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RESILIENCE
- AN ANALYTICAL FRAMEWORK EXEMPLIFIED VIA A DRILLING SUPPORT CENTER CASE STUDY

GRETHE O. OSE
Norwegian University of Science and Technology, NTNU, Department of Industrial Economics and Technology Management. E-mail:gretheose@gmail.com (Corresponding author)

TRYGVE J. STEIRO
Norwegian University of Science and Technology, NTNU, Department of Teacher Education

ABSTRACT

Integrated Operations (IO) is an ongoing change process in the oil and gas industry. New technological opportunities enable working in new ways that involve an integration of onshore and offshore personnel. This paper analyzes the results of two rounds of data gathering in an onshore drilling support center, in terms of the development of resilience. The first round took place in 2004/2005 and the second in 2012. The current study present a framework for the analysis of resilience and have used the case company as a mean of testing the framework. Our findings indicate that the support center has taken a huge step in the direction of becoming more resilient. The drilling company has tested a number of designs and sizes of support centers, each of which has different pros and cons. For the drilling discipline to develop resilience, it is essential that the number of rigs supported by a center is not too large, as they must not become involved in too many rigs and drilling operations. Our findings also indicate that the suggested framework provides a good overall picture of the development of resilience in the case company.

1. INTRODUCTION

Offshore drilling operations are considered to be a high- risk activity demanding centralized control in line with Perrow (1984) in order to ensure safe operations. In order to enhance performance and safety Integrated operations has been put forward in the oil and gas industry (Ose and Steiro, 2012; 2013). "Integrated Operations" denotes a change process that has been and still is taking place in the oil and gas industry. Integrated Operations (IO) are usually defined in the following terms: *"The vision of the Digital Oil Field is one in which operators, partners, and service companies seek to take advantage of improved data and knowledge management, enhanced analytical tools, real-time systems, and more efficient business processes"* (Edwards et al., 2010, p. 1). Furthermore, they describe three aspects that are central to recognizing operations as IO:

1. A move to a real-time or near real-time way of working.
2. The linking up of one or more remote sites or teams to work together.
3. A move to more multidisciplinary ways of working.

These new approaches are used to overcome traditional obstacles to efficient decision-making in terms of geographical, organizational or professional challenges (Skjerve & Basio, 2012). A summary of these new ways of working in IO is shown in Table 1.

Table 1. IO and traditional ways of working in petroleum companies (Skjerve & Basio, 2012).

Traditional way of working	Integrated Operations way of working
Serial	Parallel
Single discipline	Multi disciplinary
Dependence on physical location	Independence of physical location
Decisions based on historical data	Decisions based on real-time data
Reactive	Proactive
Continuous relationships with team mates	More fragmented relationships with team mates
The collaboration activity will exhibit a higher degree of informal exchange	The collaborative activity will be more formal
Lower degree of technology-mediated teamwork and use of groupware technology	Higher degree of technology-mediated teamwork and use of groupware technology
Static work processes	Dynamic work processes

We argue that organizational resilience is an important characteristic that needs to be built into IO in order to fully exploit the competence of a team and to make better-informed and safer decisions. When functions are planned to be moved from offshore installations to offices onshore, the personnel in these offices must be ready and able to take them on in such a way that safe operation is maintained or improved. Resilience increases the safety of the decisions made (Weick, 1987; LaPorte and Consolini, 1991), and it becomes vitally important when changes lead to increased onshore control. Long distances between the actual operations offshore and the control of these operations by onshore personnel affect the ability to detect potential problems at an early stage, as proximity to the operation provides rich sources of feedback that involve almost all of the senses (Leveson, 2004).

Our theoretical foundation is the theory of High Reliability Organizations (LaPorte and Consolini, 1991; Weick, 2001; Weick and Sutcliffe, 2007), in which organizational redundancy and mindfulness are important concepts, and the field of Resilience Engineering (Hollnagel et al., 2006; Hollnagel et al., 2011), in which the ability to monitor, anticipate, respond and learn is emphasized. We also include the concept of communities of practice from the field of organizational learning (Brown and Duguid, 1991; Lave and Wenger, 1991; Wenger, 1998; Wenger et al., 2002), where the development of communities that share and develop competence in a defined area of expertise is vital. We have also chosen to use the normal operation as the basis for our analysis, since what is needed in a crisis must be present in some form in the normal situation (Antonsen et al., 2012; Rosness et al., 2016). Capability platform theory (Henderson et al., 2012) is widely used in research on IO in the petroleum industry, and we decided to incorporate the categories from this theory; technology, processes, people and organization/governance, as a means of structuring the theory into a framework that can be used for analyses of resilience in the IO setting. The aim of this framework is to represent the state-of the art of resilience in the IO setting and further to provide a structure that can be applied in a practical setting and where new findings in the area can be included consecutively as research makes progress.

The framework thinking is influenced on the thinking from Morgan (1986) and Bolman and Deal (1989) in order to understand and see an organization from different angles and perspectives. Bolman and Deal´s (1989) suggestion for using a framework is to combine perspectives and thereby get a better understanding of an organization and finding better and more appropriate ways of steering and managing the organization. A similar approach is provided by Rosness et al. (2004) combining six perspectives in order to analyse safety. Nicolini (2009) argue for the importance of studying organizations through lenses and by zooming in an out on operations.

The framework has already been used to analyze the development of resilience in an onshore drilling support center, where a drilling company has implemented the new ways of working corresponding to the changes described in Table 1. We have collected data from the drilling company for two different periods. The first period was as they started to set up support centers in 2004 and 2005. At that time, they had huge centers that covered all their support personnel at a single location (Ose and Steiro, 2013). The data gathering was performed by conducting observations in the support center, in-depth interviews and examination of documentation (Kvale & Brinkmann, 2008). In the course of the years, they tested various solutions, and the second period of data collection was in the spring of 2012, by which time the company had much smaller support centers at their different office locations. The center we visited was supporting two rigs, but it was possible to use glass doors to separate both according to the rigs and the various disciplines in a flexible manner. The two data-collection periods and the inclusion of questions in the interviews concerning different solutions and experiences in the time between them gave us a unique insight into the development of resilience over time in the drilling company.

