

Enhancing Safety through Generic Competencies

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ABSTRACT: This article provides insights into proactive safety management and mitigation. An analysis of accident reports reveals categories of supervening causes of accidents which can be directly linked to the concept of generic competencies (information management, communication and coordination, problem solving, and effect control). These findings strongly suggest adding the human element as another safety-constituting pillar to the concept of ship safety next to technology and regulation. We argue that the human element has unique abilities in dealing with critical and highly dynamic situations which can contribute to the system's recovery from non-routine or critical situations. By educating seafarers in generic competencies we claim to enable the people onboard to successfully deal with critical situations.

1 INTRODUCTION

Safety is one of the maritime domain's most widely discussed topics. Often, it is instantly associated with technological innovation and the replacement of traditional nautical instruments. This development is supplemented by International Conventions such as International Regulations for Preventing Collisions at Sea (COLREGS), the Standards of Training, Certification and Watchkeeping (STCW) and standards for safe management and operation of ships (ISM Code) which have been adopted by regulating bodies.

While improving technology and regulatory respective standardization efforts are treated as pillars on which maritime safety rests, the seafaring personnel is often considered as the error-prone and safety-critical element within the world of shipping – with human error being the main cause of many maritime casualties (Allianz 2012, 2013 Hetherington 2006, Strohschneider 2010).

In a way, this censorious view of the human factor is limiting the approaches taken towards increasing safety. This paper aims at challenging the traditional perspective on the human element in the maritime domain: Acknowledging the potentials while being aware of its fallibilities and thus making the human factor the third pillar in the concept of maritime safety.

2 A PROACTIVE CONCEPT OF SAFETY

The understanding of safety as advocated by the International Maritime Organization (IMO) has recently undergone a shift from a purely reactive approach towards a more proactive concept of safety and security at sea (Carbone 2005, Brenker & Strohschneider 2012). Commemorating more than 100 years of Safety of Life at Sea (SOLAS) we should remind ourselves of that very event which triggered the whole development: The maiden voyage of the

Titanic which sank after colliding with an iceberg and caused the loss of 1,517 lives. Investigations by members of the US Senate and the British Parliament revealed tremendous safety flaws: For instance, the ratio of tonnage and the number of required rescue boats did not take into account the actual number of passengers at that point of time. Thus, the Titanic had only 20 rescue boats with a capacity for a total of 1,178 persons whereas 2,200 persons were onboard (Frey et al. 2010).

Although SOLAS was a tremendous improvement for safety at sea at that time, it was by all means a reactive approach: It considered only those factors that contributed to the sinking of the Titanic. Regulations were tailored to prevent similar accidents. While studying the past thoroughly is certainly not futile, tailoring recommendations in order to prevent what has already happened can be considered a reactive understanding of safety, one that has shaped the thinking of a majority of safety-related industries until the 1980ies (Reason 1990, Brenker & Strohschneider 2012).

However, in the past two decades, starting around 1990, the IMO adopted a more proactive approach towards safety which led to the addition of SOLAS Chapter IX in 1994 and a revised version of the Standards of Training, Certification and Watchkeeping (STCW) in 1995. Following these developments, efforts towards the development of a better safety-culture have been undertaken in the whole shipping industry: The recent adoption of the Manila Amendments to the STCW emphasizes, for instance, concepts such as “marine environmental awareness”, as key concepts of proactive behavior which is trained in Crew Resource Management courses (see also Brenker & Strohschneider 2012).

Still, one could argue that instead of educating the human element in proactive behaviors, training in the use of checklists, handbooks, and in standardized operating procedures (SOP) are used to eliminate humans’ supposedly negative impact. This also holds for mandatory drills and courses for handling emergency equipment and operating other safety-enhancing technical equipment. Even the implementation of the Manila Amendments in day-to-day operations relies firmly on the use of SOPs; safety audits, for instance, still follow checklists.

3 ACCIDENTS AS DEVIATIONS FROM ROUTINE SITUATIONS

One key element, according to the IMO, in identifying safety improvements is the analysis of accidents. Organizations such as the German Federal Bureau for Maritime Casualty Investigation (BSU) are institutions established to examine causes and factors of maritime accidents and derive safety recommendation for the future (BSU 2013).

In order to use official accident reports for scientific purposes, it is important to ponder what accidents reports reveal and about what they in fact remain silent.

These reports refer to events on the tip of the accident pyramid (Grech et al. 2008). Based on

accident reports there are hardly any conclusions to be drawn about actions or factors that actually prevented accidents. Events which might provide insights into this issue are incidents, near misses and unsafe acts which occur more frequently and do not necessarily result in accidents (see Fig. 1). Since there is room for improvement in the application of incident report systems that are in place today (Berg 2013), there is basically no data accessible which allows us to learn about those factors and actions.

