accidents. Maritime Search and Rescue (SAR) services exist to assist people in distress or danger at sea, and involves activities such as assisting ships and vessels in difficulty, accident prevention, search and rescue, medical consultations and patient transport. Maritime SAR has a legal basis in multi-lateral conventions and documents, notably the International Convention on Maritime Search and Rescue (as amended) (UN, 1979), the International Convention for the Safety of Life at Sea (SOLAS, as amended) (IMO, 1974) and the International Aeronautical and Maritime Search and Rescue Manual (IAMSAR, as amended) (ICAO and IMO, 2013). In addition, national authorities implement bi-lateral agreements and national acts and decrees.

Some research on operational aspects of maritime SAR has been presented. Abi-Zeid and Frost (2005) developed a decision support system for optimal planning of rescue operations. Breivik and Allen (2008) developed an operational SAR support model, which accounts for uncertainties in drift trajectories through ensemble techniques. Baldauf et al. (2011) proposed a concept for

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e-Navigation and situation-dependent manoeuvring assistance to enhance maritime emergency response. Steigenberger et al. (2015) presented results of an international study on decision making in maritime SAR according to situation's complexity and other influencing factors.

One area where improvements are considered necessary by especially SAR operators is the communication and information exchange between vessel crew, SAR operators and other relevant parties in maritime distress situations. Several maritime accidents tragically demonstrate that an accurate assessment of the situation as well as timely and right decisions both aboard the emergency vessel and by the Search and Rescue (SAR) authorities are of paramount importance when attempting to save the people aboard and for ensuring the safety of the vessel itself. Accidents where inadequate information and communication about the vessel's condition have been identified as factors needing improvement are for instance the flooding and foundering of the Abigail H (MAIB, 2009), the grounding and capsizing of the Costa Concordia (MIT, 2013) and the grounding and flooding of the Commodore Clipper (MAIB, 2015). The importance of shared situational awareness and the quality of information in emergency situations is also stressed by Luukkala and Verrantaus (2014) and Seppänen and Verrantaus (2015), who highlight the importance of narratives in information sharing.

According to the expert knowledge from SAR operators, there are currently no methods or classification systems available for assessing the level of safety aboard a vessel in distress. The emergency phase classification, based on the SAR Convention (IAMSAR Vol.II, Section 3.3.1), describes the urgency of response and the reliability of the information by dividing emergencies in uncertainty, alert and distress phases, but does not convey the status of the ship itself. E.g. a man-over-board situation and an out-of-control fire on board a vessel would both be classified as distress phases, although they are entirely different in terms of how safe people are aboard the vessel and what kind of response is required from maritime emergency responders. Another existing development is the Local Incident Coordinator tool, which is a method used to transfer knowledge, know-how and resources to the vessel in distress (Lübcke, 2015). While this method has its merits, one important drawback is that it requires skilled SAR personnel on the scene to use it. For specific accident types such as flooding, a Damage Control Plan and a Damage Control Booklet is onboard a vessel as required in SOLAS (IMO, 1974), Chapter II.1 Reg. 23, and may assist in defining the vessel condition. Some prototype computations-based decision support systems exist for flooding accidents (Jasionowski, 2010), but these are not yet widely used in the industry.

However, there is a lack of an easy-to-use and generic method to assess and communicate the safety status of vessels in distress situations, which covers combinations of accidental scenarios and which can be linked with operational response categories of the SAR providers. A simple but informative way to communicate this would also benefit communication between e.g. vessel crew, the shipping company, salvage companies and classification societies.

In response to this, the purpose of this paper is to present the Vessel TRIAGE method. This novel method facilitates operative decision making by offering a simple tool to assess and communicate the safety status of vessels in maritime distress situations. The basic rationale is to categorize a given vessel in one of four safety levels, which correspond to a specific operational focus for ship crew and SAR responders. The idea of a categorization of safety levels for vessels is adopted from the emergency medicine application area, where triage systems are widely applied to quickly categorize patients in different severity categories (Culley et al., 2014; Scrofine and Fitzsimons, 2014). Such systems have also been applied to categorizing patients in maritime disasters (Ryu et al.,

2010). The proposed method differs from these systems by focusing on the safety status of the vessel, i.e. on whether a vessel can provide a safe environment for the people onboard. Due to the similarities to triage systems in emergency medicine, the developed method is named "Vessel TRIAGE".

The remainder of this paper is organized as follows. Section 2 outlines the method development process. Section 3 describes the proposed method and how it is intended to be applied in practice. Section 4 shows the results of an evaluation of the method. Section 5 provides a discussion. Section 6 concludes.

2. Development process

A central feature of the development of the Vessel TRIAGE method was the cooperation between multiple stakeholders. Fig. 1 shows the types of organizations which were represented throughout the method development process.

The development process was coordinated by Finnish maritime SAR organizations and maritime authorities, which, together with shipping companies, provided the main maritime field expertise in the method development. Analytical and conceptual expertise was provided by a research institute, which was also the main contributor in the documentation of the method and its manual (Raja et al., 2015).

These core actors together defined the purpose of the method, made proposals for defining the categories of vessel safety, facilitated stakeholder workshops, analyzed and summarized information gathered from these workshops, communicated the work in progress at relevant events, finalized the proposed method, administered its evaluation and reported all steps as necessary.

In addition, a broad stakeholder network provided input and feedback at various stages of the project development, as seen in Fig. 2. These included representatives of classification societies, pilotages, volunteer/other rescue organizations, maritime industry, maritime schools, universities and research institutes. In total, about 40 organizations have contributed to the method development. Participants from one university, a maritime software company and an additional SAR Service have provided specific field, analytical and conceptual expertise, assisting the core actors in making proposals for the method's conceptual structure and content, theorizing and operationalizing its evaluation, and implementing the method in further technological developments.