Finally, we offer an overview of the findings on resilience in the drilling support center and describe the company's experience by using the framework. These experiences are currently resulting in the identification of areas for improvement and directions for further work.

2. RESILIENCE – THEORETICALLY BASED FRAMEWORK FOR ANALYSES

Hollnagel et al. (2011) defined four essential capabilities of resilience, namely: the ability to monitor, anticipate, respond and to learn. These capabilities have also been confirmed by other researchers such as Tveiten et al. (2012), Steen and Aven (2011) and Albrechtsen and Weltzien (2013). In this paper, we use these capabilities as developed by Hollnagel (2011) and include the Capability Platform theory described by Henderson et al. (2013), which introduced the sub-categories Technology, Process, People and Governance/Organization. The work of structuring the capabilities of resilience in this manner was started by Albrechtsen and Weltzien (2013) and we also include their work in this study. We have also developed criteria for resilience in earlier work (Ose and Steiro, 2013; 2012) and we restructure these criteria to fit the structure of the Capability Platform for Resilience. Our earlier work included theory from the resilience engineering literature, HROs and organizational learning. The criteria were divided into two sub-categories; practical arrangements for resilience and collaborative conditions for resilience. All of the criteria from the different sources have been edited; some of them have been eliminated when they were found to be better covered in other sources, some were merged and others were clarified or reformulated. Albrechtsen and Weltzien (2013) included many of the same sub-capabilities under the main capabilities, and we have tried to avoid extensive overlapping in order to avoid having the same discussions several times, but we recognize that there are sub-capabilities that could easily have been placed under other headings. A few sub-capabilities were supplemented in this study because we found them to be missing. Re-structuring this theory into the sub-capabilities helped to reveal that some of the topics had not been included in previous studies. We have already discussed the capability platform theory against resilience on a more fundamental level in *"Building a Capability Platform for Safety during a Change Process"* (Ose and Steiro, 2012). Relevant theory and findings from studies in the context of Integrated Operations have been included when these were found to be relevant.

Safety is a dynamic non-event (Weick and Sutcliffe, 2001). Major accidents are complex and rare. However, insight derived from HRO research encourages also the study of everyday practice. Interaction patterns lay the foundations of communities of practice and the way in which deviations are handled. Weick (1993) demonstrated that hastily-assembled groups face difficulties in establishing mutual trust in extreme situations. Sharing more of the same operation on a day-to-day basis may be an important foundation for dealing with crises. Weick and Sutcliffe (2007) argue that the ability to deal with crises requires a broad repertoire of experience and action alternatives and the ability to recombine experiences into novel responses. They also point out that knowledge of the system is important prerequisite for action. Tveiten et al. (2012) see the value of previous involvement as an important feature in dealing with emergencies. Antonsen et al. (2012) claim that what is needed in a crisis must be present in some form in a normal operation. They refer to Lagadec (1993): *"The ability to deal with a crisis situation is largely dependent on the structures that have been developed before the chaos arrives"* (Lagadec, 1993, p. 54). In a crisis situation, Weick (1993, p. 639) pinpoint the concept of "bricolage", that is the ability to "*create order out of whatever materials were at hand"*. In this paper we concentrate the work around indicators of resilience that exist during normal operation.

Hollnagel (2011) has suggested a tool for analyses of resilience called the Resilience Analysis Grid (RAG), which is based on detailing each of the four capabilities of resilience; monitoring, anticipating, responding, and learning. He also proposes four sets of issues and four corresponding sets of questions that serve as a basis for assessing a system's resilience. These issues can act as the starting point for potential concrete measures to maintain or improve resilience. The four sets of issues together comprise the RAG. Similarly, the answers to the four sets of questions characterize the resilience of a system and can be used to construct a resilience profile. It is possible to work just with the answers or ratings, but for many purposes Hollnagel finds it useful also to have some kind of pictorial or graphical representation to help communicate and discuss results. A star chart is used as a way of displaying the results. The first step in using the RAG is to provide a clear and concise system for which the RAG is to be completed. The next is to select a subset of relevant questions for each of the four capabilities. The third step is to obtain answers to the four sets of questions and to rate the answers using six categories from excellent at the top to missing at the bottom. Then, a star is drawn for each of the four capabilities. An aggregates star diagram can be drawn on the basis of the ratings of the questions for each capability (Hollnagel, 2011). For our framework, we defined the system as the drilling support center, and our framework is the set of questions systemized in terms of technology, processes, people and organization/governance. We have included Hollnagel's suggested questions into our framework and he did also say that a selection of questions is necessary – not using his questions directly. However, we have emphasized qualitative rather than quantitative discussions of the findings. Although these could have been quantified, we find that the qualitative findings are of more interest at this point and also that quantification would limit the possibilities for developing a live framework that must be updated as research in the area progresses. This is because what is regarded as being excellent at one point in time will not be given the same score if the system has not developed and improved in accordance with later standards. Furthermore, our framework is limited to the IO setting in the petroleum industry, in order to be readily applicable in this domain and to reflect the state of the art in the area at the time it is published.

In this paper, we have chosen to treat the various capabilities of resilience as a group of capabilities that must be looked at holistically, where all of them as parts of a whole picture that is larger than the sum of its parts. Having made this selection, removing one of the capabilities from this holistic picture, is not advised because they may not be complete outside of the holistic context. The following sections presents a paragraph for technology, processes, people and organization/governance for each of the main capabilities; monitoring, anticipating, responding, and learning. A summary of the main characteristics for each of them is presented in Table 2.

