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A conceptual framework and practical guide for assessing fitness-to-operate in the offshore oil and gas industry

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ABSTRACT

The paper outlines a systemic approach to understanding and assessing safety capability in the offshore oil and gas industry. We present a conceptual framework and assessment guide for understanding fitness-to-operate (FTO) that builds a more comprehensive picture of safety capability for regulators and operators of offshore facilities. The FTO framework defines three enabling capitals that create safety capability: organizational capital, social capital, and human capital. For each type of capital we identify more specific dimensions based on current theories of safety, management, and organizational processes. The assessment guide matches specific characteristics to each element of the framework to support assessment of safety capability. The content and scope of the FTO framework enable a more comprehensive coverage of factors that influence short-term and long-term safety outcomes.

1. Introduction

Industries operating in high-hazard environments must manage complex technical and social processes in a competitive economy with finite resources. Investigations of major accidents consistently identify how organizations[1] have failed to manage this complexity. Devastating events since 2009 include the BP Macondo disaster in the Gulf of Mexico in 2010, and the PTTEP Montara oil spill in the Timor Sea in 2009, as well as smaller events such as Chevron's 2012 oil spill in Brazil.

Public enquiries, research studies, and investigations highlight that better organizational practices and regulatory oversight could have prevented major accidents. Some of the issues identified include whether the organizations managing facilities encouraged questioning of operational data; communicated adequately with sub-contractors; understood and used designated lines of authority; and effectively managed pervasive cost pressures. These issues raise fundamental questions about the safety capability of organizations that are amplified by the rapid rates change in technology, engineering, and workforce demographics (Hopkins, 2009; Leveson, 2011a).

There is now a growing need to incorporate a broad view of the capabilities which allow organizations to operate safely (Grote, 2007) and to understand how safety capability is created, monitored, and improved (Strutt et al., 2006). However, the nature of safety capability is not well understood or articulated. In this study, we develop a systemic approach to the safety capability of organizations operating in high-hazard environments. In particular, we introduce a model of 'Fitness-to-operate" (FTO) developed in conjunction with the National Offshore Petroleum and Environmental Management Authority (NOPSEMA) as part of their stewardship of a strategic agenda item of the International Regulators Forum (IRF), a group of ten regulators of health and safety in the offshore upstream oil and gas industry. The FTO model provides the overarching framework for integrating diverse approaches to safety capability. We also outline practical guidelines for assessing FTO that can be used by regulators and organizations.

We define safety capability as "the capability to maintain the safety of complex systems operating in uncertain and interdependent environments". Managing uncertainty is important

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[1] Throughout the paper we use the term "organization" to describe the entity responsible for managing and operating a facility. A range of terms are used across industries and countries (e.g., "duty holder") to reference the responsible entity so we use this general term to denote primary legal and management responsibility for a facility.

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for operating effectively in both predictable and unpredictable environments, managing interdependence is important for coordination across diverse technical and social processes. Although safety capability is critically important it is inherently difficult to observe: major events occur relatively rarely and are prevented through multiple processes such as appropriate monitoring systems, effective team communication, and sustained vigilance. We develop the concept of "enabling capitals" to describe the observable characteristics and activities through which organizations achieve safety capability. In particular, we identify three forms of enabling capital that we label "organizational capital", "social capital" and "human capital". These three forms of capital have been extensively researched within the framework of intellectual capital to explain how organizations achieve a wide range of capabilities (Kang and Snell, 2009; Youndt and Snell, 2004). Based on our elaboration of safety capability and enabling capitals, we define FTO of an organization as "demonstrating appropriate organizational, social, and human capital to manage safety in uncertain and interdependent environments".

The current paper is divided into three main sections. First, we review the regulatory context of offshore oil and gas. We describe the progress of international regulators to develop a more systemic view of safety capabilities. Second, we develop a model that describes FTO in terms of safety capabilities and the enabling capitals that contribute to these capabilities. Third, we describe an assessment guide for evaluating FTO that has been developed with NOPSEMA. We describe how we have identified and developed measures of the enabling capitals that can be used in ongoing communication between regulators and organizations. We conclude with a discussion of implications and further development of the framework and guide.

2. Regulating safety capability in oil and gas

The IRF for Global Offshore Safety brings together regulators from Australia, Brazil, Canada, Denmark, Mexico, Netherlands, New Zealand, Norway, the UK and the USA. Oil and gas companies that operate in IRF member regimes must comply with licences granted by these regulators based on national legislative frameworks (Australian Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations; Norwegian HSE Framework Regulations, 2011; UK Offshore installations (Safety Case) Regulations, 2005). For entry to, or to operate in, IRF jurisdictions the regulators must determine if organizations possess the necessary competence, capability and capacity to meet the health, safety and environmental requirements stipulated in the regulations.

Most members of the IRF have moved from a prescriptive to a goal-setting regime for regulating occupational health and safety. A guiding principle underlying these goal-setting regimes, also known as outcome-oriented or performance based regimes, is that the primary responsibility for ensuring health and safety should lie with those who create risks and those who work with them. In the Australian oil and gas industry context this means that direct responsibility for the ongoing management of safety on individual facilities is the responsibility of the primary duty holder and not the regulator. Obligations on owners, licensees and operators (duty holders) of offshore oil and gas facilities are also set out in legislation.

Regulators use a range of formal and informal systems for ensuring legislative obligations are met and to provide insights into safety capability. In some regimes (for example Australia and the UK) a safety case is an integral part of this assessment process. A safety case is typically comprised of a facility description, formal safety assessment description, and safety management description. These items include information about policy, organizational structure and accountabilities, planning and standards, performance measurement, audit and review. In other regimes (for example Norway, Canada and New Zealand) there are alternative assessment processes to review operators' applications. The Netherlands State Supervision of Mines requires a short document outlining systems and commitments which the regulator is then able to follow up with more in-depth questions. The Norwegian Petroleum Safety Authority (PSA) has a similarly short document for the consent to operate, with much of the supporting information already understood by the regulator through pre-submission discussions and dialog. In most regimes the regulator must be assured that the operator's management system is adequate to ensure compliance with the relevant statutory provisions and that risks to the facility from Major Accident Events have been reduced to a level that is "as low as reasonably practicable" (ALARP).

The move from prescriptive to goal setting regimes started with the 1972 Robens report in the UK, which found prescriptive methods inadequate for assessing and regulating the safety capability of a facility. This reported resulted in reduced reliance on volumes of prescriptive legislation but resulted in the regulatory challenge of assessing how duty holders met their goals (Hopkins and Hale, 2002). Additionally, given recent disasters and ongoing change in the industry, it is also important to consider the limitations in the adequacy of the safety case and other assessment methods for assessing long-term capability to manage operations in a safe and environmentally sustainable manner (Leveson, 2011b).

Recent offshore oil and gas industry accidents have generated considerable analysis of the roles of human and organizational factors in these events (Bills and Agostini, 2009; National Commission on the BP Deepwater Horizon Oil Spill, 2011; Skogdalen and Vinnem, 2011). A challenge for regulators is that these types of human and organizational factors and their potential impact on the execution of processes cannot readily be conveyed in a safety case or similar documentation before operation commences. Once the facility is operating, visits by the regulator for inspections and audits provide opportunity to make more direct observations of the people that work there and the organizational culture. The collective observations of the inspectors form part of the regulator's view of the facility and its ability to meet legislative requirements and create a safe workplace.

However, it is still difficult to incorporate complex social factors such as safety culture in the assessment of safety capability. The PSA in Norway requires the operator to have a sound safety culture (see http://www.ptil.no/framework-hse/category408.html#p15 which notes "culture is not an individual quality, but something that is developed in the interaction between people") but there are no specific guidelines for assessment or integration with other measures. Bills and Agostini's (2009) review of the Varanus Island explosion identified limited opportunities for the Australian regulator to address safety culture and leadership within national legislation. They suggest that FTO concepts provide regulators with a framework to directly consider organizational issues such as safety culture, leadership, operator past history, motivation and current organizational capacity in the regulatory approvals process (Bills and Agostini, 2009).