While the method is developed primarily by Finnish participants, the wider international stakeholder platform provided a forum for input and reflection, with representatives of ca. 15 countries sharing expertise at various stages. The organization types and their geographical locations are summarized in Table 1. The selection of contributors was based primarily on the area where the method originated and the need to have the main relevant stakeholders included. Hence, mainly maritime SAR authorities and shipping companies in the Baltic Sea area were included, as these are the primary end users of the method. In addition, the relevant major international parties working in the field of SAR or maritime safety generally were included, in particular the International Maritime Rescue Federation, the U.S. Coast Guard and international experts on technical ship safety, namely selected class societies. This was considered important given the ultimate aim to take the method to the relevant international authorities for considering it for possible incorporation in the IAMSAR Manual. Finally, as the method would benefit other areas in the world it was decided that participation in the development should not be limited in any way, as long as organizations were willing and able to commit resources, and agreed to the working process and the time schedule. The international participation from SAR authorities, universities, research institutes and maritime schools was

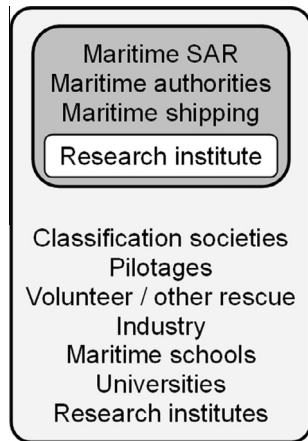


Fig. 1. Core contributors (dark gray) and broader stakeholder network (light gray) in Vessel TRIAGE development.

established through informal contacts, with an overall criterion for expertise (either theoretical or practical) in maritime risk and safety management.

The method's development process is illustrated in Fig. 2, where an indication is given of the time schedule adhered to in the development. Four phases are distinguished, which are outlined next.

Phase I. The core contributors outlined the purpose of the method, and draft the definition of the Vessel TRIAGE categories and the operational focus corresponding to each level. These are presented in Section 3.2. Relevant partners were contacted and a broad stakeholder network was established. Preparations were made for kick-off seminar and workshop.

Phase II. A kick-off seminar and workshop was organized. Representatives of several stakeholders provided perspectives on the needs for improvement on emergency communication in maritime distress situations. Furthermore, a workshop was

organized with ca. 50 participants where four working groups discussed the draft Vessel TRIAGE categories defined in Phase I. Ideas and perspectives were collected about user requirements for the method, and possible approaches for constructing the method were identified. Suggested methods included e.g. flowcharts and factor-based scoring systems. Concerning user requirements, it was stressed that the method should be as simple as possible, and that it should act as a guide which is flexible to actually occurring situations. The first requirement stems from the fact that it is intended to be used in distress situations, and should add as little as possible additional cognitive burden on the various actors. Simplicity is also beneficial as it limits the need for training, and the use of simple pen-and-pencil tools for emergency decision making has been found beneficial in various studies (Goldstein and Gigerenzer, 1999; Klein, 1995; Shanteau, 1992a). The need for flexibility of the tool stems from the experience that actually occurring situations can be very diverse in nature, depending on ship types, particular design features and so on. Thus, another user requirement was to keep the method at a high enough level of generality. This way, the method should guide an assessor to make an informed judgment rather than rigidly calculating or declaring the situation to be of a definite severity.

Phase III. After processing the results of the first workshop, the core contributors organized another workshop to elicit criteria for determining the vessel safety level. These were combined in a threat factor matrix which is used to assess the Vessel TRIAGE category, and a tool to facilitate practical application of the method was developed. The developed method was presented to and discussed with representatives of overseas stakeholder organizations in a webinar, attended by ca. 30 participants. Comments arising in this webinar and from an ensuing online survey were taken into account and the method refined. Synergies with other developments in stakeholder business areas were identified.

Phase IV. In the final phase, a publication event was organized. Here, core contributors and various stakeholders who actively participated during the previous phases presented the method and its

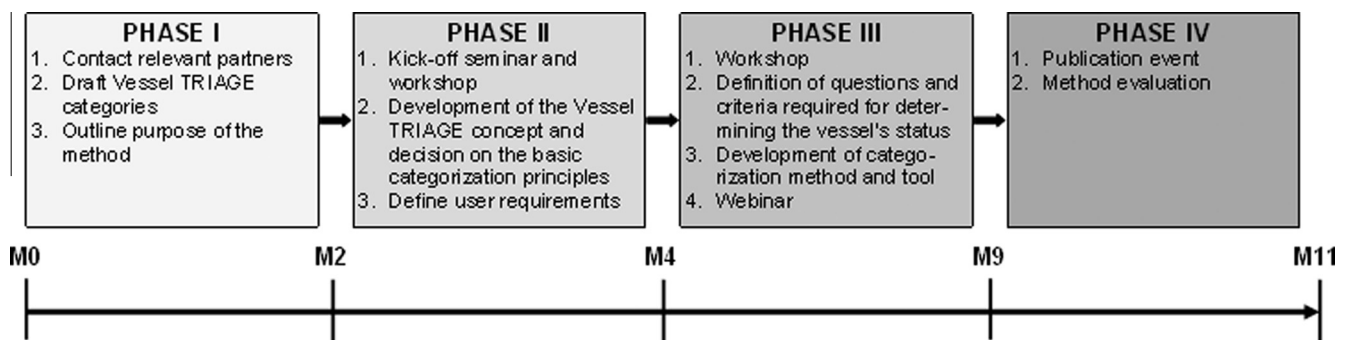


Fig. 2. Four phases of the Vessel TRIAGE method development (M: month since start of method development process).

Table 1
Contributing organizations: types and geographical location.

	ATG	CRI	DEU	DNK	EST	FIN	FRA	GBR	LVA	NOR	NZL	POL	RUS	SWE	USA	International	Total
Maritime SAR	1	1	1	1	1	1	–	–	1	–	–	1	–	1	1	2	12
Maritime authority	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	2
Shipping company	–	–	–	–	2	7	–	–	–	–	–	–	–	–	–	–	9
Classification society	–	–	–	–	–	–	1	1	–	1	–	–	–	–	–	–	3
Pilotage	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Volunteer/other rescue	–	–	–	–	–	3	–	–	–	–	1	–	–	–	–	–	4
Industry	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	2
Maritime school	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	2
University	–	–	1	–	–	1	–	–	–	–	–	–	1	–	–	–	3
Research Institute	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	3
Total	1	1	2	1	3	21	1	1	1	1	1	1	1	2	1	2	41

Note: Country abbreviations according to ISO (2015).

implications to practice. For instance, several shipping companies pledged to continue working together with SAR responders and authorities in implementing the method in their emergency response procedures. Maritime industry representatives presented technical developments which are streamlined with the Vessel TRIAGE categorization. Finally, a method evaluation questionnaire was sent out to the stakeholders to assess the degree of support for the tool.

