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Developing a Framework for Health Risk Assessment, by Integrating Infection and Spreading Aspects into RBD †

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Abstract: Communicable diseases pose a significant threat for passenger vessels, as norovirus, influenza, food, waterborne diseases, and lately COVID-19 have caused several public health events. To manage the risks deriving from communicable diseases, this work focuses on ship design by developing a framework for health risk assessment. This framework is based on the risk-based design, an emerging design process for which safety is considered as a design criterion, by also integrating infection and spreading aspects. The framework shall allow the assessment of various design solutions, as risk control options, aiming at minimizing the spread of diseases and, thus, its consequences.

Keywords: risk-based design; infection; spreading; outbreak; risk analysis; risk assessment; risk control options

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1. Introduction

The outbreak of the COVID-19 pandemic has greatly affected the maritime world, and especially the cruise industry. Unprecedented challenges were set for shipowners, ship operators, and public health authorities to initially deal with the outbreak and then restart the industry, which took a hard hit since the beginning of 2020. Indicatively, global cruise passengers decreased from 23.904 million in 2019 to only 5.769 million in 2020 (−80%) [1]. Additional threats derive also from other diseases, such as norovirus, influenza, or food and waterborne diseases. In more detail, according to EU SHIPSAN ACT Information System [2], since 2016, 34 European public health events have been recorded, of which 16 were related to foodborne diseases, six to COVID-19, four to tuberculosis, three were related to vaccine preventable diseases, two to legionella, and one to an unknown skin disease.

These observations make clear that managing outbreaks and communicable diseases is of high importance for the maritime industry, as ships can be the source of infection or could provide the setting for the spread of these diseases. Large passenger vessels especially, which are semi-closed environments with living and sleeping quarters, shared water, ventilation and sewage systems, and a common source of massively produced food, can be extremely vulnerable to communicable diseases. Additionally, the constant flow of people coming from around the world increases the risks of infection.

There are many ways for addressing the risks deriving from communicable diseases onboard ships, which can break down into proactive and reactive measures. The latter refers to the response to an infection (e.g., evacuation or treatment of passengers), while proactive measures include vaccination, sanitation measures, etc. Thus, the aim is to reduce as much as possible the spread of communicable diseases onboard large passenger vessels.

In this context, one of the most effective ways is to improve the ship design safety regarding health aspects. The current regulatory framework for ship design consists of prescriptive regulations deriving from major International Maritime Organization (IMO) conventions. However, in the context of design for safety, Risk-Based Design (RBD) has emerged as an enhanced design process where safety is treated as a design objective [3], while also allowing alternative design. In this respect, public health aspects have not been integrated in the risk-based ship design. Thus, present abstract is developing a framework for health risk assessment, by integrating infection and spreading aspects into the RBD.

2. Background

To deal with this challenge of developing a health risk assessment framework for ship design, the concept of RBD and the respective infection and spreading aspects should be carefully considered.

2.1. Risk-Based Design

Prescriptive rules and regulations have often proven incapable to balance requirements and to keep pace with technical developments, which provide new design options. To deal with this challenge, RBD is gradually introduced into industry applications. For the RBD process to work in practice, a new regulatory framework has been developed by the IMO through the introduction of the concept of Goal-Based Standards (GBS) [4]. This allows tailored solutions for complex risk scenarios, which may include outbreak of communicable diseases on passenger vessels. The basic objective of the RBD process is to provide evidence on the safety level regarding a specific design solution and subsequently prove that the safety level is within the acceptable limits or higher than before. So, RBD is a performance-based approach where safety is quantified and considered as a design criterion [5], as shown in Figure 1. The safety assessment procedure, which includes hazard identification, risk analysis, and risk assessment, follows the outline of the risk management process as described in the IMO's Formal Safety Assessment (FSA) [6]. The implementation of RBD adheres to the following principles:

- Safety must be quantified with a formalized procedure (i.e., risk analysis) and a suitable risk metric.
- The quantification of safety must be integrated into the ship design process alongside other objectives (e.g., aesthetics, performance, cost, functionality).
- Use of parametric models and fast, accurate first-principles tools (e.g., fire spreading simulations, infection spreading simulations).