To develop a more systematic view of the many factors that contribute to FTO, regulators need to create a common framework for discussion and assessment. To address this challenge NOPSEMA has supported a research project to develop a model of FTO that will support inter and intra-regulator discussion of factors relevant to assessing the competency, capacity and capability of operators. A goal of the FTO project is to assist inspectors, who come principally from technical and operational backgrounds, to assess human and

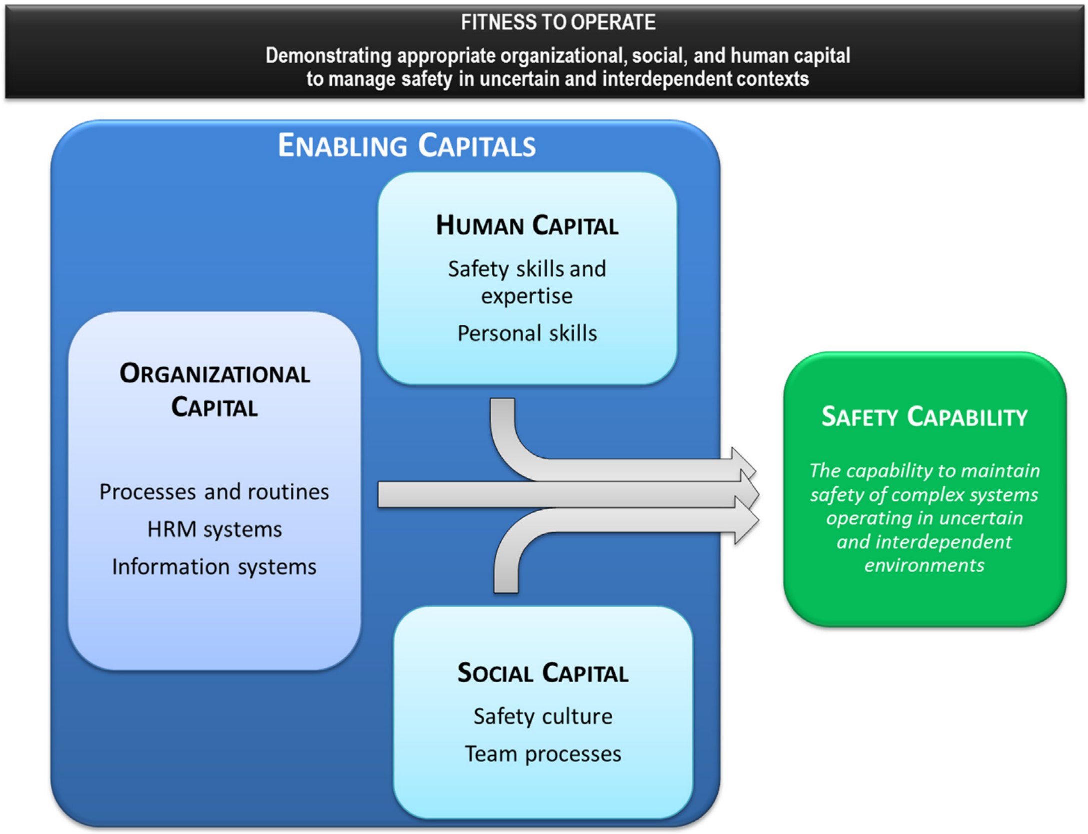

Fig. 1. Overview of FTO and enabling capitals.

organizational factors in a structured way using common terms, definitions and rankings.

3. Fitness-to-operate: safety capability and enabling capitals

3.1. Overview

It is clear that organizations can influence many of the underlying causes of major accidents (Hopkins, 2013; Leveson et al., 2009). However, there is no widely accepted view of the organizational factors that determine safety capability. A lack of consensus is not surprising given the wide range of concepts and disciplines associated with the broad idea of capability and its link to safety. Winter (2000, p. 983) described a "terminology haze" surrounding the definition of capability making it difficult to integrate diverse approaches within a multidisciplinary context.

To address this problem, we adopt a systems perspective in which we distinguish the broad concept of capability from specific processes that build capability. From this perspective, safety capability is an emergent property that arises through interactions among elements of the overall system (Leveson et al., 2009). In general, a capability is derived from the combination of organizational resources and procedures that can be deployed to meet risks, threats, and unexpected changes (Collis, 1994). We develop the concept of "enabling capitals" to describe the multiple processes that build and generate safety capability. In particular, we identify three forms of enabling capital that we label "organizational capital", "social capital" and "human capital".

The distinction between capability and enabling capitals is important because capability is expressed through actions that can be difficult to observe or that exist only as a latent potential (Grant, 1996). For example, safety capability might only be expressed in times of crisis or other extreme conditions that occur rarely or not at all. In contrast to capability, the enabling capitals are amenable to observation and provide a more tractable basis for measurement. For example, organizational capital might be assessed through documented safety systems, social capital might be assessed through team communication practices, and human capital might be assessed through safety skill audits.

In addition, safety capability is likely to be derived from multiple overlapping processes. For example, the capability to respond to unforeseen emergencies requires a mix of organizational procedures (e.g., emergency response plans), social communication (e.g., effective teamwork), and human skill (e.g., individuals with appropriate training). Our framework of enabling capitals provides a means to understand the way these different elements combine to create capability. Fig. 1 provides a summary of the relationship between organizational capitals and safety capability. The figure also summarizes the key dimensions of each capital that we develop later in the paper.

In short, we distinguish between the capability to operate safely and the enabling capitals from which this capability is derived. Below, we first outline our view of safety capability and review relevant research regarding high-hazard industries as well as general literature on capability. We then review how the enabling capitals combine to build capability.

3.2. The nature of safety capability

3.2.1. Defining safety capability

Three approaches have been influential in understanding the nature and source of safety capability: high reliability theory (HRT), resilience engineering, and safety culture. High reliability theory provides a comprehensive description of how organizations maintain safety for long periods in complex and hazardous environments. This approach identifies factors such as strategic prioritization of safety, redundancy in safety systems, and a strong culture (Weick et al., 1999). A key argument is that safety capability is derived from collective mindfulness which is embodied in systematic preparedness for and response to unexpected events referred to “action capabilities” (p. 37). Although HRT has shaped understanding of safety, it has proved difficult to define the distinguishing features of High Reliability Organizations (HROs) and the specific elements that create a HRO (Marais et al., 2004).

More recently, concepts from HRT have been incorporated into the growing field of resilience engineering. This approach argues that failure arises from inability to adapt to complexity rather than as a breakdown or malfunction (Madni and Jackson, 2009). Overall, resilience engineering describes capability as maintaining a dynamic state of stability in the presence of disruption and threat. The main characteristics of resilient organizations are the capacity to anticipate, monitor, learn, and respond (Hollnagel, 2011). Although resilience engineering builds on the concepts of HRT, there is little direct connection of ideas linking the two approaches (Hopkins, 2009). Hopkins (2013) has also criticized the lack of integration across these two areas and limited degree to which they produced testable theories or systematic measurement.

Both HRT and resilience engineering identify organizational culture as a central element of safety capability. However, the development of safety culture constructs has progressed somewhat independently of other approaches to safety and risk management (Guldenmund, 2000). Approaches to safety culture typically focus on the overall value of safety in an organization as reflected through evidence of management attitudes to safety, the development of safety skills, and communication about safety (Cox and Cheyne, 2000). However, analyses of culture do not systematically include the qualities of mindfulness emphasized by HRT or the centrality of learning and change emphasized by resilience engineering.

Although the various approaches to capability differ in their emphasis and approach to assessment, they share two fundamental concerns about the nature of capability. First, each approach seeks to describe how organizations maintain safety in changing and risky environments. Therefore, there is a strong emphasis on being vigilant for threats, preparing for unanticipated events, and learning over time. Second, there is a recognition that safety depends on complex interactions among multiple systems. Therefore, there is an emphasis on issues such as loose coupling of technical systems and coordination among social systems. We summarize these two core features of safety capability as managing uncertainty and interdependence which we describe in more detail.

3.2.2. Managing uncertainty and interdependence in complex systems

The first defining feature of safety capability is managing uncertainty in complex systems. Grote (2012) notes that uncertainty is managed either though standardization, central planning, and specialization or by empowering local decision making to respond adaptively to unpredicted events. In high hazard environments standardization and planning are essential but there is also ongoing change in technology and the operating context that require adaptive responses. Overall, a balance between stability and flexibility is needed (Grote, 2009).