3. Proposed Vessel TRIAGE method

3.1. Aims and scope

The intended use of the Vessel TRIAGE method is to assess the vessel's safety status, i.e. to understand to which degree the vessel can provide a safe environment for the people onboard. Hence, while the method is applied only after a maritime distress situation has occurred, it aims to prevent the situation to deteriorate by improving the communication between various actors. The users of the method are both the SAR operators in the rescue coordination centers, and the crew members onboard the vessels. The crew may use the method to facilitate communication onboard if the communication can be well managed onboard, subsequently communicating the Vessel TRIAGE category to the SAR operators. In situations where the crew is not able to take lead in the situation assessment, the method can be used by the SAR operators to guide the communication process and make a clearly defined situational assessment. The information related to the categorization level can be relayed to other stakeholders such as the company of the distressed vessel, port authorities and salvage companies.

The method is intended to be used alongside (i.e. not as a replacement of) the maritime emergency phase classification (uncertainty, alert and distress) in IAMSAR Vol.II, Section 3.3.1, which largely describes the urgency of the response and the reliability of the information on which the emergency response is based (ICAO and IMO, 2013). Also, the Vessel TRIAGE method is not intended to replace existing accident management procedures used by vessels and SAR authorities. Rather, it intends to supplement these by introducing a new dimension to accident management.

The method is primarily a tool to enhance communication and to improve situational awareness by providing color-coded categories and verbal descriptions of the vessel safety status. The method acts as a support to structure a discursive situational assessment and ensuing decision making, which is an acceptable use of non-predictive models (Hodges, 1991).

The method's scope of application is in maritime incidents and accidents such as black-outs, fires or groundings in which a certain harm has occurred to the vessel. Situations where no harm has occurred to the vessel are outside the application scope. Examples of these are mass passenger illnesses due to food poisoning and environmental damage due to non-vessel damage related oil leaks. The method may be applied in security related situations (e.g. bomb threats or ship hijackings), but only in cases where the safety status of the vessel as such is affected (e.g. if a bomb explodes or if safety critical devices onboard are manipulated). In case multiple vessels are harmed in a maritime distress situation, the Vessel TRIAGE method is used for each one separately. Full details about the proposed method, as well as an example application, can be found in the manual referred to earlier (Raja et al., 2015).

3.2. Vessel TRIAGE categories and operational focuses

The Vessel TRIAGE method provides an understanding of the vessel's safety status, which is expressed in terms of a Vessel

TRIAGE category. The category indicates the safety for persons onboard a vessel, accounting for the prevailing and anticipated conditions on the vessel and its environment. Fig. 3 shows the four categories and their definitions, along with a description of the general situation onboard. Black represents the most unsafe conditions, where the vessel no longer provides any safety for the people onboard. Green¹ represents situations in which the vessel safety is least compromised.²

Arguably, the most significant difference in the vessel's safety status is between the yellow and red categories. In the former, it is still safe for people to remain onboard the vessel. In the latter, their safety is severely threatened, either immediately or in the foreseeable future. This is stressed in their definitions: "there is a risk that the situation will get worse" (yellow) and "level of safety has significantly worsened or will worsen" (red).

Closely linked with the Vessel TRIAGE categories of Fig. 3, the method includes general descriptions of operational focuses for each category. These are shown in Fig. 4, and describe what kind of measures the vessel and maritime responders typically need to take to manage the respective situations. These operational focuses are informative in nature, and guide the type of actions to be taken once the Vessel TRIAGE category has been determined. In other words, the descriptions in Fig. 4 are not used to determine the appropriate category, but they are presented here because they show another perspective on the differences between the categories.

From this operational perspective, the green category differs from the others in that damage control measures are either not required or have been completed. In case injured people are onboard, these can be evacuated.

In the yellow category, the operational focus is on damage control measures and stabilizing the situation. Both the vessel's crew as well as external responders can participate in this. If the success of damage control measures is uncertain, evacuation must be started or preparations must be made to do so. As in the green category, evacuation of injured people may be performed even if the situation does not escalate.

The red category signifies an operational focus on evacuating/abandoning the vessel, as the vessel no longer provide sufficient safety to the people onboard. In certain cases, emergency towing to shallows could be an alternative to evacuation, or at least as a means of gaining time for actual evacuation.

In the black category, the operational focus is on rescuing people on the hull and those in the water, as the vessel no longer provides any safety or has been lost completely. In addition, when the vessel category is black, the rule is that SAR personnel is no longer sent into the vessel.

3.3. Vessel TRIAGE threat factor matrix

Based on the user requirements agreed on during the method development process (especially phase II as described in Section 2), the method is intentionally simple. From the available methodological options determined in phase II, it was decided to develop a threat factor matrix. This matrix lists possible threats to the vessel's safety, and includes flooding, listing/decrease of stability, decreased maneuverability, black-out, fire/explosion and danger posed by hazardous substances. These threats were defined based on joined expertise of the various stakeholders listed in Table 1, and have a close link with the ship main's safety functions which

¹ For interpretation of color in Figs. 3–5 and 9, the reader is referred to the web version of this article.

² Referring to the scope definition in Section 3.1, vessels under normal operating conditions which have not suffered an incident or accident should not be described using the green (or any other) category.





			
GREEN	YELLOW	RED	BLACK
Vessel is safe and can be assumed to remain so	Vessel is currently safe, but there is a risk that the situation will get worse	Level of safety has significantly worsened or will worsen and external actions are required to ensure the safety of the people aboard	Vessel is no longer safe and has been lost
GENERAL SITUATION <ul style="list-style-type: none"> - The situation aboard is stable. Although the vessel may have been damaged by the accident, this damage does not threaten its seaworthiness or the people aboard. - The damage to the vessel has been assessed. It is highly unlikely that the damage will spread or get worse. - The vessel still protects the people aboard against the prevailing conditions. 	GENERAL SITUATION <ul style="list-style-type: none"> - Damage to the vessel might affect its seaworthiness or the full extent of the damage has not as yet been determined. - Internal damage control measures and rescue operations have not been completed. Damage control is possible with reasonable resources available to carry out the proper measures. - Damage to the vessel may pose a direct or indirect threat to the people aboard. 	GENERAL SITUATION <ul style="list-style-type: none"> - The vessel is significantly damaged, affecting its seaworthiness, and there is a threat to the people aboard. - A fire, leak or other damages to the vessel are not under control and escalation is highly likely. - The vessel no longer protects the people aboard against the prevailing conditions. - Major external resources are required. 	GENERAL SITUATION <ul style="list-style-type: none"> - The vessel is capsized, broken, sunk, burnt or otherwise damaged so badly that it no longer provides protection to the people aboard against the prevailing conditions (that is, the vessel has totally lost its seaworthiness). - Even if the vessel is still completely or partly afloat, it is no longer safe to work aboard, even to save human lives.