A resilient system must be able to flexibly monitor its own performance as well as changes in the environment. Monitoring enables the system to identify possible near-term threats and opportunities and address them before they become reality. In order for the monitoring system to be flexible, its basis must be assessed and revised (Hollnagel, 2011). In terms of technology for monitoring, the collection, visualization and distribution of real-time data are used as well as automation and autonomous systems (Albrechtsen and Weltzien, 2013). Open-space offices (Albrechtsen and Weltzien, 2013), possibilities for transparency and technology, space and other physical opportunities to collaborate (Ose and Steiro, 2013) are also technological conditions for being able to monitor operation.

Processes must ensure data quality in terms of availability, integrity, and reliability, and mathematical and statistical analyses of both real-time and historical data enable monitoring to take place (Albrechtsen and Weltzien, 2013). In addition, processes must facilitate collaboration and the sharing of ideas and knowledge, both explicit and tacit. There must also be an adequate flow of information (Albrechtsen and Weltzien, 2013)**.** There needs to be a mixture of leading, current and lagging indicators that are defined and used, as well as analyses to enable the leading indicators to be acquired. A regular inspection schedule should also be implemented (Hollnagel, 2011).

People should be curious and have high risk awareness, and local offshore knowledge should be present onshore (Albrechtsen and Weltzien, 2013). There must also be an overlap in knowledge present, and both willingness and ability to share the knowledge (Ose and Steiro, 2012). Curiousity and involvement have been found to be important aspects that contribute to awareness of risk (Rosness, et al., 2000).

An organization that is focused on high reliability faces the conflicting goals of short-term efficiency and failure-free performance (LaPorte and Consolini, 1991; Ose and Steiro, 2012). They also must be organized in a way that involves the onshore experts in decision-making. The roles and processes should also include external experts and interdisciplinary teams (Albrechtsen and Weltzien, 2013). The organization must also provide support for the use of tools and technology (Ose and Steiro, 2013).

2.2. Anticipate

Risk assessments focuses on future threats and is suitable for systems principles of functioning are known, where descriptions do not contain too many details, where descriptions can be made relatively quickly and where systems and their environments are sufficiently stable for their descriptions to remain valid for a reasonable time after they are made (Hollnagel, 2011). For systems not covered by these criteria, the capability to anticipate future risks is essentials. Regarding technology and anticipations, simulations of future developments should be performed and operational risks assessment including different actors should be performed as well as analyses of real-time data (Albrechtsen and Weltzien, 2013).

The processes should ensure that expertise is available to look into the future, in-house or outsourced. There should also be regular assessments performed. A recognizable and clearly formulated *"model of the future"* should be developed (Hollnagel, 2011). Processes to increase risk awareness by participation in risk assessments and/or simulations should be facilitated in the processes (Albrechtsen and Weltzien, 2013). Cross- checks between different actors should also be part of the processes (Woods, 2009).

Mindfulness is essential to anticipate different outcomes (Weick and Sutcliffe, 2007). Situation awareness in order to understand, interact and predict becomes important aspects of prediction and action (Heath and Luff, 1996; Endsley et al., 2003). There also needs to be a learning process in the interaction; concurrent learning. In order to achieve such an intended and purposeful process, the participants must be aware of it and focus on the relationship between their own competence and others' expertise and diversity. It is also necessary to have trust and a balance of power among the actors (Steiro and Torgersen, 2013)

Expectations regarding future events must be communicated and shared within the organization (Hollnagel, 2011). Communities of practice, where such a community is defined as "*a group of people who share a concept, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis"* (Wenger et al., 2002, p. 4), where different groups and different ways of working as aspects of regular problem-solving and work (Ose and Steiro, 2012). There should also be a rhythm in a community of practice, which is a strong indicator of its liveliness and represents different activities and participants within a community (Wenger el al., 2002).

2.3. Respond

The ability to respond to threats and emergency situations is essential for accident prevention. Technology used to prepare for emergency response could for example be simulator or scenario based training (Albrechtsen and Weltzien, 2013).

A list of events for which systems have a prepared response should be developed and updated. Criteria for activating emergency responses should also be developed and defined, as should be the length of any response (Hollnagel, 2011). Few events actually occur, which makes it relevant to investigate the processes that take place in normal operation and to determine whether they form a community of practice that can provide support in an emergency situation (Ose and Steiro, 2013). Using Carlile's (2004) framework for managing knowledge across boundaries, where the knowledge transitions increase in complexity from transfer, to translate, to transform, gives another dimension. In order for knowledge to be transformed, as would be necessary for dealing with emergency situations, a foundation of common knowledge that has been transferred and translated should be established prior to the need for transformation and the development of new knowledge. These knowledge transitions must be part of an iterative process.

Interventions to recover from errors should be defined and planned for (Weick, 1987, LaPorte and Consolini, 1991; Rosness et al., 2000). The skills and knowledge that are required in the normal operation will also have to be used in an emergency situation, as will collaboration and insight into other operations in a center that enables personnel to support one another in an emergency situation (Ose and Steiro, 2013).

Criteria for returning to normal operation should also be defined. It is also essential that adequate resources are available for response (Hollnagel, 2011). In order to be ready for emergency response, the organization must provide sufficient time and resources for discussions that may not be directly relevant to current operations but as a facet of preparedness to solve potential problems (Ose and Steiro, 2013).

2.4. Learn

A system must be able to learn from experience and to implement lessons learned into its operation. Technology that is used in normal operation should also be used for learning purposes.