The three major approaches to safety capability emphasize the need to manage uncertainty through both stability and flexibility. Literature in the area of HRT explains the need to adapt to unexpected events (Roe and Schulman, 2008). Approaches to organizing for high reliability also emphasize the way complex systems are managed to maintain stability (Schöbel and Manzey, 2011). Resilience engineering identifies core operational safety capabilities as monitoring the environment and learning from prior events (Hollnagel et al., 2011). A key tenet of resilience engineering is that failure arises from inability to adapt to complexity rather than from a breakdown or malfunction (Madni and Jackson, 2009). Research in the field of safety culture describes the importance of aligning individuals and organizational goals and values to achieve consistent safety outcomes in the face of change (Cooper, 2000). Learning is typically seen as a fundamental element of a positive safety culture (Reason, 2000).

Recently, organizational scholars have focused on dynamic capabilities that describe how organizations adapt and change to be successful in more volatile environments (Teece, 2007). Dynamic capabilities describe activities that bring about change in fundamental capabilities, either by changing existing practices or introducing new ones (Barreto, 2010; Danneels, 2008; Winter, 2003). Zollo and Winter (2002, p. 340) defined dynamic capability as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness”. The extensive research in dynamic capability provides a stronger theoretical framework for integrating different approaches to managing uncertainty (Anand et al., 2009; Helfat and Winter, 2011; O’Reilly Iii and Tushman, 2008).

The second defining feature of safety capability is managing interdependence within complex systems. Interdependence describes the connections between different elements of a system across multiple levels of analysis. The complexity of links within systems has long been viewed as one of the fundamental causes of major accidents (Perrow, 1984). For example, tightly coupled technical systems with strong interdependencies can limit flexibility and make it difficult to plan for all contingencies.

Interdependence arises not only from interaction among technical processes but also from the management of multiple goals within a system. In high-hazard environments, organizations must manage interdependent goals such as productivity versus safety (Leveson et al., 2009), centralization versus decentralization (Weick, 1987), and process versus personal safety (Hopkins, 2009). These multiple goals go beyond the technical system to incorporate interdependence of social units. Numerous accident investigations identify a failure to manage these interdependent goals and processes. Managing interdependence in high-hazard environments requires coordination among tasks, across hierarchical levels, and between functional groups.

Interdependence of people and goals is addressed by most safety approaches but is particularly central for theories of safety culture. Studies in a variety of industries highlight the critical role of safety culture in coordinating relationships across multiple groups (Carmeli and Gittell, 2009). Specifically, Weick (1987) argued that a safety culture supports coordination across loosely coupled systems to increase reliability. Therefore, it is important that safety culture is integrated into the enabling capital that supports safety capability.

An important debate regarding safety in complex systems concerns the inevitability of accidents in complex systems. One point of view suggests that accidents are inevitable due to the nature interactions among elements of a complex system. Hopkins (2001) summarized a contrasting view by stating “if accidents are normal, what makes them so is sloppy management, not complexity and tight coupling” (p. 72). Our framework extends Hopkins’ stark conclusion by developing a more specific guide to the management of uncertainty and interdependence in complex environments. These factors are identified in the enabling capitals that we review next.

3.3. Enabling capitals

Capability arises through organizational building blocks such as technology, structure, culture, and knowledge management systems (Gold et al., 2001). We capture this idea in the concept of enabling capitals. We identify characteristics of organizational, social, and human capital that contribute to process and personal safety in uncertain and interdependent environments. These three forms of capital have been extensively researched within the framework of intellectual capital (Youndt and Snell, 2004). Research concerning intellectual capital identifies the processes, structures, and resources through which knowledge is generated and transmitted in organizations (Stewart, 1997). This approach provides a comprehensive theoretical foundation together with an extensive empirical base of research evidence across a variety of organizational domains.

Each enabling capital is distinguished by the basic unit of analysis through which it contributes to FTO. Organizational capital refers to properties of the overall system such as the organizational design and management structure. Social capital refers to capacities embedded in social relationships such as the safety culture. Human capital refers to the skills, knowledge, and motivation of individuals to enact behaviors such as speaking up about safety concerns. Although social and human capitals are defined at levels of analysis nested within the organization, they can be aggregated to the organizational level. For example, one aspect of human capital might be defined in terms of the safety expertise demonstrated by individual employees that can then be aggregated to reflect the overall level of safety expertise across all employees in an organization. In the next sections we present a conceptual review of each capital.

3.4. Organizational capital

Organizational capital describes the institutionalized knowledge and routines that reside within organizations (Youndt and Snell, 2004). Subramaniam and Youndt (2005) derived practical measures of organizational capital based on the way companies managed repositories of knowledge such as databases and on the way they embedded knowledge in processes and systems. In relation to safety, organizational capital describes the various systems that enable management of uncertainty and interdependence.

Scholars have demonstrated a variety of ways in which organizational level systems contribute to overall performance. We identify three main themes from this research and describe evidence for the link to safety capability. First, a range of human resource management (HRM) practices have been investigated under the rubric of "high performance work systems". This research identifies groups of practices that lead to sustained and superior performance (e.g., Huselid, 1995). Zacharatos et al. (2005) showed that organizations implementing HRM practices consistent with high performance were significantly safer over time in terms of personal injury. There is also evidence the effective management of safety also contributes to better overall performance for an organization (Fernandez-Muniz et al., 2009). Establishing clear empirical links between organizational systems and major accidents has proved difficult because of the relatively low frequency of these events (Rosenthal et al., 2006).

A second stream of research explores the routines through which organizational processes become an integrated and self-sustaining part of the organization (Nelson and Winter, 1982). The capacity to repeat adaptive routines in changing environments is a hallmark of high reliability organizations (Weick et al., 1999). The notion of routines emphasizes that these processes are embedded in the knowledge structures of the organization rather than tied to the skills of a particular group or individual. For example, from the perspective of routines, emergency response procedures are an institutionalized sequence of organizational responses and resource allocations that transcend the skills of particular individuals. Individual skills are, of course, important and we address these skills in the section on human capital below. However, it is important to recognize that organizational routines are maintained and enacted through an interlinked network of responses that are "learned" at an organizational level (Shrivastava, 2007).

3.5. Social capital

Social capital refers to resources derived from the network of relationships among people in the organization (Youndt and Snell, 2004). Early work viewed social capital as a resource for individuals. For example, a strong social network might create better career opportunities for an individual. More recently attention has focused on the process through which social capital is a resource for the overall effectiveness of the organization (Nahapiet and Ghoshal, 1998). This perspective recognizes that much of the knowledge developed and used by organizations is embedded in social relationships and depends on levels of trust within these relationships.

The concept of safety culture is the most well-articulated form of social capital that has been applied to high-hazard environments. Safety culture has been repeatedly emphasized by major accident investigations as a significant contributing factor (e.g., Bills and Agostini, 2009; Group, 2011). Safety culture is recognized as a key determinant of process safety and developing safety culture is promoted as an essential part of a risk based approach to process safety (CCPS, 2007).

Despite the importance of safety culture for major accidents, most research into safety culture has focussed on personal safety rather than process safety. Nevertheless, this research is important for informing a broad view of safety culture that encompasses management of both personal and process safety. In general, safety culture describes the values, beliefs and attitudes which are shared within the social context of an organization (Guldenmund, 2000). An organization's safety culture embodies the norms that shape how individuals interpret and respond to safety events (Clarke, 2006; Quick et al., 2008) and motivates safety-related behaviors (Nahrgang et al., 2011). Studies in high-risk industries show that a positive safety culture leads to greater levels of safe behaviors (Cooper and Phillips, 2004; Neal and Griffin, 2006), increased motivation to actively engage in safety behaviors rather than just comply with them (Griffin and Neal, 2000), and fewer occupational injuries (Barling et al., 2002).

A social capital perspective highlights that a safety culture involves effective team work and communication both within and between teams (Baker et al., 2006). Nahapiet and Ghoshal (1998) identified structural, cognitive, and relational dimensions of social capital. The structural dimension describes patterns of network ties and network configurations (e.g., communication links between operational and maintenance personnel), the cognitive dimension describes shared understanding across individuals (e.g., a common culture of reporting near misses), and the relational dimension describes the process of norms and trust that enable interpersonal exchange (e.g., willingness to speak up about safety concerns).