Fig. 3. Vessel TRIAGE categories: definitions and description of general situation.

are the underlying philosophy of the ship classification rules, see e.g. (DNV, 2015).

The threat factor matrix, shown in Fig. 5, provides either three or four descriptions of different degrees of threat factor severity. For instance, black-out cannot by itself lead to the worst ship safety level (black category). In contrast, stability can be decreased to such an extent that evacuation operations are no longer possible or that the ship has capsized or sunk.

In Fig. 5, the color-coded columns correspond to the Vessel TRIAGE categories of Fig. 3. The descriptions provided in each cell are indicative of the severity level of each threat factor. That is, these are not intended to cover all possible situations which might

occur in actual maritime distress situations. This simplicity and brevity is intentional: providing more exhaustive situational descriptions would make the method more complex and hence more difficult and time-consuming to apply in practical settings.

In making a judgment about the severity level for relevant threat factors in a particular situation, the user should use all available information at the time, and use the descriptions in the threat factor matrix creatively. SAR operators can focus on a range of issues and pose questions to the ship crew to gain insight in the situation and make an informed judgment about the threat factor severity. This kind of qualitative, narrative information sharing helps to create a shared situational awareness, see Luukkala and

GREEN	YELLOW	RED	BLACK
Vessel is safe and can be assumed to remain so	Vessel is currently safe, but there is a risk that the situation will get worse	Level of safety has significantly worsened or will worsen and external actions are required to ensure the safety of the people aboard	Vessel is no longer safe and has been lost
OPERATIONAL FOCUS <ul style="list-style-type: none"> - Damage control or firefighting operations are not or are no longer required. - If there are injured people aboard, the operational focus is on emergency care. - Only patients in need of urgent care are evacuated from the vessel. - Active monitoring of the situation aboard is important. 	OPERATIONAL FOCUS <p>The operational focus is on limiting damage / damage control and preparations for possible evacuation from the vessel.</p> <ul style="list-style-type: none"> - In addition to carrying out damage control measures and rescue operations, it is important to determine the actual condition of the vessel. - At the discretion of the master of the vessel, non-essential persons can be evacuated from the vessel. - Proactive measures are taken to stabilise the situation aboard so that its condition becomes "green" or alternatively to allocate more time to evacuation and other rescue operations. - Continuous monitoring of the situation aboard is important (risk of the situation turning "red"). 	OPERATIONAL FOCUS <ul style="list-style-type: none"> - The operational focus is on evacuation of the vessel. - All non-essential persons will be evacuated from the vessel. - Patient classification may not be able to be carried out aboard the vessel. - If enough resources are available, damage control/ firefighting will be carried out to provide extra time for evacuation. - Emergency towing to shallows could be an alternative to evacuation, or a means of gaining time for actual evacuation. - Continuous monitoring of the situation aboard becomes more important (damage usually spreads progressively = significant risk of the situation turning "black"). 	OPERATIONAL FOCUS <ul style="list-style-type: none"> - The operational focus is on rescuing people on the hull as well as searching for and rescuing those in the water. - Patient classification cannot be carried out aboard the vessel. - Operations involving diving or rescue by means of hull penetration are special operations that are planned and decided on separately. - As a rule, additional personnel are not dispatched from land into the vessel.

Fig. 4. Operational focuses for each Vessel TRIAGE category.

Virrantaus (2014). Some examples of such questions are listed in Table 2.

From Table 2, it is seen that the severity of the threat factors is mainly determined by observable aspects of the situation, which is aimed to make the assessment as objective as possible. Nonetheless, the information obtained from the questions and the severity assessment are judgments. The Vessel TRIAGE method thus allows the users the flexibility to select the severity level based on the best information available. It is generally agreed among the participating stakeholders that caution is to be a guiding principle in selecting the severity of the materialized threat factor: in case of doubt, the higher severity category should be selected.

3.4. Vessel TRIAGE form and application process

With the main elements of the Vessel TRIAGE method described in Sections 3.1–3.3, these can be pulled together to describe how the method is applied in practice. As a support for practical operations, a Vessel TRIAGE form has been developed, see Fig. 6. Its use is described below, distinguishing seven steps.

1. *Basic information fields.* The recorded information includes basic facts about the incident/accident, such as the vessel name, vessel type, the number of crew members and the number of passengers. The date and time is recorded to keep track of when the Vessel TRIAGE assessment is performed.

Threats	GREEN	YELLOW	RED	BLACK
Flooding	Flooding affects a limited or contained space and has no effect on the vessel's stability and seaworthiness.	Flooding can be kept under control with pumps and watertight compartments, but the seaworthiness of the vessel is restricted.	Extensive flooding or progressive flooding to undamaged watertight compartments. Flooding cannot be kept under control and poses a direct danger on the entire vessel.	Flooding is so severe that evacuation operations are no longer possible. OR Vessel has capsized or sunk.
Listing, decrease of stability	Listing or decrease of stability does not affect the seaworthiness of the vessel.	Seaworthiness of the vessel is restricted due to a decrease of stability or a notable list.	Large heel angles. The seaworthiness of the vessel is significantly impaired, its stability is threatened and there is an imminent need to evacuate.	Stability is decreased to such an extent that evacuation operations are no longer possible. OR Vessel has capsized or sunk.
Decrease of manoeuvrability	Vessel's manoeuvrability is hampered, but the vessel can still proceed on its course.	Vessel has lost its manoeuvrability, but is still capable of emergency anchoring or drifting safely.	Vessel has lost its manoeuvrability and is not capable of emergency anchoring or drifting safely.	(Not applicable)
Black-out	Functions important for ship operations are kept running by backup systems while the fault is repaired.	Operational capability of the vessel is limited: Backup systems do not work as planned OR functions important for ship operations are kept running by backup systems, but the fault cannot be repaired at sea.	A full black-out of long duration that cannot be repaired at sea poses a direct danger on the entire vessel.	(Not applicable)
Fire, explosion	Fire has been extinguished and there is no danger of reignition AND/OR the consequences of an explosion do not affect the vessel's safety.	Fire or explosion affects only a limited area and can be brought under control with the vessel's own or external damage control/firefighting resources.	Fire cannot be kept under control OR the consequences of an explosion pose a direct danger on the entire vessel.	Conditions on board the vessel are not survivable. The consequences of the fire or explosion pose a direct danger to persons aboard. OR Vessel has been destroyed.
Danger posed by hazardous substances	Release of hazardous substances on board does not pose any danger on the vessel.	Release of hazardous substances on board poses a danger in certain sections of the vessel, but the release can be contained to these sections.	Release of hazardous substances on board poses a direct danger on the entire vessel.	(Not applicable)

Fig. 5. Vessel TRIAGE threat factor matrix.