Coming back to the discussion of accident investigations, there is certainly a lot to be learned from accidents: Concrete examples of things that can go wrong and how people actually behaved in critical situations. However, the official reports represent a rather restricted access to safety at sea, since they can only provide insights into failures of safety measures. With their rather reactive and practically orientated scope, accident investigation reports represent examples of highly non-routine situations that sometimes illustrate the limits of existing safety practices. This makes them a valuable and comprehensive source for safety research (Goulielmos et al. 2012).

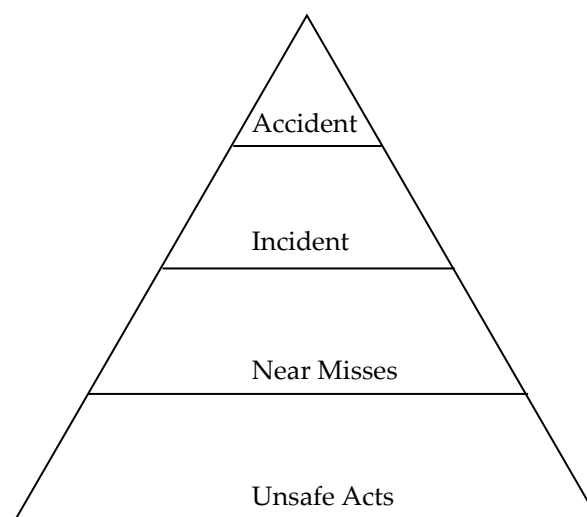


Figure 1. Accident pyramid taken from Grech et al. (2008:17) visualizing the different frequencies with which unsafe acts, near misses, incidents and accidents occur

Accident situations distinguish themselves from routinized standard operations on board a vessel by a set of specific characteristics: Accidents which are categorized as (very) serious maritime casualties pose severe threats to human life, the integrity of the vessel, as well as to the ecological and economic environment. Hence, the time shortly before, during and after the occurrence of an accident can be regarded as highly non-routine. These kind of critical situations can be described as complex: unsafe, uncertain, non-transparent and highly dynamic with crucial decisions to be taken based on conflicting, erroneous or even lacking information (Borodzicz 2004, Brenker et al. 2014).

4 CATEGORIES OF ACCIDENT CAUSES

Assessing accident reports from the BSU (2013) published between 2003 and 2012 we found evidence that there might be a need for safety recommendations beyond the pillars of regulatory issues (working procedures and standardization) and technology improvements. Some observations made by accident investigators show that the human element involved – through its knowledge, skills or behavior – could have made a difference for the better in the course of events.

Following Bainbridge’s (1983) ideas about “the ironies of automation” in which the author discusses the unintended consequences of automation (an expansion rather than elimination of operator related problems), we present selected casualties whose causes and aggravating factors suggest that several procedures and technologies, implemented for safety had, at least in these cases, a rather detrimental effect. In Table 1 we group those accidents according to six categories which we will explain in the following paragraphs.

Unlikely and unexpected events: In investigation reports one repeatedly comes across the phrase that “events took a sudden and unexpected course”. The crews had no handbook available nor was there an SOP in place that could have helped to restore safety in this particular situation. Hazards of seafaring are legion and legendary (Blackmore 2009). They are caused by sudden weather changes, phenomena such as freak waves, or the unexpected malfunctioning of instruments or machinery. Whenever we think we have ways and means to deal effectively with every course of events, even the unlikely ones, there are always exceptions no one has ever thought of (Taleb 2004, 2010). SOPs and well-rehearsed emergency drills cannot be comprehensive measures to attain safety in any and all situations – we need more ways to deal with uncertainty.

Non-compliant behavior: The rationale behind establishing rules is the firm belief that everyone adheres to them. Adherence to safety rules is an arduous task and people who choose to neglect them in favor of focusing on other aspects of their work are often even rewarded – as long as nothing goes wrong (Dekker 2005).

Safety flaws and ambiguity: In spite of thoroughly devised and adhered to rules and regulations, there are safety flaws where the application of a rule and procedures is ambiguous. We discovered a report where even in the aftermath of an investigation the correct application of rules and procedures could not be determined. It might not be the rules and regulations that are obscure, but complex critical situations definitely are.

Diffuse state of information: It is a characteristic feature of emergency situations that there is a diffuse state of information. Investigations refer to the unavailability of critical information as factors contributing to an accident and therefore propose the integration of displays that would make them available on existing bridges. Ironically, it is a common observation that there already is an overload of information on bridges, which holds especially true in critical situations (Strohschneider et al. 2006).

