

# Sensemaking and resilience in safety-critical situations: a literature review

S.S. Kilskar

*SINTEF, Trondheim, Norway*

B.-E. Danielsen

*CIRiS NTNU Samfunnsforskning, Trondheim, Norway; NTNU, Trondheim, Norway*

S.O. Johnsen

*SINTEF, Trondheim, Norway; NTNU, Trondheim, Norway*

**ABSTRACT:** Recent accidents and near-accidents, such as the capsizing of the anchor handling vessel Bourbon Dolphin in 2007 and the unintended list of the drilling rig Scarabeo 8 in 2012, underline the need for addressing sensemaking in safety-critical situations within the maritime domain. This paper is a literature review to answer the research question: *What are the characteristics of sensemaking and resilience in safety-critical situations?* The aim was to establish more knowledge on sensemaking in safety-critical situations and the relationship between sensemaking and resilience. The majority of authors provide definitions based on Weick's work on sensemaking, describing sensemaking as a social process, involving the extracting of cues and enactment to create meaning to events retrospectively. Few authors provide descriptions that characterise sensemaking in safety-critical situations. There is a lack of literature regarding sensemaking in safety-critical situations in the maritime domain that addresses the issues of training and human-machine interactions.

## 1 INTRODUCTION AND OBJECTIVE

### 1.1 Background

This literature review is part of a research project (SMACS) that addresses the issue of sensemaking in safety-critical situations within the maritime domain. The aim of sensemaking processes in an organisation is to provide meaning to an event or situation in a given context. In such situations, sensemaking can be a source of resilience, in that it enables a person or a crew to "bounce back" when put under stress. Hence, the review not only focuses on sensemaking in safety-critical situations, but also on how the literature describe the relationship between sensemaking and resilience. This paper describes the search strategy and presents the results from the literature review.

### 1.2 Purpose and research question

The purpose of the review was to answer the research question: *What are the characteristics of sensemaking and resilience in safety-critical situations?* This was done by establishing a knowledge base on sensemaking in safety-critical situations, and by exploring the relationship between sensemaking and resilience.

In addition, we wanted to examine whether this literature addresses sensemaking in relation to training or human-machine interaction (HMI). This review is not specific to the maritime domain, but it was of interest to be able to later narrow it down to maritime operations.

### 1.3 Concepts and definitions

*Sensemaking* and *resilience* are two central concepts in this study, both of which have been approached within different theoretical frameworks. In the following, we provide definitions and explanations for these terms, as well as for our use of the term *safety-critical*.

#### 1.3.1 Sensemaking

Sensemaking has been of interest in the on-going research project, since the concept supports the idea that human actors in safety-critical operations and their actions are dependent on the whole socio-technical systems consisting of organisational, technological and human factors.

The concept of *sensemaking* started to emerge in organisational literature in the late 1960s (Maitlis & Christianson, 2014), but was made prominent by Karl

E. Weick in 1995 with his seminal book *Sensemaking in Organizations*. In this work, Weick summarised the sensemaking research up to that point and presented seven key properties of sensemaking; 1) grounded in identity construction, 2) retrospective, 3) enactive, 4) social, 5) ongoing, 6) focused on and by extracted cues, and 7) driven by plausibility rather than accuracy. Sensemaking has since been the subject of considerable research and there is an extensive variation in how the term is defined in the organisational literature (Maitlis & Christianson, 2014).

Weick et al. (2005) describe sensemaking as "a sequence in which people concerned with identity in the social context of other actors engage ongoing circumstances from which they extract cues and make plausible sense retrospectively, while enacting more or less order into those ongoing circumstances" (p. 409). Maitlis & Christianson (2014) developed a definition of sensemaking rooted in recurrent themes found in their literature review: "A process, prompted by violated expectations, that involves attending to and bracketing cues in the environment, creating intersubjective meaning through cycles of interpretation and action, and thereby enacting a more ordered environment from which further cues can be drawn" (p. 67). There are several factors that can influence sensemaking. Sandberg & Tsoukas (2015) found from their literature review that context, language, identity, cognitive frameworks, emotion, politics and technology constitute the main factors.

Sensemaking is thus a *process* triggered by ambiguous events that interrupt an ongoing activity and make individuals question what is going on. Individuals will extract cues from the environment that are interpreted and they act on those interpretations and revise them through the consequences of their actions. This is an ongoing cycle and according to Weick (1995) sensemaking never starts or stops as people are always in the middle of things. The events that trigger sensemaking can range from unplanned to planned events and from minor to major events (Sandberg & Tsoukas, 2015).