Reports of operations, projects and risk assessments should be shared (Albrechtsen and Weltzien, 2013). Experiences from operations must focus not only on operational and technical matters, but should also include emotional and relational aspects in debriefings (Steiro, et al., 2010; Folland, 2009). A formal process for implementing lessons learned should be in place (Hollnagel, 2011) and updates should be made based on experience. Double-loop learning involving changes in underlying strategies (Argyris and Schön, 1978) should be supported. Formal training or organizational support for data collection, analyses and learning should also be provided, as well as support for the formation of communities of practice (Ose and Steiro, 2013).

Learning can take place on individual, collective and organizational levels, and the processes should support learning on all these levels (Hollnagel, 2011). Viable and evolving communities of practice should also be supported (Ose and Steiro, 2013) in terms of spending time and resources on them, assigning them roles in the processes that support them and implementing such arenas in the processes.

Clear principles that cover which events are to be investigated should be established, whereby the organization tries to learn from experience, as should means of confirming that the intended learning has taken place (Hollnagel, 2011). Learning needs to be of strategic importance for the organization, in which participation is legitimized and time and resources are allocated (Ose and Steiro, 2013).

Table 2. Summary of the main characteristics for the main capabilities for resilience structured according to technology, processes, people and organization/governance.

Capability Resilience	Technology	Processes	People	Organization/ governance
Monitor	Structured monitoring of current situation using available technology. Visualization and distribution of real-time data. Automation and autonomos systems.	Ensuring quality and availability of both real-time and historical data. Facilitate collaboration and sharing of ideas and knowledge; explicit and tacit. Leading, current and lagging indicators.	Overlap in knowledge. Willingness and ability to share knowledge. Curiousity and involvement.	On-shore experts are involved in decision-making. External experts and inter-disciplinary teams included. Support for use of tools and technology.
Anticipate	Simulations of future development. Operational risk assessments. Analyses of real-time data.	Ensuring expertise availability and participation in risk assessments. Increase risk awareness by participation. Cross-checks between different actors.	Mindfulness and situation awareness to understand, interact and predict. Concurrent learning. Trust and balance of power among actors.	Expectations communicated and shared. Development of communities of practice supported. Different groups and different ways of working.
Respond	Technology used to prepare for emergency respond, e.g. simulator or scenario based training.	List of events to prepare for. Support from a community of practice. Knowledge transition increase in complexity from transfer to translate to transform established.	Interventions in order to recover from errors should be defined and planned for. Skills, knowledge, collaboration and insights and from normal operation will be used in an emergency situation.	Involvement of experts during normal operation to increase the ability to provide support in emergency response. Time and resources to prepare for emergencies during normal operation.

Learn	Technology used in normal operation also used for learning purposes.	Sharing reports and experience as well as knowledge in operation. A formal process for implementing lessons learned in place. Double-loop learning.	Learning at individual, group and organizational levels.	Means of confirming that learning has taken place. Learning of strategic importance for the organization where participation in learning activities is legitimized.

3. METHODS

Data were gathered during two periods of time; in 2004/2005 and in 2012. In the first period, a project group of four researchers studied the support center and the company. Written material and oral presentations from the drilling company were used as background information before the interviews. Thirteen of the 34 employees in the center were interviewed; each lasted for approximately an hour. At least three researchers were present at each interview, and it was decided that reports checked by the researchers involved were an adequate record of the data collected. The interviewees were selected from different disciplines in the center. A longer interview was held with the center manager, and finally a videoconference with the manager, his own immediate manager and an ICT manager. The findings from this date collection period are published in Ose and Steiro (2013).

In the second period of data collection, two researchers carried out the observations and interviews during one visit to the center and through telephone conferences and e-mail contacts before and after the visit. The two researchers had also participated in 2004/2005. In this phase, nine of the total of 13 persons working in support of the two rigs were interviewed using a pre-developed interview guide. In addition, we observed how the work was done in the center for two days and also had some informal conversations with the staff.

The open-ended interviews were carried out with the aid of an interview guide (Yin, 2004; Kvale and Brinkmann, 2008; Kvale, 1996). The areas covered centered on changes in the employees' personal work situation concerning cooperation, their experiences of the change process, including any advantages and disadvantages they experienced, and possible scenarios for the future development of the center. Additional questions to produce more accurate answers and make situations more specific were asked when possible.

After each period of data collection, memos were written, that summarized the most important findings of the data-acquisition process. The memos, which were distributed to the company, enabled it to correct any misunderstandings and wrong assumptions made by the researchers.

Dijkstra (2006) questioned the notion that information on safety should be gathered only from safety personnel, and our data were gathered from all disciplines and could thus contribute to a wider perspective on safety and risk. This is important, since we see safety as a multidisciplinary responsibility. The data were also discussed by the researchers as recommended by Yin (2004), for instance, in order to limit the individual researcher's interpretations.

In the first study (Ose and Steiro, 2013) a set of criteria for resilience were developed after the data-acquisition phase. These criteria were used also when the interview guide for the second period of data-gathering was being developed. After the visit, however, we developed a new set of criteria that we found could be used as a framework for analyzing resilience in the IO setting. The theoretical foundations are High Reliability Organizations (LaPorte and Consolini, 1991; Weick, 2001; Weick and Sutcliffe, 2007) and Resilience Engineering (Hollnagel et al., 2006; Hollnagel et al., 2011). We have also included the concept of communities of practice from the field of organizational learning (Brown and Duguid, 1991; Wenger, 1998; Wenger et al., 2002). We chose to use normal operations as the basis for our analysis, since what is needed in a crisis must in some form be present in the normal situation (Antonsen et al., 2012). As a framework for structuring the criteria, we found that the structure used in the capability platform theory (Henderson et al., 2013) would provide an easy-to-follow framework. The splitting of the capabilities into technology, processes, people and organization/governance could make a valuable contribution to safety management, as this is a structure that includes all the important factors that influence safety. In this respect, it closely resembles the MTO (man/human, technology and organization) approach that has been developed by for instance Hollnagel (2004), but has also included processes which are an important element not so clearly seen in the MTO approach. In the tradition of

MTO analyses, functions that primarily involve the activities of individuals are M-type functions. T-type functions typically involve the functioning of technological systems and O-type functions primarily involve organizational aspects. The capability platform structure may also be a means of developing resilience further and may also result in a more unified, comparable and easy-to-follow approach and presentation of resilience. The framework is described in detail in section 2.