Inadequate communication: One could also argue that inadequate communication is the result of the existence of rules, well-trained SOP and automation. An increasing availability of data on the bridge in combination with one-man watch schedules on merchant vessels reduces the need for interpersonal communication, so that this essential skill withers away (Strohschneider 2010, Dekker et al. 2008). However, particularly in critical and piloting situations effective communication between the bridge team and the assisting pilots would be an essential tool (Brenker et al. 2014) which is backed up by several reports listing inadequate communication as one cause for an accident.

Table 1. Selected BSU (2013) reports which exemplify six ironies of risk mitigation and management

No.	Category
	<i>Unlikely and unexpected events</i>
176/05	Installation of a wrong shut-off valve caused a fire on a container ship
262/03	Unexpected rupture of a fairlead shackle led to hospitalization of three crew members
637/06	Death of a seaman and three injured after wave
07/10	Unexpected weather conditions led to foundering
	<i>Non-compliant behavior</i>
09/06	Collision as a result of multiple non-compliant behaviors concerning crossing the shipping channel and right of way
181/04	Assuming that bow thrusters are shut off during Diving sessions a diver was mortally injured
455/05	Omitting continuous positioning resulted in touching the sea bottom
	<i>Safety flaws and ambiguity</i>
155/04	In the course of the investigation it could not be determined who broke the right of way, resulting in a collision
	<i>Diffuse status of information</i>
167/08	Stranding on an uncharted reef
198/02	Differing convoy lists sent to a tanker are causal for a collision in the Suez Canal
119/05	Contradictory information from pilot and a crew member on lookout about an object in the shipping channel
156/03	led to a collision
	<i>Inadequate communication</i>
510/09	Communication problems between the pilot and helmsman led to collision
107/08	Communication problems between the captain and the pilot led to a collision
115/06	Discrepancies in arranging the maneuver led to a collision
	<i>Technology brings procedural change</i>
166/05	Maloperation of the autopilot and poor observation of the autopilot’s effects led to the death of a crew member
19/03	Restricted availability of the radar due to weather conditions led to a collision. Recommendation about regular training on the usage of navigational equipment.

Technology brings procedural change: Technology comes along with procedural change which is the key message of Bainbridge’s (1983) observations. Newly introduced (technical) instruments put different requirements on the operator ranging from purely operational skills, to the integration into existing procedures and, finally, the management of critical situations when technology fails. The introduction of ECDIS as a mandatory navigational instrument, for

instance, has sparked a debate about the socio-technical error-proneness of the technology and about the navigators' needs for special training (Tang 2009, Jie & Xian-Zhou 2008, Allianz 2013). Similar observations have been made with regard to the introduction of radar-technology, which has been associated with a heightened willingness to take risks in adverse weather conditions (Perrow 1984). Sifting through accident reports we found examples of procedural operator errors causing accidents.

Only in some cases the categories mentioned may have been the major accident causes. Yet they can be definitely regarded as contributing factors to a fatal course of events. They exemplify that measures intended to raise the safety level might under certain circumstances have unintended, and even contradictory, side effects. In these cases the human element is often regarded as a safety critical factor. We argue that the human element has unique abilities in dealing with critical and highly dynamic situations which can contribute to the system's recovery from non-routine or critical situations

5 GENERIC COMPETENCIES FOR RESILIENT SYSTEMS

Technology and regulations, intended to prevent, mitigate, and manage critical situations, will not be enough to achieve the best possible levels of safety. "[T]he very rules, procedures, and techniques used to bring about excellence in emergency situations may actually contribute to failure in crisis" (Borodzicz 2004:416). A point of view that has been adopted in recent years in the aviation domain as a result of research in high-risk and high-reliability environments: The human element has to be trusted (and supported) in dealing with critical situations instead of being eliminated from the control loop (Dekker et al. 2008).

Reason (1990) distinguishes between people "at the sharp end" who are located at the place in time of the accident (i.e. the crew of seafarers) and those people "at the blunt end" who are indirectly involved into the happenings as, e.g., industrial engineers, nautical architects, agents, policy makers, or designers (Celik et al. 2007). In terms of proactive risk management onboard, the "generic competencies" could be beneficial in mastering complex critical situations and allow the seafarer to mitigate or to manage them successfully. We claim that besides occupational skills and knowledge there is also the need for a set of domain-independent generic competencies that help seafarers at the sharp end to handle critical situations. These will be elaborated in the following paragraphs:

In critical situation seafarers face information overload as well as erroneous, contradicting, incomplete or even lacking information (cf. Tab. 1: diffuse state of information). The seafarer has to learn to cope with these circumstances in a quickly developing situation of stress and threat. The ability to develop strategies to handle the information available and to analyze in order to make valid decisions is called *Information Management* (Bergström et al. 2008, Dörner 1996, Strohschneider 2010).