Sensemaking has been described as an individual cognitive process that has to do with interpretation and development of mental models (Elsbach et al., 2005). However, Weick (1995) described sensemaking as a social process where people actively shape each other's meanings, and argued that even individual sensemaking is influenced by the actual, imagined or implied presence of others.

The concept has traditionally been seen as a retrospective activity that occurs as people look back on action that has already taken place (Maitlis & Christianson, 2014). Weick (1995) argued that people can know what they are doing only after they have done it. The notion of prospective sensemaking (i.e. consideration of impact of actions) has long been a part of the literature (Gioia et al., 1994). In recent years prospective or future-oriented sensemaking has

gained more attention (e.g. Gephart et al., 2010; Rosness, Evjemo, Haavik & Wærø, 2016).

### 1.3.2 Resilience

The commonly used definition of safety has been "freedom from unacceptable risk". In resilience engineering safety is defined as the ability to succeed under varying conditions (Hollnagel et al., 2011). Resilience Engineering is concerned with understanding the normal functioning of socio-technical systems and how they perform under varying conditions. Thus, performance variability is not a threat that should be avoided by the use of constraining means; in complex socio-technical systems variability is considered normal and necessary. In this view it is equally important to study things that go right as things that go wrong, with the aim to reinforce the variability that leads to positive outcomes (Hollnagel et al., 2011). Ibid define *resilience* as "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (p. 275).

According to Hollnagel et al. (2011), there are four corner-stones that characterise resilient systems: 1) the ability to respond to events, 2) to monitor ongoing developments, 3) to anticipate future threats and opportunities, and 4) to learn from past failures and successes alike.

### 1.3.3 Safety-critical

In this paper, we use the term *safety-critical situation* or *safety-critical operation* to denote situations or operations that, if they go wrong, have a large potential for causing harm to people, property or environment.

## 2 METHODOLOGY

A literature search was conducted to establish a knowledge base on sensemaking in safety-critical situations, as well as the relationship between sensemaking and resilience. Literature was obtained through Boolean searches of the following interdisciplinary databases: Scopus, Web of Science, Google Scholar and Oria. Based on the objective of the study, the keywords *sensemaking*, *resilience* and *safety-critical* were selected as the most relevant. In addition, some of the searches in the abstract databases, Scopus and Web of Science, included the keyword *maritime*. To capture variations in these keywords, more specific search terms were used as shown in Table 1. Different combinations of the terms in Table 1 were used due to different search approaches in the various databases. Broad search terms (e.g. "high-risk") were used when searching the abstract databases, Scopus and Web of Science, whereas searches in Google Scholar and Oria were conducted using more specific terms (e.g. "high-risk situation").

Table 1. Search terms

Keyword	Search terms
Sensemaking	sensemaking; sense-making; sense making
Resilience	resilience; resiliency; resilient
Safety-critical	safety-critical; safety-critical situation(s); safety-critical operation(s); safety critical; safety critical situation(s); safety critical operation(s); high-risk; high-risk situation(s); high-risk operations(s); high risk; high risk situation(s); high risk operation(s); hazardous; hazardous situation(s); hazardous operation(s)
Maritime	maritime; at sea; boat; vessel; offshore

To avoid an excessive amount of search results, general searches in Google Scholar covered all three keywords of sensemaking, resilience and safety-critical. When searching the abstract databases, and when using the "all in title" function in Google Scholar, search terms related to two of the three keywords were used. To be included, the documents either had to address sensemaking in the context of safety-critical situations or operations, or discuss a relationship between sensemaking and resilience. For this reason, documents discussing sensemaking in other contexts were excluded. So were documents that primarily discuss resilience and that do not relate to the notion of sensemaking. We did not include books in this literature review, and a few papers were excluded as we requested, but did not receive, the full-text.