4. THE CASE

The case described in this paper is a drilling company that established a support center for its onshore teams that were assigned to supporting its drilling rigs and floaters in 2004. Before the center was set up, the locations of the onshore offices were quite arbitrary, and were not closely matched to either the rigs or the various disciplines involved. All rig support personnel were located on the same floor but in separate offices in the same area. After the establishment of the support center, the various disciplines were brought together in an open landscape in which all the support personnel were located. The relevant disciplines comprised operations, maintenance, drilling support, economy, quality, health, safety and environment (QHSE), and human resources (HR). Six persons were typically involved in the support of each installation, though some of whom were assigned to two rigs or floaters. A total of eight drilling rigs and floaters were supported from the center. The onshore personnel worked in close collaboration with the offshore personnel and supported them directly in their efforts; as such they worked close to the “sharp end” of operations. The relationship with the oil company owning the rigs was that the drilling company was responsible for the operation of the rig itself, while the oil company was primarily responsible for the planning of drilling operations that were executed by the drilling company. The oil company only had the drilling leader on the rig, while the other normal personnel were employed by the drilling company. The oil company had its own onshore support center, which worked in close collaboration with the drilling company's center. This area assigned to the support center in 2004 was about 600 square meters and was the main working area for 34 employees. In addition to standard office facilities, the area included a room for videoconferences and two rooms with large screens for displaying data in real time. One of the rooms was also the emergency preparedness room. There were also two silent rooms in which staff could hold sensitive or private phone calls or meetings. The most significant change in working conditions in the support center did not concern technological changes, but rather changes in office arrangements.

The center that we visited in 2012 was much smaller than the center in 2004/2005, and only two rigs were supported by it and 13 persons were working in or close to the center. The personnel categories were also different; operations manager, operations advisor, maintenance manager and operations planner have their primary work space in the center. The QHSE advisor, HR, economy and procurement were located in offices close to the center. The video conference equipment was integrated in the operations advisor's primary work space and glass doors were used to separate the personnel supporting the different rigs and also the Operations advisors from the operationsplanner, who supports both rigs, and the operation managers. There were extra work places in the operations advisors' offices that were used by the other staff when they participated in video conferences. The maintenance personnel were located in another room separated by a door that we observed was usually open. Video conferences were held with both the rig and the operator company and internal meetings in the drilling company across rigs and office locations. These arrangements enabled them to cooperate both throughout the center and in smaller groups. In the center, a new way of working has been established, whereby they use video conferencing actively and often.

5. EMPLOYING THE FRAMEWORK IN THE DRILLING SUPPORT CENTER

The findings of the visits to the support centers are summarized according to the framework outlined in the section "Resilience – theoretically based framework for analyses".

5.1. Monitor

Technology

The question of how to use monitoring technology has been resolved in different ways since the technology was first introduced. At first, the drilling company established a large center that supported a total of eight drilling rigs. Even though there were possibilities for transparency, open offices and physical opportunities to collaborate, too much information was present in the center, forcing the staff to focus on their immediate own tasks. This experience led the drilling company to establish smaller centers, and the center we visited in 2012 supported only two rigs. In this center, the employees could participate in discussions and decision-making for both rigs. The widespread use of glass doors also made it possible to shelter them when needed and select which activities they would participate in.

Drilling data gathered from sensors and drilling mud were analyzed both on board the rig and in the shore office. Historical data from earlier wells were also studied by shore-based personnel in order to make informed decisions. The drilling company valued these date and were using their own system in addition to the oil company's system in order to keep the data within the company, irrespective of which oil company they worked for. They had a great deal of experience in using these data. The use of both real-time data from their current wells as well as historical data from earlier wells was the established way of working. In 2004/2005, part of the problem was the lack of support for the use of relatively simple equipment such as videoconference equipment, which created problems for the employees who were supposed to learn how to use it. A simple user's guide to the videoconference equipment was also lacking. This made the staff reluctant to use the equipment and schedule videoconferences because they realised that technical problems could arise. By 2012, such problems had been dealt with, and the operations advisor was in charge of the equipment as it was part of his primary work space. Support was also available from elsewhere in the building if needed. The daily routines for using the equipment reduced the need for support, as users were familiar with the equipment.

Process

The formal systems were largely directed by the oil company they were working for, and indicators were implemented for safety measures such as accidents, near-misses and related lagging indicators. The company also has a system to report and handle notifications that are reported by the employees, such as observations or areas where they believe that changes are needed. These notifications are discussed and prioritized at the morning meetings and represent current and leading indicators. The drilling company has received feed-back from the oil company that they were doing a good job of utilizing this notification system. In addition, drilling as a discipline has an advanced system for contingency planning, whereby different outcomes of bedrock conditions and events are included in the planning process itself. In 2004/2005 there were two persons with drilling competence for each rig; the operations manager and the drilling engineer. It was reports that personnel were rather unwilling to intrude on their colleagues' areas of expertise without being asked, although they did say it was easier to ask their colleagues than before the establishment of the center. Different ways of working on the various rigs and with different operators also make questioning the work of other teams more complex. The center staff worked on projects that supported several different rigs and floaters. The deployment of personnel according to discipline should move the organization towards a more matrix-oriented organization and make experience transfer within and between disciplines easier. Differences in contracts even for the same oil company also made collaboration harder. By our visit in 2012, many of the challenges in terms of different contracts, procedures and costumers had disappeared, and collaboration between the two rigs that were supported by the center was much closer.