3.6. Human capital

Human capital refers to the skills and expertise possessed by individuals within a particular organization (Youndt and Snell, 2004); it includes technical qualifications, competencies, experience, and understanding of process safety risks, together with a range of personal and interpersonal qualities that promote safety capability. The personal skills and expertise that underlie individual safety performance in high risk industries have long been the focus of both researchers and organizations.

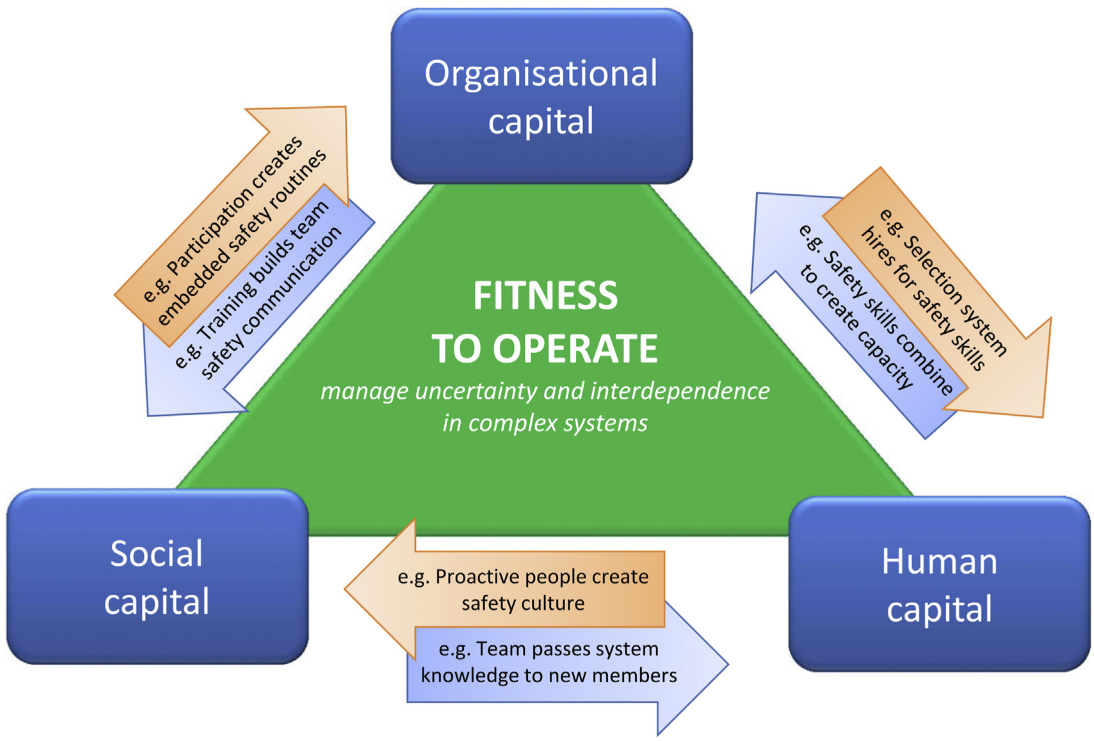

Fig. 2. Potential relationships among enabling capitals.

Traditionally, attention has focused on skills such as compliance, vigilance, and perseverance as determinants of individual safety behavior (Griffin and Neal, 2000). These behaviors, in turn, support overall safety in an organization, and thus contribute to organizational capability under routine operating conditions. However, there is also increasing awareness that individual safety behavior does not ensure that the overall system is safe even in fairly stable environments (Hayes, 2012). When we consider the capacity of an organization to adapt and change in response to internal and external pressures in order to maximize operational safety, other personal attributes are required. This broader set of attributes must necessarily encompass the ability to detect early signs of future system disturbances or malfunctions, and the knowledge and skills to forestall them before they escalate into operating emergencies. More generally, these skills and behaviors must enable personnel to respond effectively to complex and changing conditions, and to manage unexpected and volatile situations (HSE, 2005).

Ericksen and Dyer (2005) describe a range of employee characteristics that drive effective performance in high reliability organizations. These favorable attributes and behaviors include the ability to continuously anticipate and detect operational problems, and to communicate extensively with co-workers; the ability to respond rapidly and appropriately to problems and unexpected events, switching tasks and roles flexibly to deal with changing situations; the ability to respond to novel or complex problems with coordinated and effective actions; and the motivation to gain a better understanding of operating processes and procedures, and to share such information openly. These characteristics suggest that human capital include the skills of individuals to anticipate and adapt to operational changes, to maintain situational awareness, to communicate effectively with co-workers, and to make timely and appropriate decisions, not only under normal operating conditions but also in unexpected and rapidly-changing situations.

3.6.1. Relationships among enabling capitals

Organizational, social, and human capitals are enabling factors through which an organization achieves safety capability. The three capitals capture a wide range of research investigating how safety is sustained and improve. The distinction between different kinds of capital is an important advance in our capability framework because it allows a more systematic integration of processes that occur in qualitatively different ways. For example, Ericksen and Dyer (2005) propose that individual skills identified by human capital also serve to enhance its social capital, and vice versa. To illustrate how processes at different levels might combine to influence overall safety capability we present two examples below.

Fig. 2 depicts a simple example of how the different types of capital might influence each other. Moving clockwise from the top of the figure, employee recruitment systems might improve human capital by selecting employees with high levels of safety skills including interpersonal skills. Individual skills, in turn, help to build a more supportive safety culture in teams if individuals are better able to speak up and encourage learning from incidents. Over time, better team safety practices become embedded in the organizational routines (Edmondson et al., 2001).

Another example is provided by moving clockwise from the top of the figure. In this case, training systems can build social capital by developing better communication within and between team members. More effective teams, in turn are able to communicate information about the overall safety system to new employees. Over time, this process improves the capacity of the organization to understand system-level safety (Leveson et al., 2009).

The brief illustration indicates how our framework helps to conceptualize a wide variety of processes and practices that combine to build safety capability. The three capitals identify observable and measurable content of the processes that are necessary for managing uncertainty and interdependence. We next review a range of different approaches to safety assessment to evaluate the extent to which they encompass the content of the three capitals and provide practical guidance for developing evaluations.

3.7. Assessing capability

We reviewed different methods of assessing safety capability to determine the extent they provided coverage of the enabling capitals in our framework. We focused on methods going beyond traditional retrospective approaches based on analyses of incident-related data (e.g. event frequency and severity) to provide leading or prospective evaluations of capability. None of the methods provided coverage of all enabling capitals, but all methods contributed to some of the enabling capitals.

Table 1 summarizes eight systemic approaches for assessing safety capability and notes key references for the approach and the theoretical foundations. The table builds on research presented by (Sgourou et al., 2010). The eight models represent a range of different production and organizational settings, and describe a variety of methodological approaches. We included the offshore safety questionnaire not only because of the context's relevance, but to provide an example in which safety culture has a prominent role in the assessment. Although safety culture is recognized as a critical factor in long-term safety and many organizations assess their safety cultures, there is little integration of safety culture into more comprehensive assessments of capability. We address this point in more detail in Section 5.

The second row of Table 1 indicates that the approaches identified incorporate a variety of safety and organizational theories, including socio-technical systems, organizational development, and resilience engineering. Although none of the methods considered is based on a conceptual approach corresponding directly the FTO framework, many individual constructs, especially those relevant to organizational capital, are incorporated in the existing assessment instruments. The third row of the table summarizes the extent to which each approach was judged to encompass the three enabling capitals of our proposed framework. Overall, organizational capital was the aspect of safety capability most frequently addressed by these assessment systems. However, elements of social and human capital were included in various parts of the other methods. Only the RAG, MAHS, and SDC methods include significant features from each of the three types of enabling capital.

4. Development of the assessment guide

In this section we describe the development of the guide for assessing FTO. The goal of development was to produce a practical instrument that could be used to support communication between representatives of an offshore facility and the regulator. Because the instrument is intended to be used as part of this ongoing process, it is not designed as a stand-alone tool but as an aid to communication and evaluation. In the discussion below, we describe the general features of the guide that are likely to be useful for readers interested in the assessment safety capability more generally.

