“UNDER DANGEROUS CONDITIONS” – SAFETY CONSTRUCTION AND SAFETY-RELATED WORK ONBOARD OF MERCHANT VESSELS

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Abstract. The following paper presents findings from a qualitative study conducted on board of two merchant vessels. Interviews and observations have been used to obtain insights in how safety is defined and promoted by the personnel working on board. The merchant vessel, the crew and the single mariner are identified to be part of a socio-technical system displaying three levels of system aggregation; person-centred, crew-centred, and vessel-centred. The common ground of a crew, an overlap of the individual mariners’ experience and knowledge, is identified as a basis for trust and predictability of action on board, which is a necessity to be able to conduct work safely. Furthermore, the results also show how storytelling is used to transform individual and organisational experiences into knowledge that can guide safety-related work on board. The stories told among the crew often exemplify how mariners, both on an individual, but also on a crew-centred level of system aggregation, balance safety and efficiency in the light of increasing production demands.

1 INTRODUCTION

The shipping domain is one of the oldest domains in transportation. For about 5000 years goods have been transported all over the world with the help of merchant vessels. Safety-related work within the shipping domain has in general been regulated by international guidelines, regulations and recommendations. As a consequence, an exhaustive legal framework has been created through the past 30 years. Nevertheless, most of these rules and regulations have been stated as a reaction towards accidents, such as the International Safety Management Code (ISM) (IMO, 2010) introduced after the capsizing of the Herald of Free Enterprise. This demonstrates the overall reactivity of the domain's stakeholders when it comes to safety-related work conducted on board.

Furthermore, the majority of research within the maritime domain has addressed the human element as the erroneous factor, accounting for between 60-80% of the causes for accidents and incidents (Dhillon, 2007; Schager, 2008), within the system emphasising on technical advancements, simulator studies or the development of training courses (Hockey, Healey, Crawshaw, Wastell, & Sauer, 2003) to reduce and mitigate risks. As highlighted by amongst others Hetherington, Flin, and Mearns (2006), Grech, Horberry, and Koester (2008), and Chauvin (2011), this perspective shows a limited understanding of the complex interactions between human operator, technology and the work environment. There is the need to shift the perspective from the *human error* towards an understanding of the complexity of the socio-technical focusing on how the system acts at large and how its performance can be kept within the limits of the so-called performance envelope without drifting towards failure (Dekker, 2011).

This paper presents results obtained through a qualitative study of mariners' safety-related work on board of merchant vessels. The aim of the study has been to gain insights in how crewmembers define, relate to, and promote safety within the settings of their daily work. This paper therefore wants to emphasize the positive impact of the professional crewmember in the promotion of safety aboard. Concepts derived from Cognitive Systems Engineering (CSE) and Resilience Engineering (RE) are used to discuss the findings of the study, and to emphasise the gain of shifting from *human error* to *resilience* when trying to understand the work on board a merchant vessel.

2 JOINT COGNITIVE SYSTEM (JCS), CONTROL, AND RESILIENCE

This article approaches the work on board a merchant vessel with theoretical concepts derived from Cognitive Systems Engineering (CSE) and Resilience Engineering (RE). CSE emerged in the early 1980s as a theoretical framework to analyse the performance of socio-technical systems within safety-critical domains, such as aviation and the nuclear power domain. Within the framework of CSE and RE, socio-technical systems are identified to be so-called Joint Cognitive Systems (JCS) (Hollnagel & Woods, 2005).

JCS is a system that consists of two components of which at least one is a cognitive system (Hollnagel & Woods, 2005). A cognitive system is a system, which can modify its behaviour based on past experience to achieve specific goals even under disruptive influences. JCSs are in control of a process or an environment, and act in complex situations, in which multiple goals need to be balanced to meet the demands of the context. Feedback control is applied by the JCS to react on differences between the actual and a desired state. Feedforward control is applied to operate in situations where time and/or information is limited, and supports the JCS to act upon an expected change or deviation before it happens (Hollnagel & Woods, 2005).

RE strives to understand how large socio-technical systems cope with the complexity of daily operation. The focus is on examples of the positive, meaning that resilience is concerned with how a system succeeds by adapting its performance to the demands of the environment, not on a failure to do so (Hollnagel, 2006). It can offer an explanation for how the system makes trade-offs between multiple goals to meet the demands of the context in real world situations. The system adjusts its performance to the demands of the environment, which enables it to achieve its goals under a large variety of operational conditions (Hollnagel, 2011). Within the settings of the maritime domain, the goals to balance are to operate safely at the same time as shipping is a trade-based industry, meaning that the overall efficiency, i.e. to operate cost-efficient, should not be endangered by how crew and vessel at large perform.

There are four basic *system abilities* that a system needs to possess in order to be resilient: it must be able to *learn* from past events; to *anticipate* future opportunities, challenges and demands; to *monitor* the environment and its own performance for possible threats; and to *respond* to regular and irregular situations during daily operation (Hollnagel, 2011).