People

Drilling personnel are trained to be aware of risks and to look ahead throughout the drilling process, because there always are uncertainties due to the fact that they cannot know exactly how the formation is before they actually get there. The drilling company has experts onshore who have offshore drilling experience. At the 2012 support center, they also have a team of drilling experts who are up-to-date on developments in the two rigs supported there, and they are able to assist one another. The drilling personnel also overlap in knowledge and experience, which enables them to support one another. They are also willing and able to discuss and share their knowledge.

Organization and governance

In 2004/2005 we found that the case company had to live with short-term contracts, and it faced tough competition. The company had recently underwent a downsizing process following the loss of some contracts. The support center and the use of videoconference equipment were implemented to gain a competitive advantage. The employees were very much aware of their vulnerability and were highly focused on the need to develop and be at the forefront of developments in order to survive. The various disciplines met to discuss what they could gain from establishing the center prior to its establishment. All the personnel we interviewed agreed that short-term savings and cost-cutting were the objectives of establishing the center. High health and safety standards were also important, since drilling is contract work in which health and safety criteria are regulated in the contracts. The company was used to adapting to the requirements of its customers and cooperating closely with them. It also incorporated changes as a competitive advantage, thus demonstrating its ability to be proactive. Major accidents such as blow- outs also have the potential to be very damaging for the company and could even put it out of business entirely. The commercial environment in which the company operates is the same in 2012, and it was in the process of delivering tenders and competing to get new contracts with its only Norwegian customer. In 2012, the employees seemed to have become more used to the changes, and experience had shown that the drilling company was capable of adjusting to change. It had demonstrated this earlier when some contracts were lost, and this time round downsizing was not the result; instead the company was given assignments from other offices in the company. These experiences gave the employees a sense of security.

5.2. Anticipate

Technology

In general, the drilling personnel collaborate closely with their oil company customers, both onshore and offshore. The drilling program, which is the plan for producing the field, is developed by the oil company, and changes are approved by it. The highest authority during drilling is a representative of the oil company offshore, and he makes the final decisions regarding drilling activity and any deviations from the drilling program. The drilling company's own computer system is used to gather experience in addition to the system it uses in relation to the oil company. The company chose to have this system in order to be able to store its own experiences and secure them within the company if the contract with the oil company is lost. The data in this system are used to anticipate unexpected events easier, by providing access to all the wells that are drilled by the company.

Process

The process of having the support center staff work closely with the offshore personnel is designed to enable the onshore staff to act as an organizational back- up and to be an active, resilient part of the organization. Close collaboration between the drilling company and the oil company embedded in the processes strengthen the ability of both parties to anticipate because they now utilize on existing competence. One representative of the drilling company had his primary workplace at the oil company's office and the routine use of videoconferencing in 2012 enabled even closer collaboration between the two companies than previously. At the time of our visit in 2004/2005, the drilling personnel in the support center frequently went to meetings at the oil company's office. In 2012 they still went there, but they also had daily video conferences. These changes also made it easier for the entire support center to be kept up-to-date on the content of these meetings.

People

Drilling personnel are generally trained to draw up contingency plans and to be mindful and expect the unexpected. The personnel in the support center work closely with the offshore personnel at the same time as they are distanced from the actual drilling. Having drilling experience, this close collaboration with the offshore drilling personnel, as well as data from current and earlier wells, enables them to achieve a situation awareness and to be mindful. They also have offshore experience, which enables them to understand offshore activities. Learning and experience transfer in the support center and between the center and offshore personnel are valued and emphasized by the personnel. Between our visits a camera on the drilling deck had been tested when working for a different oil company. This provided the support center personnel useful information about ongoing activities and reduced the need for phone calls. They would like to have these cameras also with their current oil company customer, but control issues related to the unions had not yet been resolved.

Organization and governance

In 2012 we observed that safety was an important topic both at meetings with the customer and at internal meetings. There were discussions about findings that had been reported into the customer's system and the drilling company had received feedback from the oil company that they were good at reporting deviations. These feedbacks led to even more focus on reporting and discovering deviations and there was an attitude in the meetings to keep up the good work and to share both deviations and also positive experiences. We also observed that they planned drilling operations ahead of time and discussed what could possibly go wrong during the planned operations. In 2004/2005 the rhythm of meetings and discussions in the center was not well-defined. A routine of regular meetings to discuss the experience gained had been established, which everyone working there attended. Morning meetings with individual rigs were held every day with the oil company's onshore office and offshore personnel. The QHSE department also took part in meetings before offshore personnel went offshore. These meetings had changed to a certain extent from regular meetings where they used to travel to the helicopter bases where the offshore personnel were gathered, to the use of videoconferencing. The economy department had meetings for all the floaters every fortnight, where they spent an hour looking at similarities and parallel issues. These meetings started since the move into the center.

5.3. Response

Technology

In the course of our visits, we did not have an opportunity to observe any emergency situations or drills. However, we know that the drilling personnel have arrangements for being available on call at all times. The system is designed in such a way that they go to the center if an emergency situation occurs and the time taken to mobilize is short they are "on call", and when they are they are not allowed to be unavailable or far from the office. Their experience of using the technology in normal operation enables the personnel to use it in emergency situations too, because the normal operation has identified the challenges and these have been resolved.

Processes

Operational risk assessments are performed under the leadership of the oil company when wells are being planned, enabling them to identify possible risks and emergency preparedness related to these identified risks. They are also urged to report possible risk factors offshore and the drilling company has received feedback that they are doing a good job. Possible risks are also discussed in the morning meetings with the offshore and the onshore personnel from the drilling company and the oil company. These processes are more easily followed in 2012 than in 2004/2005 because they are similar for the rigs supported in the center, and there is only one oil company involved.