In developing the guide, we aimed to identify dimensions of enabling capital that that could be readily understood and would be perceived as relevant by potential participants (e.g. safety managers, production supervisors, senior onshore managers, and personnel working in regulatory roles). To this end, although the content was derived from theoretical and published literature, especially that relating to high technology, hazardous process industries, the guide was designed to apply to the specific context of offshore oil/gas exploration/production facilities. This process was undertaken over a period of two years.

The overall hierarchy of constructs developed for the guide is depicted in Fig. 3. The top part of the figure shows the three capitals are nested within the overall concept of FTO. The enabling capitals are further differentiated into seven "dimensions" which are in turn divided into 27 "elements". The elements are the focus of assessment by raters and each element is associated with one or more specific characteristics.

Detailed discussion of all elements and assessment characteristics is beyond the scope of the current paper. In the following sections we first outline the meaning and practical content of the seven dimensions which constitute the three enabling capitals. We then present our approach to assessing the more specific elements of each of these dimensions. This section begins with a review of existing approaches to safety assessment that provide background and input for the FTO ratings. We then outline the procedure that was developed to rate the 27 elements. Although we cannot provide detailed content for each element, we provide examples that show how the elements can be assessed in more detail. We conclude this section with information about the feedback the guide provides to participants and regulators.

4.1. Dimensions of three enabling capitals

Dimensions of organizational capital were developed first because this capital is defined directly in terms of systems and processes, either currently operating or, in the case of planned facilities, intended to operate in the future. In contrast, social capital and human capital can only be assessed in facilities already in operation because they arise from the actions and interactions of people working in the environment. A variety of sources were used to generate potential dimensions including systems and processes used within the oil and gas industry (e.g., safety cases, self-audit checklists), best practice examples from other industries such as aviation (e.g., line operations safety audit; ICAO, 2002), and literature focused on safety capability. Final dimensions were identified through an iterative process involving the research team in consultation with regulators and organizations. Next we provide brief description and examples of the main content for each dimension.

4.1.1. Dimensions of organizational capital

Organizational capital describes the systemic characteristics of organizations that give rise to FTO. This resource does not reside with a specific individual or part of the organization but depends on the overall configuration and structure of the organization.

HRM systems. Selection, training, and performance management are critical elements of most HRM systems. There is growing evidence that organizations committed to safety will implement practices such as safety in their selection criteria that build stronger safety values throughout the organization (Zacharatos et al., 2005). Hopkins (2008) showed how reward systems might prioritize cost cutting but reduce attention to major hazards. In addition, we highlight the need for safety leadership systems that formalize the structure of leadership roles and the processes for building and maintaining leaders (Zohar and Luria, 2003) and the importance of contractor management as an integral part of safety systems (Pinheiro and Kuiper, 2011).

Information systems. The technical and procedural systems through which information is collected, stored, and communicated constitute information systems for organizations. A range of formal supports are available to ensure that information systems contribute safety capability. For example, quality management system standards (ISO, 2000) provided detailed guidelines concerning the operation and improvement of information systems. Specific systems such as the line operations safety audit in aviation (ICAO, 2002) also embed safety information within decision making procedures to improve safety.

Processes and routines. The processes and routines enacted in organizations encompass formal safety systems and management

Table 1
Theoretical frameworks for selected safety management assessment systems.

	Safety element method (SEM)	Michigan OHSMS: universal assessment instrument (UAI)	Safety diagnosis criteria (SDC)	Occupational health and safety self-diagnostic tool (OHS-SDT)	OHS management system	Resilience analysis grid (RAG)	Method for assessing health and safety management systems (MAHS)	Offshore safety questionnaire	Tripod-delta	Mindfulness audit
Key citation	Alteren and Hovden (1997)	Redinger and Levine (1998)	Tinmannsvik and Hovden (2003)	Cadieux et al. (2006)	Makin and Winder (2008)	Hollnagel (2011)	Costella et al. (2009)	Mearns et al. (2003)	Reason (1997)	Weick and Sutcliffe (2001)
Theoretical framework	Organizational development theory and systems theory	Universal OHSMS model based on four existing OHS models	Developed from the SMORT (Safety Management and organization review technique) method	Model of hierarchical levels of safety performance (Roy et al., 2004)	Draws on literature from physical work environment, individual factors, management systems	Resilience engineering (RE)	Resilience engineering (RE) perspective	Draws on the offshore risk perception questionnaire and literature on organizational factors and safety attitudes	Fraws on literature from error management, organizational factors and human factors	High reliability organizations
Holistic features*/FTO model elements/resilience (RE) capacities	Organizational and human capital elements, and their inter-relations	Primarily covers organizational capital elements, and their inter- and intra-relations	Organizational, social and human capital elements	Organizational and social capital elements and their intra-relations	Incorporates person, place, and system factors (organizational and human capital)	RE capabilities and their interrelations; organizational, social and human capital elements	Four RE principles plus standard OHS requirements; aspects of organizational, social and human capital	Organizational and social capital elements	Organizational capital and some elements of social capital	Organizational and social capital

* 'Holistic features' refers to the integration of technical, organizational and human factors, their inter-relations, and their relations with the organizational and external environment, in the development of the assessment model. Organizational, social and/or human capital components of the FTO model can also be identified in the assessment instruments described, while two assessment methods derive from resilience engineering approaches to safety management. Empty cells in the table reflect the lack of information in the published documents referenced.

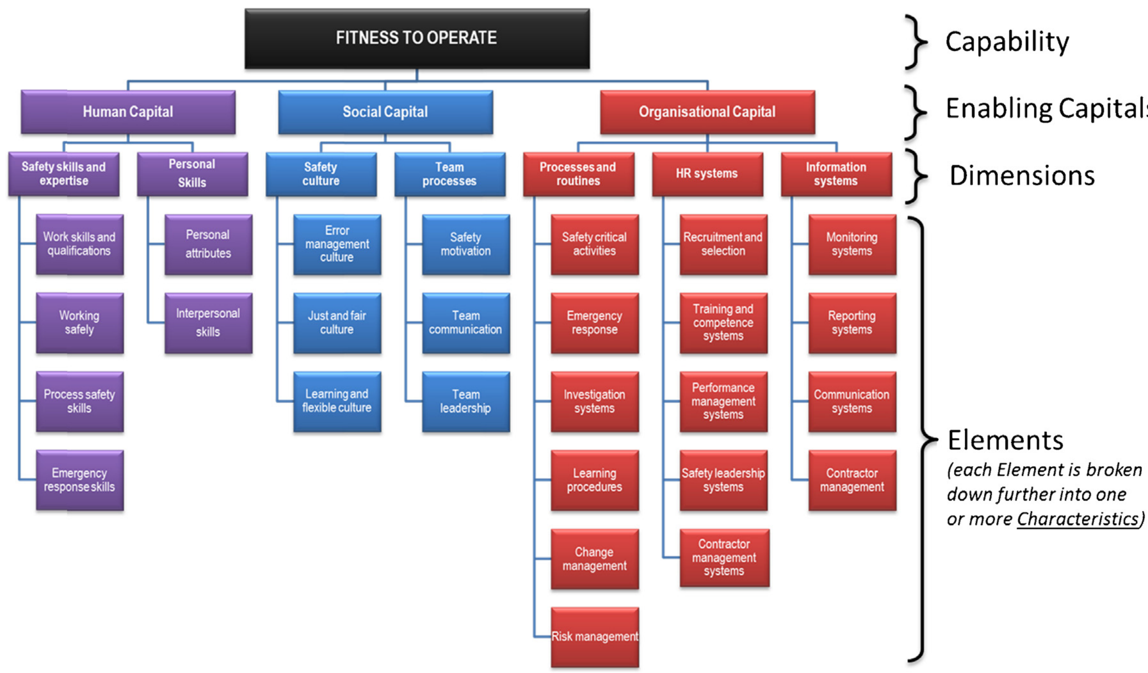

Fig. 3. Overview of enabling capitals, dimensions, and elements.

processes (e.g., hazard reporting systems) as well as informal procedures such as supervisor safety interactions. Processes and routines are patterns of repeatable activity which define an organizations habitual response to the environment (Becker, 2004). This aspect of organizational capital describes how predictable patterns of activity are implemented in response to critical challenges and demands. Many systems involve formal procedures developed internally by the organization and required externally by accrediting and regulating bodies. A key aspect of processes and routines is that they become a form of organizational "memory" through which stability of response is maintained through changing organizational structures, resources, and personnel (Argote and Miron-Spektor, 2011).