3 METHODOLOGY

This study has aimed at exploring and understanding how crewmembers define and promote maritime safety as part of their daily work on board. This is why a qualitative design using interviews and observations was chosen for the data collection.

31 semi-structured interviews with crewmembers of two vessels were conducted. 9 of the interviewees were part of the bridge-team serving as Masters or navigating officer, while the remaining 21 respondents represent crewmembers in various positions ranging from engine room personnel to mates and stewards.

The interviews conducted were semi-structured and followed an interview guide with up to 15 questions depending on the interviewees' working position on board. Of the 31 participants 24 provided their consent for a recording. These interviews were transcribed verbatim, while the other interviews were analysed with the help of notes taken during the time of the interview.

To complement the data gained from the interviews, two observations on board of merchant vessels were conducted. Five days were spent on each vessel. Crewmembers in various positions on board, e.g. bridge officers, mates, and engine-room personnel, were observed during their work. The observations were coupled with contextual inquiries during which the informants were asked why and how they would conduct certain tasks to gain deeper insights for how the subjects related the tasks performed to the overall concept of maritime safety.

The analysis of all data collected was conducted as an iterative process inspired by grounded theory (Corbin & Strauss, 2008). All aspects the informants related to their definition, promotion and understanding of maritime safety in the interviews and contextual inquiries were assembled and coupled with actions observed on board. In a second step, levels of system aggregation of a JCS of a merchant vessel were identified and assembled. In a last step, the actions of the JCS on various levels of system aggregation were identified with the help of concepts derived from CSE and RE.

4 RESULTS AND DISCUSSION

Three levels of system aggregation of the socio-technical system of a merchant vessel are identified through the analysis. The JCS of a merchant vessel incorporates crewmembers, both as individuals, but also as the crew as whole, technical artefacts, e.g. computerised safety management systems, and non-technical support, e.g. emergency procedures. Safety arises when the JCS is successfully balancing the multiple goals that arise from the increasing production demands in a vast amount of varying conditions of a vessel's operation. Three levels of system aggregation have been identified within this study: person-centred, crew-centred, and vessel-centred.

4.1 Person-Centred

The first layer of the JCS is person-centred and relates to the single crewmember and his/her tools, safety equipment and tasks that he/she is responsible for. Control at this layer of system aggregation mainly concerns conducting a task while mitigating the risk of injury as much as possible. As work on board of vessels is experienced as inherently dangerous, the informants emphasised that there is no way in which risks can be eliminated.

"If you stay on board it means that you are under dangerous conditions. You look around you and everywhere as something can come from anywhere which can damage your body" (crewmember)

Although the usage of safety equipment, such as goggles and helmets, can decrease the risk of injury, working on a vessel is considered as being inherently dangerous. Individual risk assessments at this level concern discussing whether a task can or needs to be conducted in the current situation and how the potential risk can possibly be mitigated. Nevertheless, the informants highlighted that some tasks are necessary to conduct. Safety equipment is one of the measures that can reduce, but not to eliminate the risks completely.

4.2 Crew-Centred

The second level of system aggregation, crew-centred, addresses the single mariner's position as part of a whole, the crew. At this level of system aggregation coordination of tasks and communication are most important to be able to maintain control over the processes that the crew tackles as a whole. The quote below emphasises the importance of crew for the overall safety on board by using an analogy from the information technology domain as the informant identifies the physical vessel and its equipment as hardware, while the crew is the software that makes work safe.

"Most important for maritime safety is the software" (member of the bridge-team)

It is what people do, rather than the material they have to work with, that is important for safety. Activities steered on this level of system aggregation normally involve more than one member of the crew at once and require communication and coordination of tasks. An example for such an activity is loading and unloading a vessel. While a member of the bridge-team is planning the loading and unloading, the activity itself is conducted by the crewmembers in cooperation with a port's operational personnel. Feedback on success or failure of an action or task execution on this level is slower than on the person-centred level, at the same time as the ability to anticipate and predict the system's behaviour increases in complexity as there is a higher degree of uncertainty introduced by the dynamics of the environment.

4.3 Vessel-Centred

The third level of system aggregation is vessel-centred. Tasks at this level are concerned with monitoring the state of the vessel, including the technical and non-technical equipment, and the entire crew to fulfil the overall goal of transporting cargo safely from one port to another. More than one respondent in this study emphasized that especially technology, as well as the constant pressure to operate efficiently, has a large impact on the system's ability to perform safely.

"Well, I have thought about maritime safety. It seems to be very important as long as it does not cost anything. Repairs and shipyard visits are postponed which has very negative influence on our working environment down there [in the engine room]" (crewmember)

The crewmembers often felt torn between safety and efficiency. As can be read in the statement above, what is considered to be safe for the vessel might not be what is promoted by the shipping company. The seafarers on board of vessels often felt the need to deal with the consequences of the financial pressure in the maritime domain as such. They generally stressed that several necessary improvements and reparations were postponed, which affected the system's ability to work safely.