Table 2. Overview of the literature

Author(s)	Year	Publication type	Topic
Weick	1993	Journal paper	Disruptions of sensemaking
Gephart	1997	Journal paper	Quantitative sensemaking during crises
Beunza & Stark	2004	Working paper	Organisational resilience in a Wall Street Trading Room After 9/11
Furniss et al.	2009	Workshop paper	Reflection in the control room during safety-critical work
Baran & Scott	2010	Journal paper	A grounded theory of leadership and sensemaking
Bergström	2012	PhD Thesis	Aspects of organisational resilience in escalating situations
Grøtan & Størseth	2012	Conference paper	Integration of organisational resilience into safety management
Hayes	2012	Journal paper	Operator competence and capacity in complex hazardous activities
Lundberg et al.	2012	Journal paper	Resilience in sensemaking and control of emergency response
Sanne	2012	Journal paper	Learning from adverse events in the nuclear power industry
Hutter & Kuhlicke	2013	Journal paper	Understanding resilience in the context of planning and institutions
Rankin	2013	Licentiate's Thesis	Adaptive performance and resilience in high-risk work
Rantatalo	2013	Thesis	Sensemaking and organising in the policing of high-risk situations
Rankin et al.	2014	Journal paper	A framework for analysing adaptations in high-risk work
Busby & Collins	2014	Journal paper	Sensemaking about risk control in offshore hydrocarbons production
Haavik	2014	Journal paper	The nature of sociotechnical work in safety-critical operations
Norros et al.	2014	Journal paper	Operators' orientations to procedure guidance in NPP process control
Saleh et al.	2014	Journal paper	Safety diagnosability and observability of hazards in design
van den Heuvel et al.	2014	Journal paper	Police strategies for resilient decision-making and action implementation
Barton et al.	2015	Journal paper	Contextualised engagement in wildland firefighting
Dahlberg	2015	Journal paper	Exploration of resilience and complexity
Grøtan & van der Vorm	2015	Symposium paper	Conceptual approach to operational and managerial training of resilience
Hunte et al.	2015	Symposium paper	Dialogic sensemaking as a resource for safety and resilience
van der Beek & Schraagen	2015	Journal paper	Adaptability and performance in teams to enhance resilience
Danielsson	2016	Journal paper	Cross-sectorial collaboration in a potentially dangerous situation
Jahn	2016	Journal paper	Adapting safety rules in high reliability contexts
Hoffman & Hancock	2017	Journal paper	How to measure resilience
Landman et al.	2017	Journal paper	A conceptual model for pilot's ability to deal with unexpected events
Lofquist et al.	2017	Journal paper	Why different sub-cultures interpret safety rule gaps in different ways
Siegel & Schraagen	2017	Journal paper	Making resilience-related knowledge explicit through team reflection
Takeda et al.	2017	Journal paper	Developing resilience in disaster management promoting sensemaking
Teo et al.	2017	Journal paper	How leaders utilise relationships to activate resilience during crisis
Favarò & Saleh	2018	Journal paper	Temporal logic for safety supervisory control and hazard monitoring

Going through the identified documents, we found some key references that we included in this review as background (i.e. not included in Table 2).

### 3 FINDINGS FROM THE LITERATURE REVIEW

The literature search resulted in 33 documents that were included in the review. See Table 2 for the complete, chronologically listed, literature overview. As can be seen from the table, the reviewed literature includes 25 articles published in peer-reviewed scientific journals, four papers presented at international conferences, workshops or symposiums, three theses and one working paper.

No inclusion criteria were applied regarding publication year. The results clearly indicate that the use of the term sensemaking in the context of safety-critical situations, or in relation to the term resilience, is relatively recent. Except from the papers by Weick (1993), Gephart (1997) and Beunza & Stark (2004), the rest of the included literature was published in the ten-year period from 2009 to 2018.

In addition to the 33 publications in Table 2, we have also included often cited key research, among others Weick (1995) and Endsley et al. (2003).

The following chapters describe how this literature use the term sensemaking; how it characterises sense-making in the context of safety-critical situations; and how it describes the relationship between sensemaking and resilience. In addition, we describe the few issues we have found of sensemaking in relation to training, human-machine interface, the maritime domain and design/development

### 3.1 *The use of the term 'sensemaking'*

As outlined in chapter 1.3.1, the concept of sensemaking does not have one single definition. Weick (1995) stated that "(...) people can make sense of everything. This makes life easy for people who study sensemaking in the sense that their phenomenon is everywhere" (p. 49). For this reason, we started the review by taking a closer look at how the various authors of the included literature use the term.

In 1993, Weick reanalysed the Mann Gulch fire disaster in Montana in which 13 firefighters died. Here he provided analyses of sensemaking as a generic phenomenon, explaining that "the basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs" (p. 635). He further uses the example of Mann Gulch to argue that sensemaking is about contextual rationality and that it is "built out of vague questions, muddy answers and negotiated agreements that attempt to reduce confusion" (Weick, 1993, p. 636).

As described by Maitlis & Christianson (2014), the term sensemaking is often used without any associated definition from the literature, and when definitions are provided there are a variety of meanings asserted to it. Correspondingly, in our study we found that several authors include sensemaking as a general notion and do not provide any associated definition (e.g. Favaro & Saleh, 2018; Saleh et al., 2014; Sanne, 2012). Some provide references to the work of others, but without reproducing the actual definition (e.g. Grøtan & van der Vorm, 2015; Jahn, 2016).

