INTRODUCING THE CONCEPT OF RESILIENCE INTO MARITIME SAFETY

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Abstract

The maritime industry is still characterized by prescriptive standards and reactive approaches in relation to safety and risk management to a large extent. For a very long time, responses to maritime accidents have been in terms of automation, regulation and training. While this as such is not wrong, it does not offer the full potential that concepts of resilience seem to suggest. The typical question that is predominately asked is still why things go wrong when accidents occur and search for causes and explanations is undertaken. An evaluation of the safety level achieved system and a focus on system components and characteristics that help the system to usually perform safe is typically not part of the investigation. This creates a need to review the current ideas about safety regulations and risk management in the maritime industry as they have probably reached a limit of what they were able to achieve. The concept of resilience engineering with its focus on system performance rather that system failure is a promising concept to be considered in the shipping business, but needs further investigation.

1 INTRODUCTION

The maritime industry is characterized by prescriptive standards and reactive approaches in relation to safety and risk management (Schröder-Hinrichs et al., 2013). Maritime safety standards have traditionally focused on the design of ships and the equipment to be used for shipboard operations. Efforts to improve safety have therefore often addressed specific areas and aspects of ship design and operation, such as stability measures, but not addressing the ship as a socio-technical system (STS) and the organisational context of operations, including the impact of the flag or port state. However, at the end of the 1980s it was realized that the focus on technology alone would not help to make ships and their operations safer. In order to emphasize the need to address human factors in the design and operation of vessels, the International Maritime Organization (IMO) introduced the term Human Element and encouraged the development of a systemic approach to decrease human and organisational error within the maritime domain. Despite these efforts, rulemaking processes in IMO and the development of maritime safety standards in particular have remained accident driven, and thus primarily reactive.

This article attempts to discuss if resilience engineering can contribute to maritime safety standards becoming more proactive in contrast to being an *"after-the-fact ad-hoc reaction to a single accident"* (Psaraftis, 2002). We will briefly introduce the concept of resilience engineering, safety-I and safety-II and then discuss these concepts within the context of the maritime domain by providing examples for how efforts to improve maritime safety tend to follow the more traditional safety-I (Hollnagel, 2014) perspective. Furthermore, the potential of safety-II (Hollnagel, 2014) and where it might be an asset to the approaches practiced today will be discussed. In the end, some recommendations are given how a resilience engineering perspective can contribute in regulatory developments for safer maritime operations.

2 RESILIENCE, SAFETY-I and SAFETY-II

Resilience as a concept was introduced in the early 1970s and was originally defined as an ecological system's ability to arrive at an equilibrium, or stable state, over time in a dynamic and changing environment (Holling, 1973). In the context of STSs (human operators, technology and organisational settings), resilience is the ability to sustain required operations and achieve system goals under a large variety conditions, including anticipated and unanticipated events. Within the framework of resilience engineering, four cornerstones (monitor, respond, anticipate, and learn) are used to characterise and analyse system performance in the light of normal operations and disturbances. The focus is on the adaption of performance to the current operating conditions, with an emphasis on positive examples (Hollnagel, 2006), i.e. situations where the system successfully manages to meet production goals through adapted performance. Another line of research developing from resilience engineering with practical implications, are the concepts of safety-I and safety-II (Hollnagel, 2014). These two concepts represent different approaches to safety management in high hazardous industries. They represent complementary perspectives on how to define, measure, monitor and improve system safety in these industries. Safety-I is often associated with a traditional approach to safety based on quantitative risk assessment, while safety-II is associated with the theoretical concept of resilience and qualitative inquiries into how safety can be identified as the result of successful performance (Hollnagel 2014). Table 1 offers an overview of the salient features.

Within the maritime domain, the research conducted with focus on resilience, safety-I and safety-II is, to the best of our knowledge, sparse and foremost limited to research concerning frontline operations and safety construction in everyday operations (Praetorius and Hollnagel, 2014; Praetorius and Lundh, 2013), as well as addressing using resilience engineering to offer alternative explanations of the concept of human error (Lützhöft, Sherwood-Jones, Earthy, & Bergquist, 2006). Further, the methodological approaches range from simulator studies (Morel & Chauvin, 2006; Bergström et al, 2009) to qualitative inquiry as a basis for functional modelling (Praetorius, Hollnagel and Dahlman, 2015; van Westrenen, 2014).