2.2. Infection and Spreading Aspects

Compared to other typical risks like fire or flooding, infection and spreading risks on passenger ships are very complex and present specific challenges in respect to spreading, which need to be carefully considered for risk assessment and design purposes:

- Different types of diseases may be brought onboard the ship, with different frequency of appearance, communicability, virulence, and symptoms, which can formulate a different severity to be taken into account.
- There are various transmission modes that need to be considered, different for each disease case. These modes are mainly the following: airborne, droplets, water, surfaces, and food.
- Various accelerating factors should be also taken into account, including different types of ship spaces and their equipment, and the access for people or the activities into those spaces.
- Health risk assessment within the maritime RBD framework should be related to societal risk, and therefore, events that serve the analogy to major maritime accidents, such as collisions and fires, which are usually the cases where the RBD framework focuses. Thus, health risk assessment should be related to major outbreaks onboard passenger vessels.

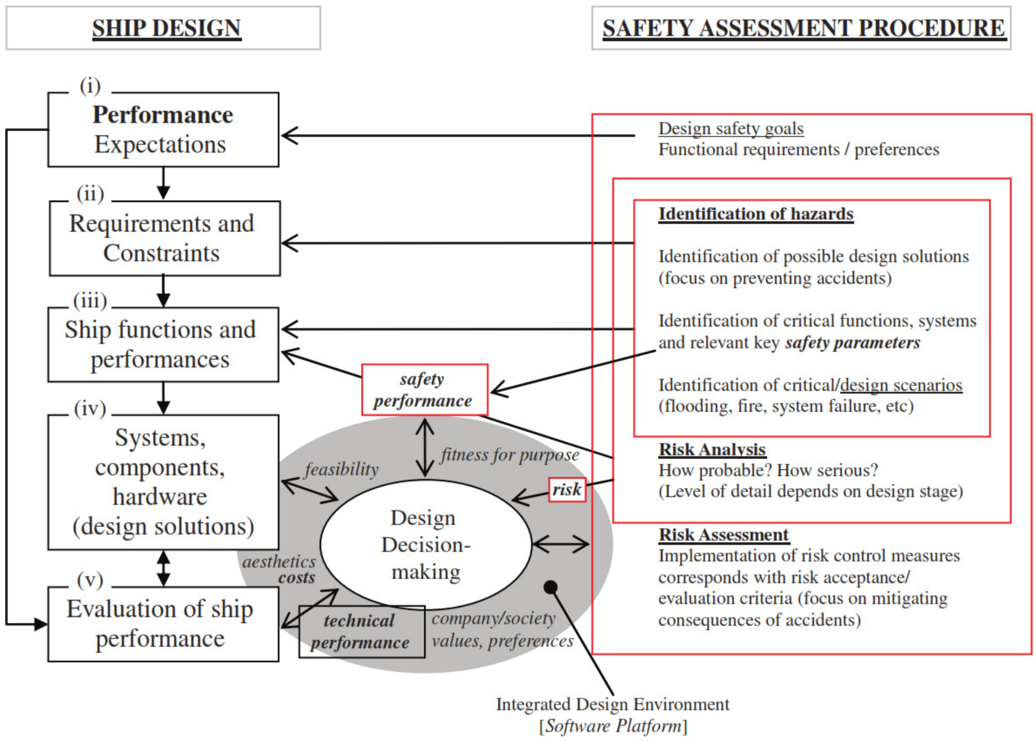

Figure 1. High level description of the SAFEDOR RBD framework [3].