2. *Realized threat factors fields.* For each threat factor, it is assessed whether or not it has materialized. Apart from options “yes” or “no”, an additional option “not known” is included in the form. This is to account for the fact that in some situations, it may be a time-consuming task to perform a thorough assessment of the consequences of an accident and the crew may not know whether or not the threat factor is relevant. Selecting the “not known” option allows the Vessel TRIAGE evaluation to continue, while simultaneously serving as a reminder that this threat factor should be considered at a later stage.
3. *Severity of the materialized threat factors.*
 - 3.1. The information about the situation onboard the vessels is compared with descriptions of situations of different severity presented in the threat factor matrix, shown in Fig. 5. The example questions of Table 2 can be used for this purpose.
 - 3.2. For each realized threat factor, the appropriate severity level is selected based on the obtained information. In case of doubt, the more severe option is selected.
4. *Crew capabilities and weather conditions.* Apart from threat factors related to the ship main safety functions as such, as listed in the threat factor matrix, the overall situational severity level may be negatively affected by impairment of crew capabilities (e.g. lack of expertise in emergency management, large number of crew injured due to accident) or due to adverse weather (e.g. stormy weather). These can e.g. hinder the performance of measures which would, under more favorable conditions, stabilize the vessel's safety status. These factors affect the vessel's safety on their own, and not just through the threat factors of the threat factor matrix, which is why these are assessed separately.
5. *Vessel TRIAGE category.* Based on the severity assessment of the realized threat factors, the overall Vessel TRIAGE category is determined. The basic rule in this assessment is that the overall category should be at least as severe as the most severe identified threat factor. Depending on the case, the user may select a higher severity level than the most severe identified threat factor, e.g. when crew capabilities or weather conditions worsen the vessel's safety status.
6. *Remarks.* The form reserves some space to make notes about the threat factors, crew capabilities and weather conditions. These can be some key issues obtained from the information gathering process (item 3.1).
7. *Repeat evaluation.* The Vessel TRIAGE category may (and typically does) change over time as the situation evolves and the assessment may be repeated to reassess and possibly re-categorize the vessel in one of the four categories, using a new form. As a rule of thumb, in less critical situations, the frequency of updating the assessment form can be longer than in more critical situations.

Table 2

Example questions to elicit information serving as a basis for assessing the severity level of the threat factors shown in the threat factor matrix (Fig. 5).

Threat factor	Example questions to obtain insight in the severity level of the threat factor
Flooding	<ul style="list-style-type: none"> • What is the immediate cause of flooding? • What is the extent of flooding? How many compartments are affected? • What is the location of flooding? • Can the flooding be kept under control? Are control measures still available? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Listing/decrease of stability	<ul style="list-style-type: none"> • What is the immediate cause of listing? • How large is the list? Is the list angle increasing? • To what extent does the list affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Decreased maneuverability	<ul style="list-style-type: none"> • Has the malfunction been caused by an internal or external cause? • Are the propulsion system, rudder and steering propellers of the vessel functioning normally? • Has a suitable steering method been correctly selected and is it usable? • Is the vessel using its backup steering system? If so, how does this limit operations? • Can the malfunction be repaired using the vessel's own resources? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Black-out	<ul style="list-style-type: none"> • What is the reason for the malfunction? • What is the extent of the black-out? Does it affect only certain sections/systems or the entire vessel? Are the critical systems operational? • Has the emergency generator been switched on in the network? • If the vessel is running on backup power, how long can it continue to operate? • Can the malfunction be repaired using the vessel's own resources? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Fire/explosion	<ul style="list-style-type: none"> • What is on fire? What has exploded? • Where is the fire? Where has the explosion occurred? • How extensive is the fire? How extensive are the damages? • Is the smoke toxic? Are hazardous substances involved? What amount? What is their nature? • How does the fire behave? Has it spread beyond the section where it initialized? • To what extent does the fire affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Danger posed by hazardous substances	<ul style="list-style-type: none"> • In which section of the vessel are the hazardous substances released? • Have the released substances been identified? What are they? In what form? What are their hazardous characteristics? Is there a possibility of a chain reaction? • How much of these substances are on board? Can these be removed from the vessel? • To what extent does the released substances affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?

4. Evaluation

4.1. Method evaluation process

As described in Section 2, the Vessel TRIAGE method is the result of co-operative efforts of a wide range of stakeholders. Thus, the engagement of various potential user groups and stakeholders with relevant expertise has resulted in a shared understanding of what the method should do, how it should do this and what is needed for the method to do so. The method is based primarily on the judgments of the experts participating in the method development, to ensure that a simple and practical tool with the right level of information for maritime distress situations is developed (Goldstein and Gigerenzer, 1999; Klein, 1995; Shanteau, 1992a, 1992b).

The evaluation of expert-based methods is a process in which a reasoned argument is put forward that it can be used as intended (Barlas and Carpenter, 1990; Goerlandt, 2015; Hodges and Dewar, 1992). It is a conversational process, which focuses on three main issues: the design of the method itself, the method

in relation to its use, and remaining uncertainties. This is illustrated in Fig. 7.