Table 1: Salient features of safety-I and safety-II (adopted from Hollnagel, 2014)

	Safety-I	Safety-II
Definition	Safety arises when the risk of adverse events is as low as reasonably possible	Safety arises when as many things as possible go right.
Safety management approach	Reactive response; safety is improved through eliminating the causes for failures/errors based on examples of what goes wrong Work-as-imagined as baseline Linear and linear complex accident models	Proactive, trying to identify and anticipate developments and events with focus on what goes right. Work-as-done as baseline Systemic accident models
Attitudes towards human operators	Humans are sources of error and therefore a liability or hazard	Humans are a resource providing the system with flexibility to adapt quickly to changing demands
Performance variability	Harmful and should be eliminated or decreased as much as possible	Source of flexibility and should be monitored and managed rather than eliminated

3 MARITIME SAFETY STANDARDS IN THE SAFETY-I WORLD

As highlighted before, maritime safety standards have often been introduced in response to accidents (Schröder-Hinrichs et al., 2013) as the question of how an accident can be avoided is a central to all discussions regarding maritime safety. A prominent tool in the IMO rule-making processes is Formal Safety Assessment (FSA) (IMO, 2007). The purpose of this tool is to assist in the identification of safety problems and appropriate countermeasures. Based on quantitative approaches to risk assessment, such as Fault-Tree-Analysis, potential risk reducing measures are evaluated and suggested. Step 1 of the FSA guidelines is consumed with the identification of hazards that may lead to accidents.

However, accidents in the past have demonstrated that STS in the maritime industry have become too complex to be understood by the means of linear or complex linear accident models, which often build the core for traditional risk assessments. The different interactions between operators and subsystems are so diverse and context-dependent that it becomes impossible to forecast a system’s performance in its entirety. The work done in a system is often different from the work as it was imagined by the system designers (Hollnagel, 2012). This applies specifically to accident situations. In the aftermath of an accident, safety improvements and policy making mainly focus on engineering and design solutions (Psaraftis, 2002) in order to "out-design" the possible failure sources.

In complex systems it is, however, very difficult to foresee how even small changes may affect the overall system performance. As a result, we see on the one hand more and more comprehensive safety standards and on the other hand new accident patterns emerging. It is like in the old German tale from the rabbit who challenged the hedgehog for a running competition. The rabbit over-confident of its running skills did not realize that the hedgehog had asked another hedgehog for help. One hedgehog hides soon after the start and the other one waits already at the finishing line and claims that it has already arrived. No matter how many times the rabbit asks to race again, it does not discover the trick and loses the race again. Concentration on one single parameter in a system does not always help to master the overall performance of the system. In a similar way, one could argue that a system adapts to every change so quickly and often in a very unpredictable way that the anticipated increase of safety is not always achieved. The following two examples may highlight this more specifically.

Example 1: Introduction of new enhanced technologies

The introduction of the radar technology in the merchant fleet after World War II has not only reduced the challenges for navigation officers on ships in areas of restricted visibility. It has also caused a new accident category called "radar assisted collisions" as an unanticipated side-effect (Schröder-Hinrichs et al. 2012). Navigators did not reduce the speed any longer in such situations, manoeuvred closer to other ships and thus reduced the safety margin provided by the new radar technology. Similar developments were seen during the introduction of ECDIS and AIS, causing accidents due to over-reliance on technology, poor lookout and improper situation assessment.

Example 2: Fatigue reduction measures

Fatigue has been recognised as a danger for the safe operation of ships and a minimum of 77 hours of rest during a 7-day period with no less than 10 hours a day has been set as an requirement in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) (IMO, 2011 - refer in particular to Section A-VIII/1 Fitness for duty). It aims to eliminate fatigue as a cause of accidents and errors related to the (cognitive) performance of the seafarers. As a control measure for fatigue management, it is required to keep a record of seafarers' rest hours. While this might be an effective way to address the single cause for an accident (fatigue), it neglects the consequences of this control measure to the organisation and work routines on board. Increased workloads as a result of administrative tasks are a source of complaints from ship officers and engineers, and may also lead to accidents.