4.1.2. Dimensions of social capital

Social capital describes the capability derived from interactions among individuals and their networks of interrelationships. Building social capital requires a collaborative organizational environment that supports data reporting and communication (Youndt and Snell, 2004). We identify two specific dimensions of social capital that reflect the value of interactions among individuals in creating safety capability.

Safety culture. A wide range of concepts are associated with safety culture and much research has addressed ways of building a stronger safety culture. A common feature of different approaches is the need to communicate the intrinsic value of safety and for individuals across the organization to share common safety values. Achieving this level of communication and shared values depends on the degree of learning and trust that is expressed throughout an organization (Burns et al., 2006). According to (Reason, 1997), a good safety culture has positive features of learning, fairness and flexibility.

Team processes. Teams are the main group structure through which social capital is achieved and are implicated in all process of safety information (Hofmann and Stetzer, 1998). We use the notion of teams broadly to capture the variety of interpersonal processes that occur through the work activity of individuals (Hackman, 1990). Team processes are the communication and coordination activities through which teams achieve their safety goals. Research has identified activities that support task achievement and maintain group commitment across different phases of activity (Marks et al., 2001). Team processes include encouraging vigilance, supporting others to report hazards and threats, and discouraging team behaviors that threaten personal and process safety.

4.1.3. Dimensions of human capital

Human capital is the collective knowledge, experience, skills, abilities, and personal attributes of the people in an organization. It therefore depends directly on the characteristics of the work force operating at a given point in time. It is important to distinguish the human capital that exists within an organization from the organizational process through which human capital is developed. For example, effective HRM systems (organizational capital) have the potential to create a skilled workforce (human capital) but the quality of these skills can only be determined by assessing individual skills.

We differentiate two main categories of human capital. The first category is specific to safety whereas the second category encompasses the personal qualities important for sustained organizational operations. Generally, 'skills and expertise' includes cognitive abilities; interpersonal, communication, leadership, and coping skills, together with more specific role-related technical qualifications and competencies.

Safety skills and expertise. Expertise refers to an individual's accumulated knowledge, understanding, perceptions and cognitions derived from long-term exposure to particular roles, situations, and environments (Griffin and Neal, 2000) and, in the present context, to exploration and production processes in the oil/gas industry. For example, in Australia, the importance of fundamental safety skills for all employees in offshore facilities has been recognized through implementation of a common safety training program mandated across the industry (APPEA, 2013).

Personal skills. Research has identified a range of safety-relevant attributes such as decision-making, coping with stress, and risk awareness that combine to create an organization's human capital. For example, Ericksen and Dyer (2005) identified skills related to initiative as important for high-reliability organizations. It is not practical to create an exhaustive list of personal attributes that support an organization's safety capability. However, the overall profile of demographic factors such as gender, age, and education can identify systematic strengths or weaknesses in the level and diversity of organization's human capital profile.

4.2. Developing rating formats and feedback

In this section we describe development of the practical elements of the guide. We first reviewed the assessment methods in Table 1 in terms of rating source, format, and feedback to identify the most appropriate approach and format for the guide. We then describe the process for developing rating systems and feedback.

4.2.1. Review of assessment methods

We reviewed the practical application of the eight assessment methods to inform the development of our FTO guide (see Table 2). All the assessment instruments reviewed are sufficiently flexible to allow application in different work settings or industries although, to date, implementation has generally been restricted to a few domains or only a single domain, and application in other settings may necessitate tailoring of assessment characteristics to meet specific requirements.

Practical application of several of the assessment methods requires a basic understanding of the underlying conceptual model, knowledge of the industry involved, and experience of rating the constructs concerned. Thus, the UAI and OHS methods rely on ratings by specialist auditors, using people, observations, and available documents as sources of information. Assessment of resilience capabilities presents particular challenges, thus, the RAG and MAHS resilience assessments combine information obtained from multiple sources such as focus groups, interviews, document reviews, observations, and discussion with experts. The SEM, SDC, and OHS-SDT methods are less demanding of auditing expertise and assessments can be made by employees of the organization concerned.

Most of the methods reviewed use multiple evaluation elements (ranging from 12 elements for SEM, to 140 for SDC), and a five-point rating scale for responses; higher ratings reflect better safety management. Notably, both the SEM and the RAG have an assessment format similar to that of capability maturity models (Macgillivray et al., 2007; Strutt et al., 2006), in that upward progression through successive stages implies the attainment of greater maturity. For reporting purposes, assessment data are normally aggregated or summarized using mean or total scores (UAI and SDC), hazard profiles (OHS management system), a matrix showing the stage reached on different assessment components (SEM), or graphical plots and charts (RAG).

4.2.2. Assessing FTO elements: characteristics, questions, and ratings

The project team developed specific elements to represent each of the dimensions based on previous research, assessment approaches, and workshops. For each element, one or more characteristics were identified at a level of specificity suitable for assessment by raters. The characteristics were defined so that raters, working either individually or in small groups, could assess the current level of each characteristic with appropriate information from sources such as observation, documentary evidence, interview, or questionnaire. Each characteristic was elaborated with more open-ended questions to guide thinking about the operational meaning of the characteristic.

Each characteristic is rated using two criteria designed to encompass the depth and breadth of each characteristic. This process for rating a characteristic is analogous to combining attributes in a risk assessment (Cameron and Raman, 2005). Depth refers to the quality or level of a characteristic while breadth refers to the extent it encompasses the whole organization. The definition of depth and breadth differed somewhat across the three enabling capitals to reflect the different content in each capital.

Table 3 shows how the two criteria combine for the characteristics within each of the enabling capitals. The descriptors in the left hand columns capture depth of coverage while the descriptors in rows capture breadth for characteristics in the three capitals. For organizational capital, the depth descriptors concern the degree of compliance and the breadth descriptors concern the coverage of systems and documentation. For social capital, the depth descriptors concern the consistency of attaining each characteristic and the breadth descriptors concern the coverage of across teams in the organization. For human capital, the depth descriptors concern the overall level of attainment for each characteristic and the breadth descriptors concern the coverage of across individuals in the organization

For each characteristic, a final rating score is derived by combining the scores on the two axes of the matrix. For example, a rating of 3 is achieved by a high score on one axis combined with an intermediate score on the other axis. Similarly, joint minimum scores on both axes result in a rating of 0, while a maximum rating of 4 can only be achieved if high scores are assigned on both axes. To guide the rating of each characteristic, a range of evidence can be used such as process maps and documents, alongside records which demonstrate that the process is being used as designed, and that compliance is assessed regularly and systematically. Once a rating for a characteristic is determined it is recorded in a summary document that summarizes the characteristic in relation to the FTO elements, dimensions, and enabling capitals. Table 4 provides an example of one characteristic in the guide summary. The examples show that different combinations of breadth and depth can result in an overall moderate score.

4.2.3. Feedback generated by the FTO assessment

After the rating process has been completed for all the FTO characteristics, various types of feedback can be generated to represent the facility's current level of FTO. One advantage of the FTO guide is that it allows immediate presentation of FTO feedback. Thus, aggregated scores are computed, and converted into percentages of the maximum possible scores, using macro routines in the spread sheet software used for the guide. For example, the feedback information can be presented in the form of graphical radar plots that allow visual comparison across different dimensions as shown in Fig. 4.

By examining the feedback information provided, organizations and regulators can gain insight into how performance across organizational, social and human capital compares, and if any one type of capital falls below an acceptable standard. More detailed information can be derived by examining the profile of ratings across individual characteristics, and identifying specific short-comings which require attention. If the guide is applied industry-wide, operators can use it for benchmarking FTO on their facility against industry leaders and recognized industry standards. Also, by repeating the FTO assessment at regular intervals over an facility's life cycle, the effect of any improvement efforts can be assessed.