Processes have been defined to enable the support center in the drilling company as well as the emergency response center in the oil company to work together with the offshore personnel in an emergency situation. The drilling company participates in training organized by the oil company.

In 2004/2005 the drilling company had not implemented learning processes, and communities of practice in drilling were not highly developed. For the drilling operations too much information was available in the center, many meetings were being held with individual oil companies and multiple oil companies and contracts led to different processes being designed and implemented. In 2012, the drilling discipline has evolved into a strong community of practice that is supported by internal processes, and with the center supporting only two rigs it is now possible to keep informed of what is going on board both of them. They have already transferred, translated and transformed knowledge and are capable of handling new situations as a community. The drilling discipline is the most vital discipline for safety, but the supporting disciplines do not, in the small center of 2012, have the same opportunities for collaboration because they are few in number. The QHSE manager in this center had his background from drilling and participated in the drilling community as an integrated part.

People

The drilling personnel are always on the alert for possible emergency situations. The drilling programs, which include contingency plans, also keep people constantly alert to the potential outcomes of their actions. Besides skills and knowledge, established ways of working form the basis of collaboration in emergency situations. Developments in the center between our two visits and the strengthening of collaboration and a development of a community of practice for drilling have led to major improvements, and the center would appear to be much better able to handle any emergency situations that might occur. Sharing of experiences is also reported to be more valued in the 2012 center.

Organization and governance

In 2004/2005 the drilling company was serving different oil companies under different contractual conditions, which led to differences in the required responses to emergencies. In 2012, with only having one oil company as customer in Norway and standardized contracts, the emergency response is also standardized and thus easier to prepare for. With regard to responding to emergency situation, the drilling company is working in close collaboration with its oil company customer. The fact that there is only one oil company customer and that this company has one way of preparing for emergency situations enables the personnel in the center to organize and plan for emergency situations as a team.

5.4. Learn

Technology

In 2012 the technology was implemented and used as a natural part of daily work. It was used both for collaboration with the rigs, internal collaboration with different office locations in the drilling company and with the customer. They no longer had separate collaboration rooms, but had incorporated the collaboration equipment in the workspace, thereby creating a more natural flow and rhythm of work. Flexibility was achieved by extensive use of glass doors which allowed the work spaces for different rigs and disciplines to be separated. The drilling company also put some effort into collecting experience from earlier and current wells in its own data system. In 2004/2005 the drilling company did not prioritize learning and activities that were not directly related to current operations, but expected learning to take place because people were placed together.

Processes

By the time of our visit in 2012, collaboration and sharing knowledge had largely been incorporated in the work processes. In 2004/2005, collaboration was primarily with offshore personnel, and closely related to the work at hand. Among the developments between our visits has been the inclusion of internal knowledge- sharing for the purpose of learning from experience throughout the entire company – at least the Norwegian part of it. Learning is included in support processes that the company regards as important. It also has processes concerning the storage and use of data from earlier wells. In the interval between our visits, the drilling company implemented a strategic process to develop its support centers, and this has resulted in the development of the strategic importance of these centers within the company. The customer also demanded such a development, and company also received feedback that this customer was satisfied with the manner in which the drilling company has met its demands.

People

This company is used to adapting to changes in demand and is doing this successfully; otherwise, it would not still be in operation. Double-loop learning involves asking questions about the fundamental issues of whether the right things are being done, and asking questions not only about "what", but also "what if" and "why". The underlying rationale, we believe, is more related to trust. The drilling company did this, for instance, when maintenance was exploring the possibility of offering onshore monitoring of drilling equipment as an additional service to customers. Furthermore, the focus on new services to offer was present in the operating part of the organization and was discussed at meetings. An example of this was to offer to take on responsibility at the bases where equipment was being shipped offshore for making it ready for shipping. Here, an employee had identified a need and discussed it with his peers, and this was actively welcomed by management and taken further by the company. It also possessed very good indicators for one well that was being drilled while we were there, and emphasized that one also needed to learn from positive experience. The internal meetings in the different disciplines were also arenas for discussions and sharing of experiences. These meetings increase the probability that changes and improvements that have been identified on one of the rigs will be implemented at other rigs supported by the company.

Organization and governance

The opportunities for learning and also the demands to learn were highly supported in the center in 2012, and the strategic importance of learning was followed through by actions in the organization. In 2004/2005 such a strategy was set out by the management, but learning was not prioritized in the activities in the center. Perhaps the greatest change was the one in which learning was prioritized, supported and functioning well in the center. Management was concerned with the development in the company and looked at changes as opportunities more than treats. Extensive experience of working within the setting of Integrated Operations also produced security and positive attitudes. Emphasizing learning in the organization will ultimately enable support center staff to handle emergency situations better.

6. OVERALL DISCUSSION AND CONCLUSION

As our findings show, there have been large changes in the ways in which people collaborate in the drilling company following the introduction of IO and new technologies for communication and handling real-time data. At the time of our first visits in 2004/2005 the company was struggling to implement and start using the new technology and the center they established was too large to share information efficiently. The drilling company exploited this experience to establish smaller centers and incorporate technological solutions into the primary work area for some of its staff instead of having dedicated collaboration rooms. The company has always had a strong customer focus and much of these developments introduce at the instance of their oil company customers. In the first phase of IO implementation, the company focused on short-term savings and cutting personnel. At our last visit in 2012, these areas had evolved into a concern regarding internal learning and knowledge-sharing processes enabled by new technology, changes as an ongoing process, providing opportunities for more interesting jobs and the will and the resources to participate in activities for other rigs than the one to which they were primarily assigned. The improvement was extraordinary and increased resilience was a product of the improved learning processes.