The question need to be asked why the focus is to extensively laid on accidents – in other words on things that can go wrong. There are a number of arguments that can be used against this perspective. First, in the maritime business, an accident is still a rare event. Every day, the vast majority of officers and engineers master the challenges related to operations on board ships without causing an accident. Second, a safety-I perspective is characterised by a so-called causality credo impacting the basic assumptions about safety and accidents; i.e. accidents are caused by one or more errors or failures which can be eliminated or neutralised once they have been identified (Hollnagel, 2014). However, human beings are limited in their capability to predict in which ways accidents can be caused in complex systems. Pro-active, probabilistic risk assessment is therefore to a certain extent speculative in its attempts to identify all possible combinations of future courses and events.

One important limitation of the safety-I perspective seems to be its focus on one specific error that occur under very specific conditions of a dynamic STS. If things are mostly go right then the safety-I focus obviously neglects/ignores the ability of a STS to compensate lacks and shortcomings during most of the cases. So, instead of focussing only on accidents, why not to focus on the ability of a system and the ability especially of the operators/actors in the system to do things right and strengthen this capability? Is technology that flexible that it is able to compensate an operator's lack or shortcoming as it is vice versa that the human operator is able to compensate malfunctioning of technical systems?

4 DEVELOPING A SAFETY-II PERSPECTIVE FOR THE MARITIME WORLD

As outlined above, many of the safety-related efforts within the maritime domain focus on improving safety in accordance with a safety-I perspective. This section will therefore in contrast discuss how resilience engineering may contribute to a paradigm shift towards a safety-II perspective in the maritime domain.

Following the capsizing of the Herald of Free Enterprise in 1987, the International Safety Management (ISM) Code (IMO, 2014) was introduced to the shipping industry. The main task of the Code is to clarify the role and the influence of shore-based and ship-based issues/factors in shipboard operations. This was probably one of the few accidents that has led to a systematic review of the STS 'ship' from a holistic perspective. The Code itself consists of two Parts – A and B, whereas Part A deals with the implementation and Part B with the certification of the safety management system to be developed for an individual shipping company. The elements in Part A provide for principles and objectives in a very general way. Unlike most of the IMO standards, the ISM Code is very general for the specific reason that any two shipping companies are different from each other and therefore need different ISM systems. Therefore, a shipping company is free to develop its own interpretation of the requirements under the Code.

The Code contains a few statements that can be used as an argument for the introduction of a safety-II perspective. Companies are required to provide for safe operational practices (Code, paragraph 1.2.2.1) and develop related policies (Code, paragraph 1.4.1). A designated person (DP) responsible for the implementation of the safety management system (SMS) has to be appointed with direct access to the highest management level (paragraph 4). It is furthermore stated that the ISM Code has a self-regulatory nature (MSC-MEPC.7/Circ. 8, paragraph 3.2 – refer to IMO, 2014). However, the ISM Code is deeply rooted in safety-I paradigms. Companies are required to proceduralise the main functions and operations and thus directly pushed in a 'work as imagined' perspective. In the IMO context where a stronger focus is laid on the global eradication of sub-standard shipping this is an understandable objective. Certification guidelines for administrations require objective evidence (A 28/Res. 1071, paragraphs 3.3.4 and 4.12.3 - refer to IMO, 2014), which typically is written procedures, documents etc. This cannot be avoided, but limits the flexibility of a company. The IMO recognizes that prescriptive criteria used by administrations for the verification of the implementation of the Code are counterproductive (A 28/Res. 1071, paragraph 3.1.3 - refer to IMO, 2014).

The ISM Code achievements are discussed controversially. There is no doubt that this tool is a major achievement in the objectives of the IMO to foster a safety culture in the shipping industry. On the other hand, a number of authors (refer, e.g., to Bhattacharya, 2009) claim that it has not developed its full potential. One argument for such conclusions may be that the shipping sector is caught in a compliance culture rather than a safety culture (Mathiesen, 1994). It could also be that the organizational set-up of shipping operations with crews typically supplied by external crewing agencies limits the development of a company based safety culture. This also explains, why the Oil Companies International Marine Forum (OCIMF) considers compliance with the ISM Code only as level one out of four in achieving safe maritime operations (OCIMF, 2008).The safety system of OCIMF specifies various key performance indicators (KPIs) that can be used in order to determine on which safety level a company works. This is a similar development as the Shipping KPIs developed by InterManager. While these indicators are helpful, they just are a mere indication of what has happened in the past (e.g. accident ratios). If a safety-II perspective is to be introduced, a different type of indicators would be needed.