5. Discussion

The FTO model and guide presented in this paper provide a new framework for understanding and assessing safety capability. The

Table 2
Features of selected safety management assessment systems.

	Safety element method (SEM)	Michigan OHSMS: universal assessment instrument (UAI)	Safety diagnosis criteria (SDC)	Occupational health and safety self-diagnostic tool (OHS-SDT)	OHS management system	Resilience analysis grid (RAG)	Method for assessing health and safety management systems (MAHS)	Offshore safety questionnaire	Tripod-delta	Mindfulness audit
Industry	Mining and other high risk industries	Public and private sector organizations	Production industries	Semi-autonomous work groups in various industries	Any industry, but with a focus on smaller businesses	Any industry; used in rail, healthcare, and offshore	Any industry; used in manufacturing, aviation, electricity	Offshore	Oil exploration and production	Any industry
Tool users/intended users	Practitioners/ employees	Auditors	Employees from all organizational levels	Employees	Auditors	Selected employees with domain expertise	Team of examiners, with internal and external assessors	Employees	Employees	Employees
Sources of information	Individual assessments by managers and employees, which are combined in a consensus process	Auditor assessment of documents, field notes, interviews with OHS personnel	Employees' survey responses	Employees' survey responses	Risk assessments require technical competence, knowledge of the workplace and risk assessment skills	Focus groups; inter-views; discussions with experts. Standard items tailored to provide domain-specific questions	Document analysis, Interviews, and direct observation used to obtain structural, performance, and operational data	Employees' survey responses	Documentation and obser-vations by an employee	Employees' responses
Assessed elements	6	27	13	9	3	4	7	7	11	9
Sub-elements	12	118	140	67	57	38	112	45	220	85
Scoring/rating method	Data identifies five progressive stages for each element (coded 1–5)	Ratings of 27 sections (in 5 categories) covering 118 OHSMS principles, and 486 measurement criteria	Sub-elements scored 0–1. Evaluation elements, and overall assessment, scored on a 5-point scale	10-point rating scale for each survey item	Risk ratings on 0–4 scale for each component item	Rating scale from 'Excellent' to 'Deficient' in 5 steps, plus a zero 'No capability' rating	Assessment of items in relation to a pre-determined matrix scoring	The rating scale is different for each element (either a 5-point or 3-point scale). Descriptors such as 'fully agree' to 'fully disagree'	Checklist – yes/no response for each indicator. Each GFT has 20 indicators	The rating scale is different for each element (either 3-point scale or agree/disagree). Descriptors such as 'not at all' to 'a great deal' are used
Presentation of results	Matrix showing actual stage and desired future stage for each of the six safety elements, plus score totals	Scores summed for each principle, aggregated for each UAI section, and aggregated across sections	Scores on general management and safety-specific management derived from evaluation elements	–	Hazard profiles for safe place, safe person, and safe systems, before and after interventions	Graphical (radar) plots for each of the 4 elements; star chart with 4 axes for aggregated results	Assessment report prepared by the team of examiners	Assessment report prepared by developers that provide a variety of results and comparisons	Bar charts indicate the areas of most concern, requiring immediate attention	Scores are tallied and scores lower/higher than a specified number indicate the need for improvement
Validity	Satisfactory	Under evaluation	Satisfactory	Further validation needed	–	–	–	Satisfactory	–	–

Table 3
Matrix for rating characteristic within the three enabling capitals.

Organizational capital				
Depth – level of compliance (roles and resources assigned)	Systematic and proactive compliance testing on a scheduled basis	1	3	4
	(Reactive) Compliance testing in response to internal or external events	1	2	3
	Informal (roles and resources not assigned) compliance testing	0	1	1
		Informal systems and processes in place	Systems and processes in place and documented	Systems and processes are documented, reviewed and improved regularly
		Breadth – systems and documentation		
Social capital				
Depth – consistency of attainment	Teams always exhibit this characteristic	1	3	4
	Teams generally exhibit this characteristic	1	2	3
	Teams seldom or never exhibit this characteristic	0	1	1
		(None or) few teams	Some teams	Most or all teams
		Breadth – coverage across the organization		
Human capital				
Depth – level of attainment	Demonstrate an exemplary level of this characteristic	1	3	4
	Demonstrate basic competency of this characteristic	1	2	3
	Demonstrate little or nothing of this characteristic	0	1	1
		(None or) few individuals	Designated individuals	Most or all individuals
		Breadth – coverage across the organization		

guide was developed as a resource for regulators and operators in the offshore oil and gas industry but is relevant to any industry operating in high-risk and dynamically changing environments. The framework has a number of positive features to enable a more holistic and systemic approach to safety capability. Below we outline how the conceptual framework and guide support a number of practical applications around FTO. We then discuss some issues for further development and application.

5.1. Contributions of the FTO framework

We discuss three ways that the FTO framework helps to better understand safety in high-risk environments. First, the framework develops a more systematic definition of safety capability based on achieving safety in uncertain and interdependent contexts. Second, the framework recognizes that safety capability itself is difficult to observe and outlines how enabling capitals can be evaluated

Table 4
Example characteristic of the element performance management systems.

Organizational capital
Human resources systems: performance management systems

Characteristic	Critical questions	Level	Level descriptions	Score
Systematic performance management processes	Have you ensured performance management processes are fit for purpose such as: • Use of appropriate sources of performance information? • Constructive use of performance information? • Appropriate oversight? • Objectivity? Relationship with position requirements and performance plans?	Level 4	Performance management processes are systematically tested on a regular basis and functional requirements are periodically reviewed against broader internal and external requirements and inputs	☐
		Level 3	Performance management processes are updated to meet internal or external changes	☐
		Level 2	Performance management processes meet functional requirements and are being implemented by appropriately competent people	☐
		Level 1	Performance management processes are documented and used or available for use	☐
		Level 0	Performance management processes are ad-hoc or informal	☐

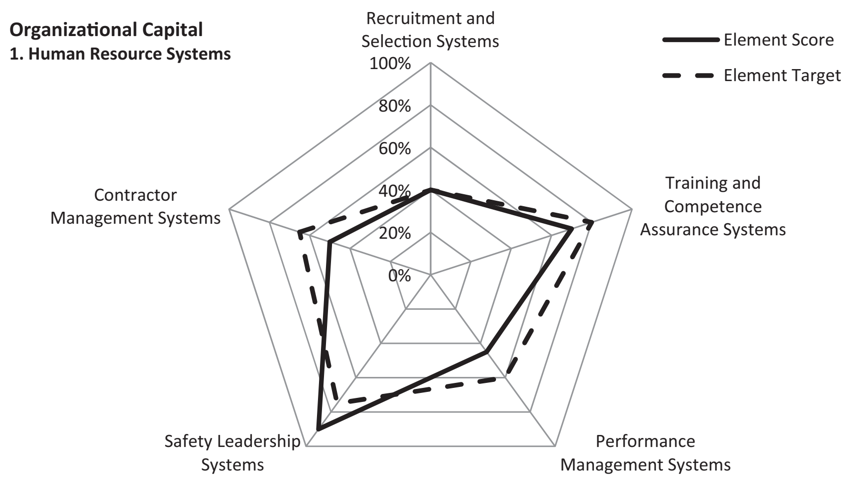

Fig. 4. Example of radar plot for the element human resources systems.

to understand underlying safety capability. Third, the framework helps to integrate important concepts such as safety culture, organizational learning, and resilience in to a more coherent set of measures.

5.1.1. *Uncertain and interdependent contexts*

Our framework adopts a systems perspective to identify uncertainty and interdependence as fundamental issues that must be managed to minimize risk. These concepts have been central to debate about the characteristics of complex systems in hazardous environments (Hopkins, 2013; Perrow, 1984; Rijpma, 1997; Roberts, 1990). By defining FTO in relation to uncertainty and interdependence, the framework contributes to ongoing integration of systems thinking into the management of safety.

Leveson et al. (2009) note that organizations in high-risk environments must manage significant levels of uncertainty together with changing technical processes in competitive economic markets. They argue that these conditions were not adequately recognized in earlier debates about normal accidents and high reliability. More recent analyses of high reliability, resilience engineering, and safety culture emphasize the importance of learning, change, and adaption.