However, most of the papers in this review provide definitions or references based on Weick's work on sensemaking, describing sensemaking as a social process, involving the extracting of cues and enactment to create meaning to events. These include, among others, the work of Baran & Scott (2010), Danielsson (2016), Hayes (2012) and Tekeda, Jones & Helms (2017).

Some describe sensemaking as a more cognitive process and refer to Klein's macro-cognitive/data-frame model (Hoffman & Hancock, 2017; Siegel & Schraagen, 2017), whereas others refer to the work of both Weick & Klein (e.g. Landman et al., 2017; Norros et al., 2014; Rankin et al. 2014).

Some authors describe sensemaking as a process building and supporting situational awareness (Lundberg et al., 2012; van den Heuvel et al., 2014).

Situational awareness being a tactical (short term issue) while sensemaking is a broader strategic concept (long range issue) creating and supporting understanding. In his paper on sensework, Haavik (2014) uses the definitions of Weick to explain how sensemaking is a theoretical, generic framework that addresses mental processes and aspects of work. Alternatively, a few papers focus on the Cynefin sensemaking framework described in the work by Kurtz & Snowden (2003) (Dahlberg, 2015; Grøtan & Størseth, 2012).

The concept of sensemaking has traditionally, and in accordance with the work of Karl E. Weick, been described as retrospective in the sense that we make sense of our actions and experience after they have occurred. Most of the literature in this review uses the notion of sensemaking accordingly, often referring to Weick when doing so (e.g. Baran & Scott, 2010; Rantatalo, 2013; Teo et al., 2017). However, a few of the authors use the term in a more future-oriented sense. As an example, Barton et al. (2015) introduce the term of proactive leader sensemaking, arguing that leaders in particular play a critical role in creating and maintaining a context for actively managing uncertain contexts.

### 3.2 *Characteristics of sensemaking in the context of safety-critical situations*

There are several factors that can influence sensemaking; context, language, identity, cognitive frameworks, emotion, politics and technology (Sandberg & Tsoukas, 2015). Thus, in the context of a safety-critical situation there might be characteristics of sensemaking other than or more prominent than the characteristics of everyday sensemaking. For instance, it might be expected that strong negative emotions like stress and fear would be influential on sensemaking in such circumstances. However, the literature found in this review did not discuss these characteristics explicitly.

In his analysis of the Mann Gulch fire disaster Weick (1993) describes the disaster "was produced by the interrelated collapse of sensemaking and structure". The smokejumpers expected to find a fire that they would have control over within the next morning. This positive illusion prohibited them from making sense of the cues in their environment contradicting this expectation. Weick describes unclear roles, identity issues and in the end the intense emotion of panic that led to the disintegration of the group and to the primitive tendency to flight. Unfortunately, this response was too simple to match the complexity of the fire and 13 men lost their lives.

After completing a field study of 80 interviews, Busby & Collins (2014) categorised the many ways of acting through which informants made sense of the risk control task. The authors provide explanations to each of their 32 categories, but elaborate on the five

more commonly used. These are 1) being circumscribed (constrained, realistic, moderate), 2) being engaged (closely involved, concerned), 3) being resolute (rapid, and consistent in acting) 4) being socialised (social outcomes and systems of social obligation), and 5) being solicitous (seeks opinion and external references). The authors use their qualitative findings to suggest that the sensemaking of organisational members is simultaneously optimistic and pessimistic about the capacities of social organisation to manage risk. This balance is, however, not of individual sensemaking and is not a deliberate choice.

Lundberg et al. (2012) explored a model for describing and studying resilience in management of safety-critical/irregular events. The model was based on changes in the ongoing process, the actors sensemaking and control functions and the technology used for sensemaking and control. The model helped to identify resilience building processes and sources of resilience emergency responses.

Several other authors describe the characteristics of sensemaking by describing it in terms of how it relates to the concept of resilience. This is the topic of the following chapter.

### 3.3 *The link between sensemaking and resilience*

As described in the introduction, one goal was to establish a knowledge base on the relationship between the two concepts of sensemaking and resilience.

In his reanalyses of the Mann Gulch fire disaster, Weick (1993) states that the disaster was produced by the interrelated collapse of sensemaking and structure. Weick mentioned the importance of nonstop talk as a critical source of coordination in complex systems. He proposes four potential sources of resilience that "make groups less vulnerable to disruptions of sensemaking" (p.628). These include improvisation and bricolage, virtual role systems, the attitude of wisdom, and norms of respectful interaction. Thus, from this perspective, resilience is core to maintaining sensemaking in critical situations.