The first evaluation category concerns whether the method in itself is a good representation of the considered problem. This is considered through an introspective and sequential scrutiny of various features of the method, in particular content, structure, discretization, parameterization and behavior. The *content* category considers whether the method includes the relevant factors to describe the problem, while *structure* concerns whether these factors are combined in a meaningful way. The *discretization* addresses the question whether factors included in the method are split in meaningful categories, while *parameterization* concerns whether the right category is assigned for a specific case. Finally, *behavior* addresses whether the rules based on which certain categories are selected are appropriate. These generic evaluation categories have been proposed and applied in e.g. systems dynamics modeling (Forrester and Senge, 1980), operations research and simulation modeling (Eckerd et al., 2011), Bayesian Network modeling (Pitchforth and Mengersen, 2013) and risk analysis (Goerlandt, 2015).

The second evaluation category concerns whether the method is indeed useful in its intended context. This is considered by spec-



Vessel TRIAGE

Vessel name: _____ Vessel type: _____

No. of crew members: _____ No. of passengers: _____

Date and time: _____

Threat factors	Threat factor realised	Severity of threat factor	Remarks
Flooding	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Listing, decrease of stability	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Decrease of manoeuvrability	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Black-out	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Fire, explosion	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Danger posed by hazardous substances	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not known		
Are crew capabilities impaired in a way that affects the vessel's safety status negatively?	<input type="checkbox"/> Yes <input type="checkbox"/> No		
Are weather conditions affecting or will they affect the vessel's safety status negatively?	<input type="checkbox"/> Yes <input type="checkbox"/> No		
Vessel's Vessel TRIAGE category			
GREEN		Vessel is safe and can be assumed to remain so	
YELLOW		Vessel is currently safe, but there is a risk that the situation will get worse	
RED		Level of safety has significantly worsened or will worsen and external actions are required to ensure the safety of the people aboard	
BLACK		Vessel is no longer safe and has been lost	

Fig. 6. Vessel TRIAGE assessment form.

ifying one or several usability criteria, and assessing how the method scores on these. For instance, if the method aims at improving communication, it can be studied if it actually helps to this effect (Hodges and Dewar, 1992).

The third evaluation category concerns uncertainties. Where uncertainties remain about the adequacy of the method to perform as intended, such uncertainties need to be made explicit (Douglas, 2009). The first two evaluation categories can, apart from providing arguments in favor of the method, also reveal possible weaknesses of the method, and issues which would benefit from further study. Such an uncertainty assessment can be a qualitative, descriptive enumeration of issues to consider when deciding on whether to implement the system in practice.

4.2. Vessel TRIAGE evaluation questionnaire

For evaluating the Vessel TRIAGE method, a questionnaire was developed which covers the first two evaluation categories described in Section 4.1. The questionnaire was made using an online tool and sent to stakeholders. With the questionnaire, a brief outline of the method was included, describing its main features as described in Section 3. In particular, the Vessel TRIAGE categories and operational focuses (Figs. 3 and 4), the threat factor matrix (Fig. 5) and the application form (Fig. 6) were presented to the participants. Apart from the questions concerning the method, some basic information about the participants, such as country and organization of employment, age and sex were

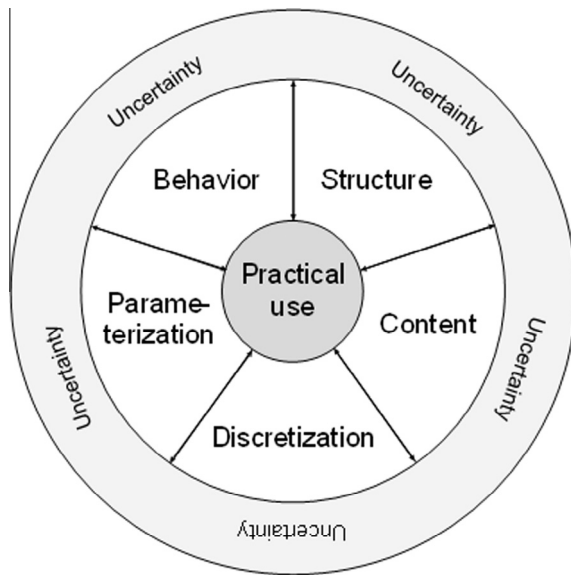


Fig. 7. Schematic overview of the elements of the evaluation process, adapted from Goerlandt (2015).

gathered. The questions are shown in Table 3, along with a classification among the different evaluation clusters.

Participants were asked to rate their level of agreement with the 22 statements on a five-level scale, ranging from “Strongly disagree” (1) over “Neither agree nor disagree” (3) to “Strongly agree” (5). An option was also given to opt out from the question by marking “No basis for judgment”. Finally, the option was given to provide free-text comments where respondents could freely comment on the method.

Comparing the questionnaire design of Table 3 with the theoretical aspects of method evaluation processes described in Section 4.1 and Fig. 7, it is seen that no questions are asked about the parameterization. Such questions would focus on the question whether, in a given situation, the correct Vessel TRIAGE category would be selected. Such questions would be difficult to ask in a questionnaire, as it would require the inclusion of a case study based on which the category would be selected. Furthermore, a cross-check of selecting “the correct category” is troublesome, because it would require participants to evaluate one another’s responses. Therefore, the parameterization is left for further study, e.g. through tests in SAR exercises, where it can be assessed whether participants agree on the selected category.

4.3. Evaluation results

The questionnaire has been responded by in total 25 participants. This is a relatively low number, which means the results should be considered as indicative of the method’s performance. Table 4 shows a breakdown of the background of the participants. It is seen that multiple stakeholders in maritime distress situations are represented, from various countries of employment. Finnish participants constitute the largest group, and the majority of respondents were male. The 51–60 years age group is the largest, with younger participants represented as well.

Fig. 8 shows the results of the evaluation questionnaire. It is seen that the response is in general very positive, with a similar response profile for all questions. Referring to Table 3, these results indicate that the structure (question 1), content (questions 2–17 and 19), discretization (questions 2–4 and 6–17), behavior (questions 18 and 19) and use criteria (questions 20–22) receive strong agreement of over half of the participants in the survey. For all

Table 3
Questions in the Vessel TRIAGE evaluation questionnaire.