The most important findings from the drilling company's development of resilience are shown in Table 3.

Table 3. Findings related to the capabilities for resilience in the drilling company.

Capability Resiliene	Technology	Processes	People	Organization/ governance
Monitor	From a large center with 34 employees supporting 8 rigs, to a small center involving 13 and supporting 2 rigs. Sheltering of personnel possible by the extensive use of glass doors. Use of historical and real-time data. Video conferencing implemented as normal way of working.	Challenges related to different contracts and customers were overcome in 2012. The drilling company used the oil company's systems and has received positive feedback on the use of the reporting systems. Closer collaboration in the center in 2012.	Drilling personnel are good at contingency planning as they are used to working with a high degree of uncertainty. The drilling personnel onshore and offshore overlap in knowledge and experience. Willingness to share knowledge. Drilling supported in the center.	A change from focusing on short-term savings to being used to changes and seeing opportunities between our visits. Time was spent on keeping each other up to date.
Anticipate	The drilling company used input from current wells in both the oil company's system and their own system in 2012. Data valued by the drilling company. Data used to anticipate unexpected events.	Close collaboration between the oil company and the drilling was embedded in the processes in 2012. Daily video conferences between the oil company and the drilling support center implemented in 2012.	Possible outcomes were discussed. Onshore experts have offshore experience and work closely with offshore personnel. This close collaboration, as well as data from current and earlier wells, enabled them to achieve a situation awareness and to be mindful.	The organization did not allow time to be spent on internal discussions in 2004/2005; in 2012 internal discussions were mandatory. Experience transfer in the company was valued in 2012.
Respond	Critical personnel "on call" in case of an emergency. Extensive experience of using technology in normal operations in 2012. In 2004/2005 technology had not yet been implemented.	Operational risk assessments are performed under the leadership of the oil company when wells are being planned. Processes have been defined for the oil company and the drilling company to collaborate in an emergency situation. Foundation is collaboration in normal operation.	The development of communities of practice for drilling enables personnel to support different rigs if an emergency situation should occur in 2012. In 2004/2005 they were not able to because they did not have the necessary knowledge of the other rigs.	Organizational support for internal support made the organization better equipped to deal with emergency situations in 2012; such activities were not supported in 2004/2005.

Learn	Technology was being employed for learning purposes in 2012. In 2004/2005 learning was believed to take place by placing personnel together. The collaboration equipment is incorporated in the workspace, thereby creating a more natural flow and rhythm of work.	Learning is included in support processes that the company regards as important in 2012.	Personnel are willing and eager to learn from both positive and negative experiences in 2012. In 2004/2005 they focused more on getting their jobs done due to high demands.	A major improvement between our visits was the prioritization of internal learning processes and valuing these processes as strategically important.

Monitoring drilling operations is an essential part of the work of the drilling support center to assist offshore personnel. Data from earlier wells are used in addition to real-time data from the current drilling operation. Drilling is always subject to large uncertainties and contingency planning is always a part of the drilling program. The central finding of our study related to monitoring activities, is that the support centers must be of a size that enables employees to assimilate the available information, otherwise it will just be noise for them. Determining the right size such centers is not a simple matter, because so many different disciplines are involved. For drilling, the most important from a safety point of view, the number of rigs supported by a center must be limited and the two platforms supported by the center in 2012 were quite sufficient. It is possible that the number of rigs could be increased to three. The supporting disciplines, however, found that the rigs were too few in number to have a team to work with within the disciplines. These challenges would be improved if there were more than one center at one office location.

Anticipating potential hazards is crucial for safety. The drilling discipline is used to planning for contingencies and it also actively participates in meetings and reports dangerous elements to their oil company customer. This close collaboration was embedded in the processes and possible outcomes were discussed. In the drilling company case, the changes between our visits in using video conference equipment, with the introduction of flexible solutions for protecting and including personnel besides daily meetings at which all the personnel in the center could get relevant information were significant. These changes had reduced stress and offered more possibilities for individual adjustments, making the work more focused and increasing the number of participants involved in the process of anticipating hazardous situations.

Fortunately, having to respond to dangerous situations is not often required. Planning and training for them, however, are essential. The company has processes for being on call and mobilizing if something should happen. Its oil company customer assumes the major responsibility in case of emergencies, and is also responsible for training and developing the relevant processes. The foundations of the emergency response are embedded in the normal work and the drilling company has a well-developed community of practice that uses the previous transfer, translation and transformation of knowledge to solve problems that require new solutions and hence transformation of knowledge. Emphasizing learning during normal operations also gives the drilling support personnel a larger team than those primarily assigned to one rig, and this is able to participate directly if needed.

We found learning to be extremely important in our study of resilience, partly because we have included the concept of communities of practice in our model. We argue that learning is an essential capability for monitoring, anticipating and responding, and that learning itself should therefore not be a category. The results of learning in terms of improved capabilities for monitoring, anticipating and responding are what is important, rather than the learning as such. We also argue that introducing communities of practice and the different knowledge transitions; transferring, translating and transforming, increase the ability to be more specific in this area. Our case has shown that when learning is emphasized, prioritized, structured and supported, resilience is built into the communities of practice that are able to assist one another during normal operation as well as in crisis situations. It was clear that the mindset of the personnel in the center had changed from seeing changes as threats and as a means of increasing their work load, into being something positive that made their work more interesting and as a natural part of their jobs.

Having developed and reviewed a framework for analyzing resilience based on normal operation, we find that the categories from capability platform theory; technology, processes, people and organization/governance fit the need to shed light on all these aspects. Including the processes and organization/governance separates these categories and puts a stronger emphasize on both the actual processes that are used in daily operation and the organizational constraints and opportunities that affect the development of resilience.

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