Other authors argue that sensemaking is an important source to achieving resilience. Through their review of disaster management literature, along with illustrative examples from global disasters, Takeda et al. (2017) highlight the importance of resilience in disaster management. They argue that heedful interrelating and sensemaking are two of the central tenets of resilience research and that a greater attention to resilience in the disaster management process could be achieved through a focus on the development of sensemaking and heedful interrelating. Takeda et al. (2017) conclude that future research is needed to further understand resilience and sensemaking.

Rankin (2013) draws lines between Hollnagel's four central abilities to characterise a resilient system and the sensemaking capabilities of seeking information, ascribing meaning and action as described by

Grøtan et al. (2008). In a paper from the same year, Rankin and her co-workers present a framework for analysing adaptations in high-risk work (Rankin et al., 2014). Here they explain how *sensemaking variety* "includes the ability to process information and revise it as the world changes, given contextual constraints and the experience and knowledge of the individuals involved" (p.84). Thus, sensemaking is important for adaptive behaviour, which in turn is a prerequisite for resilience. They focus on the importance of observing sharp-end adaptations as critical to identify system brittleness and resilience.

Others suggest that sensemaking plays an important role in accomplishing tasks that facilitates organisational resilience, especially when the sensemaking is carried out by leaders (Teo et al., 2017). According to Hunte et al. (2015), "shared (social) sensemaking creates and nourishes common awareness and understanding of the 'operating point', and in so doing facilitates coordination and safer performance. This is an essential condition for the emergence of safety and resilience" (p.1). Similarly, van der Beek & Schraagen (2015) list sensemaking, or situation assessment, as one of several team resilience abilities. However, they do not provide a thorough discussion on sensemaking as such.

The sensemaking perspective is also used in the literature as a means to analyse or explain resilience. According to Bergström (2012) "the development of a theoretical framework for analysing organisational resilience in escalating situations needs to relate to the explanatory potential of sensemaking theory" (p. 8). To enhance a dynamic understanding of resilience, Hutter & Kuhlicke (2013) analyse its elusive character from a sensemaking perspective. In their paper, resilience is understood as a "content of sensemaking processes in the context of a crisis" (p. 294). The authors state that the work of Weick in 'sensemaking in organisations' on the one hand and 'resilience' on the other is only loosely coupled, and they connect the two a bit more explicitly for planning research about resilience. To understand how groups, organisations and networks make sense of resilience in the context of a crisis, one should consider the four processes of committing to resilience, expecting resilience, arguing about resilience and manipulating with resilience. These are referred to as sensemaking processes in planning research and practice (Hutter & Kuhlicke, 2013).

In their paper, Lundberg et al. (2012) study resilience in the context of sensemaking and control in emergency management of irregular emergencies, and proposes an emergency management analysis model. The model unifies and complements existing models by explicitly modelling resilience factors and the actors 'sensemaking and control functions and technologies' variety. Other authors using sensemaking theory to describe aspects of resilience, is Siegel

& Schraagen (2017). In their article on team reflection, they make an attempt to use reflection and the data-frame theory of sensemaking to show the relationship between knowledge and resilience.

Finally, Hoffman & Hancock (2017) aim to promote a discussion on how to measure resilience. They explain how sensemaking provide information to the work system about whether and when the system needs to change its understanding of problem situations, and further argue that this means that "adaptive and resilient sensemaking requires mechanisms for recognizing anomalies and situations that mandate change" (p. 571).

### 3.4 *Sensemaking as a basis for change, innovation, creativity and design*

The literature has indicated how sensemaking supports innovation, design and creativity. Sensemaking has often been limited to an organisational context, seldom discussing issues such as system design. Saleh et al. (2014), point out that safety science seems to have drifted from the engineering and design side of system safety towards organisational and social sciences or refinement of probabilistic models. To improve safety and resilience in safety-critical operations, we must have a broad based approach involving the socio-technical system, and also how cues and prospective sensemaking can be enabled from the design phase on.

It is also mentioned that sensemaking is a key process for learning in organisations, teams and individuals (Maitlis & Christianson, 2014) – one challenge is to use new information rather than engage in sensemaking based on prior beliefs. Sensemaking is also concerned with new meanings that can underpin new ways of organizing, understanding and design. When sensemaking of organisational members are impacted, the participants are motivated to change their own roles and practices. This has especially been supported by looking at interpretations and actions through the process of action research, Greenwood & Levin (2006).