#	Cluster	Vessel TRIAGE evaluation questions
1	S	The Vessel TRIAGE method on the whole is an appropriate tool to categorize the safety status of a vessel in maritime accidents and distress situations
2	C, D	The number of categories of the Vessel TRIAGE method (green, yellow, red, black) is adequate
3	C, D	The interpretation of the Vessel TRIAGE categories appropriately distinguishes situations representing a different ship safety level (Fig. 3)
4	C, D	The interpretation of the Vessel TRIAGE categories appropriately distinguishes situations representing a different operational focus (Fig. 4)
5	C	The threat factors (flooding, listing decrease of stability, decrease of maneuverability, black-out, fire explosion, danger posed by hazardous substances) are adequate to globally determine the vessel safety status
6	C, D	The categories of the threat factor “flooding” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
7	C, D	The categories of the threat factor “flooding” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
8	C, D	The categories of the threat factor “listing decrease of stability” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
9	C, D	The categories of the threat factor “listing decrease of stability” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
10	C, D	The categories of the threat factor “decrease of maneuverability” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
11	C, D	The categories of the threat factor “decrease of maneuverability” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
12	C, D	The categories of the threat factor “black-out” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
13	C, D	The categories of the threat factor “black-out” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
14	C, D	The categories of the threat factor “fire explosion” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
15	C, D	The categories of the threat factor “fire explosion” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
16	C, D	The categories of the threat factor “danger posed by hazardous substances” are adequate to appropriately distinguish situations representing a different ship safety level (Figs. 3 and 5)
17	C, D	The categories of the threat factor “danger posed by hazardous substances” are adequate to appropriately distinguish situations representing a different operational focus (Figs. 4 and 5)
18	B	The basic rule for assigning the overall Vessel TRIAGE category based on the severity assigned to the realized threat factors (i.e. the maximum severity level is taken as the overall category) is adequate
19	C, B	The rationale of the modification (increase) of the overall Vessel TRIAGE category based on the crew functionality or the influence of weather conditions is adequate
20	U	The Vessel TRIAGE method is easy to use during operations
21	U	The Vessel TRIAGE method does not take too long to apply in an operational setting
22	U	The Vessel TRIAGE method improves communication in operational settings

Notes: C = content | S = structure | D = discretization | P = parameterization | B = behavior | U = use, clusters as described in Section 4.1 and Fig. 7.

these categories, the second-most chosen response is the still very favorable “Somewhat agree” (4) option. However, there is also one response suggesting strong disagreement with the method.

For the questions related to the method use (questions 20–22), it is seen that some respondents found they did not have a sufficiently strong basis for making the judgment. This may correspond

Table 4
Overview of background of questionnaire participants.

<i>Organization</i>	
Maritime SAR	7
Maritime authority	3
Maritime shipping	3
Classification society	1
Salvage company	1
Volunteer/other rescue	4
University/research institute	3
Other	3
<i>Sex</i>	
Male	21
Female	4
<i>Age group</i>	
21–30	2
31–40	5
41–50	8
51–60	10
<i>Country of employment</i>	
Belgium	2
Brazil	1
Canada	1
Cyprus	1
Denmark	1
Finland	11
Iran	1
Latvia	1
Morocco	1
Russian Federation	1
The Netherlands	2
United States of America	1

to the fact that the questionnaire asked participants only about how they would expect the method to perform in practice, i.e. without actually having tested it. As with the note on parameterization in Section 4.2, the actual use of the Vessel TRIAGE method should be tested in SAR exercises and in actual maritime distress situations.

Only a few free-text comments were given by the respondents. These mainly provided positive feedback (e.g. “Very nice method”, “It is very good to have such a system for assessing vessels”, “Vessel TRIAGE is a good system to categorize ships in distress”, “An excellent way to improve SAR”). Some concerns were also vented, mainly related to the practical use (e.g. “I’m not sure that this [method] would be appropriately used by different parties” and

“This seems to add another checklist to the already heavy burden to the Coast guard operator whose main duty should be to save life at sea as efficiently as possible”).

In other words, these comments suggest that participants have a positive attitude towards the evaluation category focusing on the method per se (category 1 of Section 4.1). However, attitudes are somewhat more mixed concerning the evaluation category related to the method’s use (category 2 of Section 4.2). This is in line with the above mentioned need for testing and evaluating the method in practical settings, about which some uncertainty currently remains (category 3 of Section 4.1).

5. Discussion

While the evaluation results for the Vessel TRIAGE method indicate a broad agreement among various stakeholder groups, further studies on its theoretical validity and its practical use are recommended for future research. Especially evaluations in SAR exercises and analysis of feedback from actual use in maritime distress situations, accounting for the perspectives of the various actors, would be valuable for further establishing credibility of the method, or for making adjustments to the proposed system. In this context, it should be noted that the validity of medical triage systems is an ongoing research area, even for well-established triage systems such as the Manchester Triage system (Parenti et al., 2014; van der Wulp, 2010). Future research concerning the method could also address the crew’s willingness to use the method in actual distress situations given other concerns (e.g. financial losses due to possible reputational damage after reporting a maritime incident) and strategies to train ship crew and SAR operators to use the method.

Notwithstanding the desirability of more practical feedback about the method in exercises or actual maritime distress situations, the method already has implications to organizational practice and has led to further technological developments. First, Finnish maritime SAR organizations and shipping companies are currently planning to perform simulator exercises to test the Vessel TRIAGE method in practical settings. Steps are taken to implement the method in SAR responders’, shipboard and shipping company emergency response procedures. Second, Finnish maritime authorities are taking steps to propose the method to be included in the IAMSAR manual through international legislative

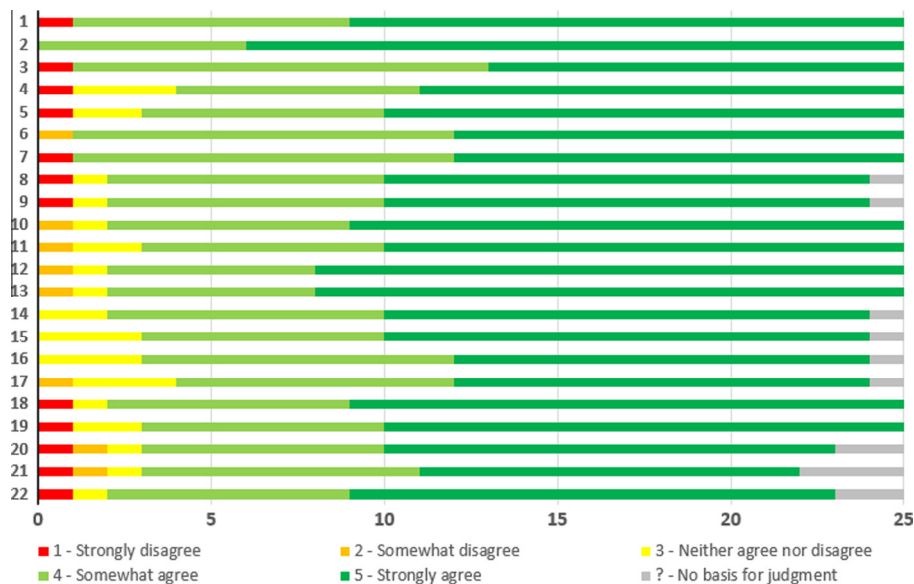


Fig. 8. Results of the Vessel TRIAGE questionnaire, questions from Table 3.