3. Framework Development

Considering the principles of RBD and the infection and spreading aspects presented earlier, the developing framework introduces the health risk assessment through a formulation which will calculate the initial risk related to an outbreak of a disease. The formulation is presented below as Equation (1). Before risk analysis, the design goals should be defined, while the identification of hazards (e.g., diseases to be considered) needs to be carried out as a prerequisite. Then, the aforementioned formula will be used to estimate quantitatively the health risk level. Given certain thresholds, the health risk level could also correspond to a green, yellow, or red level. This risk level will be used to characterize the entire ship, ship compartments (e.g., fire zones, decks), and individual spaces, for a more accurate modeling of a possible spread. Thereafter, the introduction of a Risk Control Options (RCOs) into the health risk assessment will produce the residual risk for a given space, through which the efficiency of the developed innovative design solutions will be assessed, as per the RBD approach.

$$R = \sum_i \left(P_{Disease(i)} \times \sum_j \left(\begin{array}{c} P_{Location(j)|Disease\ (i)} \times \\ \times \sum_k P_{ShipOutbreak\ (i,j,k)|Disease(i),Location(j),TransmissionMode(k)} \times \\ \times \sum_l P_{Consequence(l)|ShipOutbreak(i,j)} U_{consequence(l)} \end{array} \right) \right) \tag{1}$$

Equation (1) breaks down the four distinct framework factors; the probability of disease i being onboard, the probability of this diseases, through the infected persons, to be present at a specific location j onboard the ship, the probability of a specific disease, given the locations of spreading j and its transmission modes k, to evolve into a ship outbreak, and finally the probability of l consequences for a given ship outbreak together with the passengers exposed to the outbreak.

Conceptionally, health risk levels are defined below, without considering actual thresholds. Additionally, Figure 2 provides an indicative representation of the health risk levels per ship space.

- The green level refers to a low-risk level space which may correspond to spaces with limited access for passengers, or spaces with increased sanitation levels.
- The yellow level represents a marginal infection and spreading potential, which can be tolerable, but respective ship spaces should be carefully treated or enhanced with RCOs.
- The red level indicates that the ship space can be easily compromised, leading to a potentially uncontrolled spread, or the space can be the source of the spread (e.g., public spaces such as bars and theaters). Thus, certain RCOs and measures should be in place to prevent spreading.

Figure 2. Conceptual approach of the health risk level of ship compartments, individual spaces, or the entire ship.

4. Discussion and Conclusions

The developing framework introduces a way of assessing the risk related to infections and spreading onboard passenger vessels by integrating infection and spreading aspects into RBD. This allows the characterization of ship spaces and compartments, with respect to their use, equipment and spreading vulnerability, which then can be utilized to assess the performance of various technological solutions, as RCOs, aiming at reducing the spread and avoiding a possible outbreak. This framework is only conceptually defined and should be further examined through its implementation in actual ship design cases and by considering qualitatively and quantitatively the full spectrum of diseases to be considered, transmission modes, and the various types of passenger vessels.

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References

1. Lin, L.-Y.; Tsai, C.-C.; Lee, J.-Y. A Study on the Trends of the Global Cruise Tourism Industry, Sustainable Development, and the Impacts of the COVID-19 Pandemic. *Sustainability* **2022**, *14*, 6890. [CrossRef]
2. EU SHIPSAN ACT JOINT ACTION. *European Manual for Hygiene Standards and Communicable Diseases Surveillance on Passenger Ships*; 20122103; European Commission Directorate General for Health and Food Safety: Brussel, Belgium, 2016; ISBN 978-960-99647-3-9.
3. Papanikolaou, A. *Risk-Based Ship Design: Methods, Tools and Applications*; Springer: Berlin/Heidelberg, Germany, 2009. [CrossRef]
4. *IMO. MSC 81/INF.6*; Goal-Based new ship Construction Standards—Linkage between FSA and GBS, Submitted by the International Association of Classification Societies (IACS). IMO: London, UK, 2006.
5. Vassalos, D.; Fan, M. Risk-based design-realising the triple-a navy. In Proceedings of the 13th International Naval Engineering Conference and Exhibition (INEC 2016), Bristol, UK, 26–28 April 2016; pp. 1–13.
6. *IMO. MSC-MEPC.2/Circ.12*; Revised Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process. IMO: London, UK, 2015; Vol. MSC-MEPC.2, p. 72.