In routine situations and some particular critical situations (such as man-over-board, abandon-ship, or fire drills) responsibilities and functions onboard are clearly structured. Yet, in a critical situation these structures might need to be adjusted according to the given circumstances. *Communication and Coordination* (cf. Tab. 1: inadequate communication) are indispensable competencies to articulate causal coherences and adapt to unfolding events (Bergström et al. 2008, Strohschneider 2010).

Non-routine situations are characterized by uncertainty as well as their dynamic character (cf. Tab. 1: unlikely and unexpected events, safety flaws and ambiguity). Therefore, decision-making has to take into account all available and relevant information while still being aware of current developments. The process of continuously structuring decision-making and the implementation of decisions is described by *Decision and Implementation*. This competency helps to make decisions based on what is actually happening and to develop alternatives for action (Bergström et al. 2008, Dörner 1996, Strohschneider 2010).

In rapidly progressing situations it is vital to perform *Effect Control* (cf. Tab. 1: non-compliant behavior, technology brings procedural change). This is the process of checking whether the intended effects of actions are achieved (or not) and whether the situation develops according to or in contrast to the expectations (Bergström et al. 2008, Dörner 1996, Strohschneider 2010).

This set of generic competencies supplements requirements like "situation awareness" or "shared mental models" that are often referred to in the human factors literature as being critical for safe voyages (Stanton et al 2001, Stout et al. 1999). It is comparable to Dörner's (1996) model of decision making and problem solving competencies which describes skills that help in transferring knowledge and analogies from one context to another to allow for flexible problem solving.

Predefined and well-rehearsed SOPs, can only prepare for expected critical situations and might fail under (slightly) different conditions, such as similar but yet different scenarios or in the absence of key players. In these situations, a more flexible approach seems promising: "It was found that in every single case of a successfully managed crisis event, the positive outcome could be directly linked to creative or flexible rule breaking by key decision makers in the response" (Borodzicz 2004: 418).

6 CONCLUSION

We neither intend to appeal nor to ban emergency drills and SOPs. Instead we pledge to question them in situations when they reach their limits and complement safety by educating seafarers on the use of generic competencies. There is a place and time for each SOP and each regulation – but also for generic competencies. Seamen should trust their own knowledge and skills in decision making and be able to abandon rules and routines if they are detrimental to the safety of crew, ship, or environment. We argue

that the human element has unique abilities in dealing with critical and dynamic situations and thus can contribute to the system's recovery from non-routine or critical situations. These abilities do not come out of nowhere, they have to be trained and further developed.

While the value of non-technical skill taught in courses like Crew Resource Management or Engine Room Resource Management has been widely accepted (Wu et al. 2014), there remains the challenge of an effective integration of a crew's resources across all working areas (Brenker et al. 2014): As pointed out above, emergency situations demand a coordination of all crew members to manage the situation effectively. Therefore, we make the case for the training of generic competencies as a set of competencies that reach beyond occupationally anchored skills and facilitate the handling of new and uncertain situations. From this vantage point, generic competencies are best described as a toolbox that could provide seafarers with the necessary tools to regain control of situations that are difficult to control if they are approached by the book.

7 FURTHER RESEARCH DIRECTIONS

Educating seamen on generic competencies confronts us with many challenges. They range from educational and didactic questions to challenges which distinguish the maritime domain from many workplaces ashore. Three questions seem to be of special importance:

- 1 The concept of generic competencies is in accordance with current maritime training and qualification approaches (Hill et al. 2014). It remains open how to best adapt and integrate various approaches and concepts to match seafarers' demands.
- 2 How can generic competencies be taught in an effective and sustained way? This is a current research question in various domains (Bergström et al. 2009, Heijke et al. 2003 Strohschneider & Gerdes 2004).
- 3 Who are the key players to be educated? Bearing in mind that crews are affected by high fluctuation (Carbone 2005) and have to work across language barriers (Kahveci et al. 2002, Sampson & Zhao 2003) this becomes a major issue. How can we assure that crews have collectively acquired adequate generic competencies so that the level of safety onboard is actually enhanced (Brenker et al. 2014)?

We do not claim that we already have answers to these questions. However, we argue that trusting the human element at the sharp end and acknowledging its contribution to successful mastering of critical situations is a proactive measure for safety management. It depends on the conception of the human element whether a flexible handling of critical situations in order to return to a routine state is judged as rule breaking or a paradigm shift (Borodzicz 2004) in maritime safety.

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