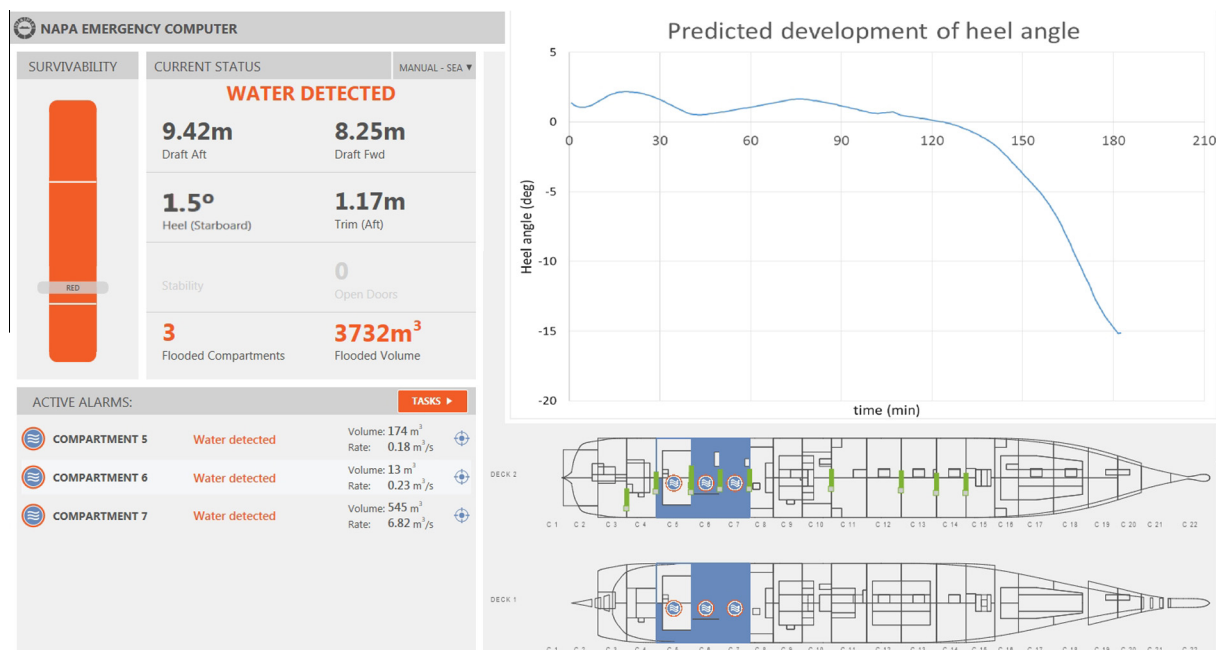


Fig. 9. Visual presentation of the survivability assessment for a flooded passenger ship: Vessel TRIAGE category, time-domain heel angle prediction and flooding extent (Pennanen et al., 2015).

efforts, notably the Maritime Safety Committee at the International Maritime Organization.

Finally, the four-level rationale of the categorization system has been implemented as an output of a decision support system for ship flooding of passenger vessels, see Ruponen et al. (2015), showing that the method is compatible with engineering-based technological decision support systems. This software system uses the data from the flood level sensors and status of doors to detect the breaches in the hull. The progress of floodwater is calculated in time-domain with flooding simulation, Ruponen et al. (2007). Based on this prediction, the stability and survivability of the people onboard is estimated. The system handles the threat factors flooding and listing/decrease of stability. The categorization is in line with the Vessel TRIAGE method (Figs. 3 and 5). The threshold values for determining the color coding are based on IMO regulations. More details and background on this are given by Ruponen et al. (2015). The system constantly updates the time prediction based on latest available data. After each prediction also the Vessel TRIAGE category is re-evaluated and presented to the user, see Fig. 9. The advantage of the time-domain approach is that also evacuation time can be taken into account. For example, the color code will be red if the estimated time for orderly evacuation and abandonment is shorter than the predicted time-to-capsize. In this context, the capsizing limit is the maximum heel angle where the lifeboats can be lowered. The compatibility of such a computations-based decision support system with the Vessel TRIAGE method is considered important in the context of further technological developments in integrated decision support systems for emergency response, as it can link quantitative calculations on specific accident types with qualitative knowledge in an ongoing situation, as recommended by relevant resolutions (IMO, 1995).

6. Conclusions

This paper has introduced the Vessel TRIAGE method, which offers a novel way to assess and communicate the safety level of

vessels in a maritime distress situation, addressing a need voiced by especially SAR operators. The method is developed in close cooperation with various stakeholders, and is used to categorize the situation in one of four Vessel TRIAGE safety levels. These have implications to operational focuses by the involved actors. A central element is a threat factor matrix, which is used alongside a set of questions to determine the safety level, accounting for contextual factors such as crew capabilities and weather conditions. A form for using the method in practice has also been developed.

The results of a survey among various stakeholders in maritime SAR indicate that the method in itself is a good tool to categorize the vessel's safety level. Notwithstanding some negative feedback, the method is very positively received by the survey respondents. Some concerns about the practical use of the method suggest that one area of further study should be to test the method in SAR exercises and ultimately in actual maritime distress situations. Nevertheless, the Vessel TRIAGE method is already being implemented in Finnish SAR organizations and several Finnish shipping companies' emergency procedures, and has led to technological developments in operational survivability decision support systems.

A key advantage of the Vessel TRIAGE method is that it has been developed in close cooperation between multiple stakeholders. This way, the method is kept as simple as possible, while condensing knowledge from diverse sectors and organizations. The authors believe this is an important reason why the evaluation results are so positive across the range of evaluation criteria.

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