### 3.5 *Topics partly covered in the literature review*

Accident reports have shown that insufficient training and poor HMI may impair sensemaking processes and thus lead to incidents and accidents. After the incident at Scarabeo 8 the investigation report attributed the incident to insufficient training of control room personnel and weaknesses in the control room's human-machine interface (Ptil, 2012). As discussed by Endsley et al. (2003) human-machine-interface is a key factor shaping operator performance, via concepts like sensemaking and situation awareness. We thus expected some of this literature to address sensemaking in relation to training or HMI. However, we did not find much relevant literature through our

review. In the following, we have summarised our findings related to training, HMI and sensemaking in safety-critical situations within the maritime domain.

Not many of the reviewed documents look at ways of training to improve sensemaking. However, Takeda et al. (2017) focus on building capacity for individual actors to interrelate in a heedful manner. In Saleh et al. (2014) it is mentioned that the ability to diagnose hazardous states provides one way to improve operators' sensemaking and situational awareness after an adverse event. It is synergetic with organisational factors in support of accident prevention, particular safety training, that can be shaped by including off-nominal conditions. Rantatalo (2013) describes how observations that were carried out were targeted joint police management training in the setting of full-scale simulated scenario, arguing that "from sensemaking and organisational reliability perspectives, high-strain situations like that described above offer a possibility to observe interaction patterns during incident management in a realistic setting" (p. 55). One of the conclusions drawn in the paper by Landman et al. (2017) about dealing with unexpected events on the flight deck, is that interventions should focus on "increasing pilot reframing skills (e.g. through the use of unpredictability in training scenarios)" (p. 1161). The authors propose a conceptual model for explaining pilot performance in surprising and startling situations; a model that can be used to design experiments and training simulations. However, several of the reviewed papers discuss training that is aimed at enhancing resilience (Bergström, 2012; Grøtan & van der Vorm, 2015; van der Beek & Schraagen, 2015).

Siegel & Schraagen (2017), describe processes and HMI tools to make boundaries explicit in railway operations. In the maritime sector the ability to handle demanding operations safely is increasingly dependent on ICT-based control systems, e.g. dynamic positioning and ballasting. Hence, the impact of HMI on sensemaking is an important topic for our project. However, few of the documents covered by this literature review address this issue. Relevant, but brief, discussions on such interaction are made in the papers by Dahlberg (2015), Landman et al. (2017) and Sanne (2012).

Furthermore, almost none of the identified publications on sensemaking in safety-critical situations are related to maritime operations. A couple of the papers discuss sensemaking in the context of offshore oil and gas production (Busby & Collins, 2014; Hayes, 2012). The doctoral thesis by Bergström (2012) is the only publication in our review that is related to navigation and shipping, although not specifically concerning sensemaking.

### 3.6 Limitation of the review

Our findings should be considered in light of the limitation in the search terms. In addition to the search terms related to the keyword *safety-critical*, we could have included *surprising*, *emergency*, etc. Also, we could have obtained interesting findings had the review included papers on *situational awareness*. However, we chose to keep this review focused on the terms of specific interest for our project.

## 4 DISCUSSION AND CONCLUSIONS

The current literature review aimed at describing how the selected literature use the term sensemaking; how it characterises sensemaking in the context of safety-critical situations; and how it describes the relationship between sensemaking and resilience.

We found that several authors use the term sensemaking without providing a definition, and those who do refer to Weick's work describing sensemaking as a social process, involving extracting cues and enactment to create meaning to events retrospectively.

Sensemaking and resilience were found to be described as related in the reviewed literature. Sensemaking creates the context for being resilient; at the same time sources of resilience, such as redundancy (i.e. redundant clues), help to make sense of the situation. Lundberg et al. (2012) have suggested a model for resilient sensemaking, exploring changes in the ongoing process, the actors sensemaking and control functions and the technology used for sensemaking and control. However, little is written on the issue of sensemaking in safety-critical situations that also concern aspects of training, human-machine interaction or the maritime domain; thus, we see a need to increase our knowledge in these areas by observation studies and targeted literature reviews.

Sensemaking is seen as a long term strategic process, creating understanding. There has been a discussion whether sensemaking is something that happens inside the individuals' heads or if it is a social construct. In our further work, we would like to explore sensemaking as a social construct, impacted by organisations, technology and human factors. Also, sensemaking has been described as both a retrospective and a prospective process. We would like to build on the research of prospective sensemaking to understand how to build resilience through future actions.

Sensemaking is accomplished through perceiving cues, creating meaning/learning (through interpretations and actions) as discussed in Maitlis & Christianson (2014), thus it is dependent on responsibilities, procedures, training and technology (such as human machine interactions). However, unexpected or safety-critical situations do not necessarily trigger sensemaking; it happens when there is a discrepancy

from what one expects. The expectations are influenced by the amount of experience, training and the degree of questioning attitude, i.e. in line with existing group norms or organisational culture.