If resilience can be defined as the ability of the system to adjust its performance prior, during and after an unexpected event, a system must have the ability of being proactive. In a wider context, proactivity may indicate an early stage identification of problems or factors that may affect safety together with the development of regulatory actions before an accident occurs. As pointed out above, even though a broad definition may fit and stimulate the scientific discussion, companies and policy makers require measurable indicators to detect and then satisfactorily respond to safety threats. Hopkins (2009) fostered a debate within the (safety) scientific community about the definition of leading and lagging variables. In several scientific contributions the lead/lag dissimilarity, in fact, is strictly related to the distinction between proactive and reactive monitoring of the system. Currently, indicators used by the maritime industry mainly refer to what has occurred in the past (e.g. lagging indicators such as incident/accident ratio, deficiencies/inspections ratio etc.) and are used as potential company performance indicators. Distancing ourselves from the current discussion on a harmonised definition of process and personal indicators, the development of appropriate leading indicators and their implementation in the SMS, would allow management and regulators to be proactive in managing the causes of accidents (Wreathall, 2009) and work as input to comprehend safety issues from within. Two examples should be given.

Example 1: Anticipating consequences of change

One promising approach to integrate resilience engineering principles in the maritime domain has been suggested by Rigaud et al. (2012). They focus on the problem-solving aspect of FSA (IMO, 2007) that does not take the effects of risk control options into account. Consequently an assessment methodology is suggested based on a mixed-method approach using focus groups, expert interviews and simulation-based exercises to determine the possible side-effects of changes to the overall system performance. Today's complex STSs require the involvement of both frontline operators, company representatives and administrations to make sure that potentially negative side-effects, as well as opportunities for successful operations, are identified and assessed prior to changes being implemented, regardless whether these are technical, organisational or regulatory.

Example 2: Integrating the end-user perspective into system design

Another example might be the currently ongoing CyClaDes project (http://www.cyclades-project.eu). This project aims at developing a framework for obtaining user feedback for the design of shipboard equipment. A benchmarking approach is used for determining how "user-friendly" equipment is designed. This could be used for a proactive assessment of ship safety.

Admittedly, the numbers of examples given here is not very high. There are unfortunately not too many examples at this point in time. The few references are therefore given in order to outline in which direction future research and discussions should proceed.

5 SUMMARY AND CONCLUSIONS

As discussed above, efforts to increase maritime safety often focus on a reactive approach implementing changes to the system in the aftermath of an adverse event. Further, a large body of research (e.g. Chauvin, 2011; Schröder-Hinrichs et al., 2013) indicates that the maritime domain continues to reflect a safety-I perspective (Hollnagel, 2014) emphasising the need to eliminate the causes of vulnerabilities. While safety-I has been a fruitful approach during periods when systems were tractable and their components had limited interaction, contemporary systems are becoming far too complex to identify and eliminate individual causes. A failure to acknowledge this implies a gap in the stakeholders' understanding of the system and of how it actually operates. Design is always based on assumptions, but as socio-technical systems develop in interaction with their environment, design assumptions must be checked and frequently evaluated. Eliminating the reasons for failure does not help to understand how systems adapt to continue operating in a changing environment.

Although the IMO acknowledges the need to address the human element, there is still a gap in terms of guidance in how to approach this multifaceted issue in a systemic way. Furthermore, as many researchers (e.g. Amalberti, 2001; Dekker, 2011; Vicente, 2006) have stressed, contemporary STSs are too complex to be understood in terms of a structural account of the system and its components. STSs change constantly in response to the demands of their environments. Acknowledging the maritime domain as a complex STS demands not only a new focus on the human element but also the realisation that a new or extended approach to maritime safety and safety management is needed. This does not imply that the current regulations need to be demolished, but that they need to be re-evaluated. At the same time, it has to be realized that the safety-I approach cannot be completely abandoned. Technical specifications in the design of a ship very often need prescriptive regulations. The same applies to the ISM Code, which has to be seen in a wider/global perspective. Nevertheless, the ISM Code is the key instrument to introduce a safety-II perspective in the maritime domain. The safety-II perspective could be seen as a complementary set of principles that could help to achieve and maintain maritime safety. As it was highlighted above, proactive indicators may help to foster the safety-II perspective and more research need to be done in order to expand on the few existing approaches.

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