4.4 Common Ground as Basis for Resilience

Anticipation, learning, monitoring and responding are abilities that need to be present for a system to be resilient. Within the setting of the merchant vessel JCS, these abilities are found to be based on experience and common ground. Common ground in this study is identified as the overall of experience and knowledge of the individuals working on board. It is shaped by the experience of the single crewmember, but also builds on his/her knowledge and connects the crew to each other as it is constituted by overlaps in the members' knowledge and experience as depicted in fig 1. These overlaps arise in situations where work is conducted in a team, where the work of one crewmember is depending on the work of another one, or when the crew is conducting drills and trainings. It is dynamic and highly depending on the individuals that constitute the crew. As teams and tasks change, the common ground is either increasing or decreasing depending on the team size, the experience and the knowledge of the individuals aboard.

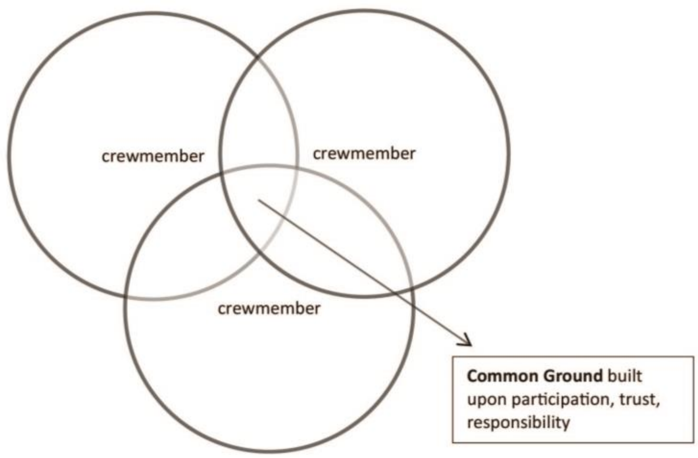

Figure 1: Common ground constituted by the overlap of knowledge and experience of every crewmember on board a vessel.

In a highly hazardous work environment, such as a vessel, each crewmember has to be able to trust into own and each other's competencies. Furthermore, similar to findings from Sanne (2008), the mariners part of this study displayed a high degree of pride within their professional roles, and storytelling among crewmembers was constantly used to confirm the norms and values of the profession, but also to emphasise importance of learning from each other. Crewmembers learn from each other's experience, and common ground and storytelling are used to transfer certain values and norms, as well as to show ways of balancing multiple goals and production demands. Many of the stories told from one crewmember to another contain essential information on how to work around conflicts within the operational work environment and the organisational environment.

4.5 Making Trade-offs

The results obtained show that the JCS faces several trade-offs between production demands and safety at each level of system aggregation due to the organisational environment constituted by the shipping company and the overall legal framework.

"(...) these books [SOLAS, MARPOL, STCW] can only say the roughly conditions and

the most average conditions, you know, of the ship." (member of the bridge-team)

The seafarers interviewed in this study highlighted that the basics of safety are built upon an understanding and knowledge of current rules, regulations, recommendations and guidelines issued by either national administrations or international bodies, such as the International Maritime Organisation (IMO). Although these documents frame the options of available actions, safety itself arises from how these documents are interpreted and balanced with each other as regulations can state conflicting rules. It is therefore up to the crew themselves to decide which framework to prioritise. Further, due to increasing the regulating framework, a lot of new tasks have been introduced to the work of mariners. One example frequently named by the informants is the upcoming of checklists.

"I cannot find a checklist so important. As I told you before how I contribute to maritime safety is according to common sense and good seamanship practice."(member of the bridge-team)

The quote above shows that although checklists are present, they are not always considered meaningful. While they might be a good reminder, safety itself is promoted by applying experience and knowledge to deal with the variability of operating conditions met within the daily work settings. Overall the informants felt that checklists have only little to do with the actual work that needs to be conducted within a certain timeframe. When time is limited, the informants highlighted that experience is the key to getting work done in a safe manner. In addition to checklists, several of the informants also stressed the conflicting role of new technical equipment. While technology from a shipping company's perspective provides a clear cost and calculated benefit, it might not always support the mariners in their tasks. Often crewmembers experienced that equipment was just added without being properly integrated with already existing technology, rather increasing the overall workload than decreasing and supporting task execution.

6 CONCLUDING REMARKS

As outlined above, mariners face multiple trade-offs between production demands and safety as part of their daily job. The results have identified common ground, an overlap between knowledge and experience among the crewmembers, as an essential part of what makes the JCS resilient. Professional roles are assigned based on individual capabilities, but it is only on the crew-centred level where both common knowledge and individual capabilities are needed to keep the system within the limits of safe performance. Further, the importance of storytelling was highlighted in the results. Stories serve as guidelines of how to deal with the daily trade-offs between efficiency and safety in a highly hazardous work environment.

This study has been a first step towards a deeper understanding of how mariners relate to safety within their daily work. However, there is the need to look further into how both common ground and storytelling assist and support mariners' safety perception and construction.

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