Discrepancies must also be supported by design, i.e. having redundant systems that can reveal discrepancies, and by training to ensure a questioning attitude. This is in line with sensemaking in HRO - High Reliability Organisations, where practices such as "preoccupation with failure", "reluctance to simplify" and "sensitivity to operations" support the explorations of cues and interpretations (Weick & Sutcliffe, 2011).

Further work in the project will focus on how to strengthen the loop of perceiving cues, creating interpretations, assert meaning to events taking actions. Further, how to improve the design of interfaces between automation (i.e. HMI and procedures) and how to train to facilitate sensemaking and resilience. Through this work, we aim to contribute to improve the ability to handle safety-critical situations in demanding maritime operations.

## 5 REFERENCES

- Baran, B.E. & Scott, C.W. (2010). Organizing ambiguity: A grounded theory of leadership and sensemaking within dangerous contexts. *Military Psychology*, 22 (Suppl 1), 42-69.
- Barton, M.A., Sutcliffe, K.M., Vogus, T. J. & DeWitt, T. (2015). Performing under uncertainty: Contextualized engagement in wildland firefighting. *Journal of Contingencies and Crisis Management*, 23(2), 74-83.
- Bergström, J. (2012). *Escalation: explorative studies of high-risk situations from the theoretical perspectives of complexity and joint cognitive systems*. Lund University (Media-Tryck),
- Busby, J.S. & Collins, A.M. (2014). Organizational Sensemaking About Risk Controls: The Case of Offshore Hydrocarbons Production. *Risk Analysis*, 34(9), 1738-1752.
- Dahlberg, R. (2015). Resilience and complexity conjoining the discourses of two contested concepts. *Culture Unbound*, 7(3), 541-557.
- Danielsson, E. (2016). Following Routines: A Challenge in Cross-Sectorial Collaboration. *Journal of Contingencies and Crisis Management*, 24(1), 36-45.
- Endsley, M. R., Bolte, B., & Jones, D. G. (2003) Designing for situation awareness: an approach to user-centered design. *Boca Raton, FL: CRC Press*
- Elsbach, K.D., Barr, P.S. & Hargadon, A.B. (2005). Identifying Situated Cognition in Organizations. *Organization Science*, 16(4), 422-433.
- Favarò, F.M. & Saleh, J.H. (2018). Application of temporal logic for safety supervisory control and model-based hazard monitoring. *Reliability Engineering & System Safety*, 169, 166-178.
- Gephart, R. (1997). Hazardous measures: An interpretive textual analysis of quantitative sensemaking during crises. *Journal of Organizational Behavior*, 583-622.
- Gephart, R., Topal, C. & Zhang, Z. (2010). Future-oriented sensemaking: Temporalities and institutional legitimation. In T. Hernes & S. Maitlis (Eds.), *Process, sensemaking, and organizing* (pp. 275-312). New York: Oxford U.P.
- Gioia, D.A., Thomas, J.B., Clark, S.M., & Chittipeddi, K. (1994). Symbolism and strategic change in academia: The