By incorporating uncertainty as a core feature of our framework, we highlight the need for organizations to manage both stability and change. This challenge is complex because change and stability are often viewed as opposites (Farjoun, 2010). The FTO framework is based on the premise that safety requires processes and procedures that maintain stable operations in the face of change as well as new operations that anticipate and generate change. The need for ongoing change has been emphasized in a range of recent approaches to safety capability. For example, Woods (2011, p. 124) states "resilience is about how systems learn to modulate their adaptive capacities to continuously update their fitness relative to an environment". Change and stability are identified at all levels of the framework. For example, within organizational capital dimension "processes and routines" we identify elements that support stability such as "safety critical activities" (e.g., responding to emergencies) and "learning" (e.g., learn from internal monitoring data).

The concept of interdependence also helps to integrate systems thinking into safety management. It has long been recognized that tightly coupled systems contribute to risk by increasing interactive complexity in hazardous environments (Perrow, 1984). Although the original concept of loose-coupling incorporated both technical and social processes (Orton and Weick, 1990), interdependence in technical systems has been viewed somewhat separately from interdependence among human and social processes. The framework helps to identify and integrate social processes that are necessary to manage interdependent systems. For example, trust is increasingly seen as a necessary condition for effectively coordinating interdependence in high reliability organizations (Cox et al., 2006). Trust underpins appropriate communication about hazards necessary for monitoring, response, and anticipation. The framework identifies trust as a key element of safety culture that links social processes to the systems that support reliability and safety. We discuss this point further below.

5.1.2. *Differentiating enabling capital from capability*

A further benefit of the framework is the distinction between enabling capitals that produce capability and the more abstract notion of capability itself. The major focus of both the framework and the guide is enabling capital which comprises observable factors that produce capability. The distinction provides a rationale for assessing facilities in terms of their actual operations rather than the potential outcomes. As discussed below, regulators need to understand the potential capabilities that will be enacted before a facility is operational.

A further benefit of differentiating enabling capital and capability is the opportunity to build a more comprehensive map of leading and lagging indicators for safety. A continuing challenge for an integrated picture of safety is the complex link between distal events and ultimate outcomes of harm and failure, particularly low-frequency events (Hopkins, 2009). There is good evidence from safety research and other areas of organizational operation that the enabling capitals influence safety outcomes. In this sense, the enabling capitals are a systematic picture of leading indicators that precede harm and failure. Companies, regulators, and researchers can use the elements of enabling capital to develop a more nuanced picture of potential lead indicators and build more comprehensive picture of safety capability.

The distinctions within the framework also allow a logical extension to the safety case currently used by regulators as the principal mechanism for determining FTO (Maguire, 2008). A safety case generally includes management system elements such as policy, organizational structure and accountabilities, planning and standards, performance measurement, audit and review. In presenting the safety case, an operator identifies potential risks and the organizational capabilities that will be in place to minimize and manage risk. The safety case as an approach is largely unchanged since its inception in the aftermath of Piper Alpha in 1988 and the changes to offshore health and safety regimes following the recommendations of the Cullen enquiry (Cullen, 1990). The FTO framework addresses capability in a way that allows for a wider range of risks in a more dynamic and changing environment. The specification of enabling capitals identifies the characteristics needed to respond in an environment with rapid technological change, reduced time to test new designs and systems, new types of hazards, increased complexity and coupling, and more complex relationships between humans and automation.

5.2. Safety culture

A significant contribution of the FTO framework is the systematic inclusion of safety culture into a broad assessment guide. Safety culture is widely recognized as a critical factor for creating and supporting a safe organization. However, the concept of culture is often invoked to cover an extremely broad range of factors that contribute to safety. Safety culture is identified as a causal factor in many accident and disaster reports, yet has proved difficult to define and manage (Cox and Flin, 1998; LeCoze, 2013). Over the past decades, safety culture tools have been used to assess various elements of organizational, social and human capital including individual motivations, group processes, job characteristics, organizational norms, and safety management systems. A limitation of this broad coverage, as noted in our review of assessment systems, is that safety culture is often assessed as part of stand-alone measurement procedure. Although this approach results in comprehensive assessment of safety culture, it does not provide systematic links to other elements of the framework such as the safety skills in human capital or the monitoring systems in organizational capital.

To enable better integration of safety culture assessment, the FTO framework provides a more specific and constrained conceptualization of the social foundations of culture. (Bills and Agostini, 2009) emphasized the need for regulators to incorporate safety culture into broader assessments used in regulating entry and ongoing operation of offshore facilities. By specifying the content of safety culture in terms of social capital our framework provides greater conceptual clarity for regulators and operators as well as a more systematic link between safety culture assessment and other forms of safety assessment.

5.3. Further development

The FTO framework and guide is an ongoing project which will be developed and refined through further consultation with industry and research partners. The guide encourages the integration of multiple approaches to measurement but remains limited by the degree to which these measures can gather reliable data and produce valid conclusions. Some of the key areas for further development include building links to other measurement systems, incorporating complex patterns of FTO, and supporting whole-of-life approaches to safety.

5.3.1. Link to other capability assessment

Researchers in the field of resilience engineering have developed assessments that place an emphasis on flexibility and anticipation (Hollnagel et al., 2011). The key dimensions identified by resilience engineering identify important elements of safety capability. It is possible to provide conceptual links between the elements of enabling capital and the dimensions of ability to respond, anticipate, monitor and learn identified in the resilience analysis grid (RAG). Current research is investigating the validity and utility of linking ratings of enabling capitals with assessment obtained from the RAG. A promising future direction involves weighting the individual characteristics of the FTO framework on the extent to which they encompass the abilities identified by the RAG. This weighting would allow a map of the RAG abilities to be produced based on the ratings of the enabling capitals. Research is needed to examine the extent to which reliable weightings can be allocated and the validity of the link between enabling capitals and capability.

5.4. Alignment and fit

The alignment between the dimensions in the framework is an important part of overall safety capability that is not currently addressed in the guide. Organizational researchers have emphasized the need to understand the configuration of practices that lead to effective outcomes beyond the effectiveness of single practices or processes (Delery and Doty, 1996). The notion of alignment means that safety capability is not achieved simply by high levels of enabling capitals but also by the specific combinations of the elements of enabling capital. For example, if there are high levels of automated systems for monitoring (organizational capital) then there needs to be high levels of vigilance from the operators of these systems (human capital) and strong communication procedures developed by leaders and supervisors (social capital). This alignment means that the range of higher and lower scores in an assessment can have different meanings depending on the pattern of scores and the context in which they are produced. It is important to develop the overall guide in a way that recognizes how strengths in one area might be complemented by or depend on strengths in another area (Lepak et al., 2005).

5.5. Whole-of-life approach

Our framework conceptualizes FTO as an ongoing capability determined by enabling capitals that evolve over the life-span of a facility. This whole-of-life perspective is seen as critical for successfully managing projects, infrastructure, and facilities (Kerzner, 2001). There is also increasing recognition of the need for innovation and change to be integrated into the control systems of a project's life cycle (Lenfle and Loch, 2010).

Regulation of offshore facilities has typically focused on establishing initial conditions for FTO, with less opportunity for regulators to develop an overview of the longer term life-cycle incorporating change and continuous development. The FTO framework provides a means for understanding how capability prior to entry into the regime integrates ongoing development of the facility. Further research and consultation will enable development of the guide to inform understanding of capability from the design and start-up of the facility through the development of mature operating capabilities. For example, when a facility is being designed, built, or moved to place, the concept of enabling capitals provides guidance in determining the factors that can be assessed earlier in the lifecycle (e.g. safety reporting systems) and monitoring other enabling factors as they come on line (e.g., employee safety skills).

6. Conclusion

The FTO framework and guide presented in this paper support a systemic and comprehensive approach to safety over the lifetime of a facility. The need for high reliability and responsiveness to change and means that it is important for regulators and operators to recognize the key factors that influence safety capability. The FTO framework identifies organizational, social, and human factors that combine to create the safety capability of a facility. The systemic nature of the framework encourages integration of safety culture and human skill with the organizational procedures and processes that enable reliability and adaptability.

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