- dynamics of sensemaking and influence. *Organization Science*, 5(3), 363–383.
- Greenwood, D.J. & Levin, M. (2006). *Introduction to action research: Social research for social change*. SAGE publications.
- Grøtan, T.O. & Størseth, F. (2012). Integrated safety management based on organizational resilience. In C. Berenguer, A. Grall, & C. G. Soares (Eds.), *Advances in Safety, Reliability and Risk Management: ESREL 2011*, pp. 1732-1740.
- Grøtan, T.O., Størseth, F., Rø, M.H. & Skjerve, A.B. (2008). *Resilience, Adaptation and Improvisation—increasing resilience by organising for successful improvisation*. Paper presented at the 3rd Symposium on Resilience Engineering, Antibes, Juan-Les-Pins, France.
- Grøtan, T.O. & Van der Vorm, J. (2015). *Training for Operational Resilience Capabilities*. Paper presented at the 6th Symposium on Resilience Engineering, Lisbon, Portugal.
- Haavik, T.K. (2014). Sensework. *Computer Supported Cooperative Work (CSCW)*, 23(3), 269-298.
- Hayes, J. (2012). Operator competence and capacity—Lessons from the Montara blowout. *Safety Science*, 50(3), 563-574.
- Hoffman, R.R. & Hancock, P. (2017). Measuring resilience. *Human Factors*, 59(4), 564-581.
- Hollnagel, E., Pariès, J., Woods, D.D. & Wreathall, J. (2011). *Resilience engineering in practice: A guidebook*: Ashgate Publishing, Ltd.
- Hunte, G.S., Schubert, C.C. & Wears, R.L. (2015). *Dialogic sensemaking as a resource for safety and resilience*. Paper presented at the 6th Symposium on Resilience Engineering, Lisbon, Portugal.
- Hutter, G., & Kuhlicke, C. (2013). Resilience, Talk and Action: Exploring the Meanings of Resilience in the Context of Planning and Institutions. *Planning Practice and Research*, 28(3), 294-306.
- Jahn, J.L.S. (2016). Adapting Safety Rules in a High Reliability Context. *Management Communication Quarterly*, 30(3), 362-389.
- Kurtz, C.F. & Snowden, D.J. (2003). The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM systems journal*, 42(3), 462-483.
- Landman, A., Groen, E.L., van Paassen, M.M.R., Bronkhorst, A.W. & Mulder, M. (2017). Dealing With Unexpected Events on the Flight Deck: A Conceptual Model of Startle and Surprise. *Hum Factors*, 59(8), 1161-1172.
- Lundberg, J., Törnqvist, E. & Tehrani, S.N. (2012). Resilience in sensemaking and control of emergency response. *International Journal of Emergency Management*, 8(2).
- Maitlis, S. & Christianson, M. (2014). Sensemaking in Organizations: Taking Stock and Moving Forward. *The Academy of Management Annals*, 8(1), 57-125.
- Norros, L., Liinasuo, M. & Savioja, P. (2014). Operators' orientations to procedure guidance in NPP process control. *Cognition, Technology and Work*, 16(4), 487-499.
- Ptil (2012) Investigation Scarabeo 8 (Gransking Saipem – Balasthendelse Scarabeo 8, 4.9.2012) from www.Ptil.no
- Rankin, A. (2013). *Resilience in High Risk Work: Analysing Adaptive Performance*. (Licentiate's Thesis), Linköping University Electronic Press,
- Rankin, A., Lundberg, J., Woltjer, R., Rollenhagen, C. & Hollnagel, E. (2014). Resilience in Everyday Operations. *Journal of Cognitive Engineering and Decision Making*, 8(1), 78-97.
- Rantatalo, O. (2013). *Sensemaking and organising in the policing of high risk situations: Focusing the Swedish Police National Counter-Terrorist Unit*. Umeå Universitet,
- Rosness, R., Evjemo, T.E., Haavik, T. & Wærø, I. (2016). Prospective sensemaking in the operating theatre. *Cognition, Technology & Work*, 18(1), 53-69.
- Saleh, J. H., Haga, R. A., Favarò, F. M., & Bakolas, E. (2014). Texas City refinery accident: Case study in breakdown of defense-in-depth and violation of the safety–diagnosability principle in design. *Engineering Failure Analysis*, 36, 121-133.
- Sandberg, J. & Tsoukas, H. (2015). Making sense of the sense-making perspective: Its constituents, limitations, and opportunities for further development. *Journal of Organizational Behavior*, 36(S1), 6-32.
- Sanne, J.M. (2012). Learning from adverse events in the nuclear power industry: Organizational learning, policy making and normalization. *Technology in Society*, 34(3), 239-250.
- Siegel, A.W. & Schraagen, J.M. (2017). Team reflection makes resilience-related knowledge explicit through collaborative sensemaking: observation study at a rail post. *Cognition, Technology & Work*, 19(1), 127-142.
- Takeda, M., Jones, R. & Helms, M.M. (2017). Promoting sense-making in volatile environments: Developing resilience in disaster management. *Journal of Human Behavior in the Social Environment*, 27(8), 791-805.
- Teo, W.L., Lee, M. & Lim, W.-S. (2017). The relational activation of resilience model: How leadership activates resilience in an organizational crisis. *Journal of Contingencies and Crisis Management*, 25(3), 136-147.
- van den Heuvel, C., Alison, L. & Power, N. (2014). Coping with uncertainty: Police strategies for resilient decision-making and action implementation. *Cognition, Technology & Work*, 16(1), 25-45.
- van der Beek, D. & Schraagen, J.M. (2015). ADAPTER: Analysing and developing adaptability and performance in teams to enhance resilience. *Reliability Engineering & System Safety*, 141, 33-44.
- Weick, K.E. (1993). The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative science quarterly*, 628-652.
- Weick, K.E. (1995). *Sensemaking in organizations*: Sage.
- Weick, K.E., Sutcliffe, K.M. & Obstfeld, D. (2005). Organizing and the Process of Sensemaking. *Organization Science*, 16(4), 409-421.
- Weick, K.E. & Sutcliffe, K.M. (2011). Managing the unexpected: Resilient performance in an age of uncertainty (Vol. 8). John Wiley & Sons.