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Dynamic Safety Capability and Organizational Management Systems: an Assessment Tool to Evaluate the "Fitness-To-Operate" in High-Risk Industrial Environments

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Aim. The paper outlines a systemic approach to understanding and assessing safety capability in high-risk industries, like off-shore oil, gas industry, chemical operators. The "Fitness to Operate" framework (acronym: FTO) (Griffin et al., 2014) has been recently defined by three enabling capitals that create safety capability: organizational capital, social capital, and human capital. Furthermore, each type of capital is identified by more specific dimensions based on current theories of safety, management, and organizational processes. In this paper, we will present a multidimensional assessment tool that offers a comprehensive picture of safety capability by real industrial operators in order to understand and evaluate their "fitness-to-operate" (FTO).
Method. This current paper aims to describe the multi-phase development process of a FTO assessment tool in the format of a multidimensional survey questionnaire. A) The first research phase consists of the item generation of a large prototype pool with about 200 contents-items covering the 27 dimensions of the conceptual representation of the FTO framework. This initial pool was developed by a team of academic researchers, through a deductive process, and in the light of the original FTO conceptualization, as defined by Griffin and colleagues (2014) B) In a second research phase, the initial pools of items were re-examined by a new pool of academic researchers, assessing the quality of the contents, and in order to refine the extensive version of the prototype, eliminating potential redundancies and inadequate items. C) In a third phase with structured interviews to a pool of industrial experts (senior safety managers; senior executives), the authors assessed the quality of the prototype tool developed by the academic researchers, in order to evaluate and ranks the items of the prototype in term of quality, in order to define and identify a shorter version of the prototype. All the items were assessed by the experts considering criteria such as: i) relevance ii) clearness iii) verifiability iv) specificity v) ease of answer. *Implications.* Overall, the FTO assessment tool enables a comprehensive coverage of factors that influence short-term and long-term safety outcomes. The tool may serve to help safety regulators and industrial operators to understand, assess, and eventually implement and improve the safety capability and fitness-to-operate in complex industrial and organizational contexts.

1. Understanding Dynamic Safety Capability (DSC): conceptual definitions and foundations

This paper focuses on the concept of ''dynamic safety capability'' (DSC) to describe an organization's capacity to proactively improve its core safety systems in high-risk environments characterized by complexity and uncertainty (Griffin et al., 2016). Managing improvements is a central concern for all organizations but is particularly challenging in hazardous industries where the reliability of safety systems is essential. Investigations of major accidents frequently recommend major changes both within the organization and across the broader industry. Ongoing changes in economic, social, and environmental conditions also require change and adaptation in hazardous industries. Maintaining reliability and safety under frequently changing conditions is an equally pressing imperative that is highlighted by extensive research into high-reliability organizations (HROs). The study of HROs emphasizes how successful organizations maintain reliability while adapting to unexpected change and unplanned events (e.g., Curcuruto et al., 2016).

Distinct types of change are reflected in the response to significant accidents and critical incidents compared to the continuous improvement of HROs described before (Curcuruto et al., 2014; Saracino et al., 2015). In contrast, changes to highly reliable systems involve more proactive and forward-looking changes that tend to be more incremental in nature. Both types of change have been the motivation for substantial improvements in safety operations for hazardous industries. However, according with Griffin, Cordery and Soo (2016), there is currently a relative lack of conceptual frameworks for describing qualitatively different kinds of change in safety systems. More precisely, the authors argued that the process of proactively changing core safety systems is not well articulated in current approaches to safety. Consequently, they introduced the concept of ''dynamic safety capability'' (DSC) to explain the nature of this capability and the nature of organizational change that is involved. They defined DSC as "an organization's capacity to generate, reconfigure, and adapt operational routines to sustain high levels of safety performance in environments characterized by change and uncertainty" (Griffin et al., 2016, p. 249). The construct of DSC is funded on the theories of dynamic capability (e.g., Ambrosini & Bowman, 2009) which seek to understand an organization's ''ability to sense and then seize new opportunities, and to reconfigure and protect knowledge assets, competencies, and complementary assets'' (Augier & Teece, 2009, p. 412). In other words, the notion of dynamic capability might be also defined 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" (Zollo & Winter, 2002, p. 340).

2. Enabling "DSC" in industrial organizations : Human, Social, Organizational Capitals

In the field of risk and safety management, the construct of DSC is especially important because many hazardous operations face substantial change arising from new technology, evolving environmental imperatives, and workforce demographics (Griffin et al., 2016). Although specific changes are unpredictable, there is a need to prepare for new conditions and operate safely and competitively. DSC provides a bridging concept to integrate relevant research from both organizational management and safety management (Griffin et al., 2016). In another paper, Griffin et al. (2014) outlined a systemic approach to understanding and assessing safety capability in the off-shore oil and gas industry. The authors presented a more comprehensive conceptual picture of safety capability for regulators and operators of offshore facilities, namely "Fitness-to-Operate" (acronym: FTO) (Griffin et al., 2014). The FTO framework defines three enabling capitals that create safety capability: organizational capital, social capital, and human capital. For each type of capital, the authors identified more specific dimensions and sub-elements 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. As such, the content and scope of the FTO framework enable a more comprehensive coverage of factors that should influence short-term and long-term safety capability and outcomes. For instance, the human capital domain includes personal attributes of the employees, like technical *safety-skills and expertise* and not-technical *personal skills,* which have been frequently investigated as proximal antecedents of safe conducts in the workplace (Griffin & Curcuruto, 2016). Similarly, the social capital domain covers multiple collective properties of work-teams such as *safety culture* and *team processes,* which have been empirically associated with team safety performances (Curcuruto et al., 2015). Finally, the organizational capital domain includes different collective properties that align with the organizational such as *information systems* and *organizational systems*, which aim to manage and link together information from complementary organizational processes and routines, like risk management and HRM (Saracino et al., 2015). Figure 1 illustrates an adaptation of the overall structure of the original framework proposed by Griffin et al. (2014). The picture shows how each enabling capital is composed of an articulated set of dimensions and sub-elements. We will use this framework as a general conceptual guide.

3. Research aim: to develop a FTO assessment tool to evaluate the three enabling capitals

After describing the conceptual definitions and foundations of DSC and illustrating the hierarchical structure of the enabling capitals of DSC (dimensions; sub-elements), we will shortly present now our research aims and the methods we used. Essentially, the scope of our research is to contribute to develop an original multidimensional survey tool that might be used to provide an assessment of the quality of the human, social and organizational capitals enabling DSC, including an estimation of their internal structures (dimensions; sub-elements). We believe that such a tool can be useful for public institutions, industries and safety regulators to assess the "fitness to operate" in high-risk environments. A similar tool could be used to help companies and organizations in different ways: *a)* to develop an understanding of their safety capability using a common language and framework *b)* to diagnosis the factors impacting safety performances *c)* to monitor the general quality of their safety management systems and sub-systems c) to detect potential weakness that might need potential changes and improvements *d)* to support a life cycle approach to maintaining safety capability.

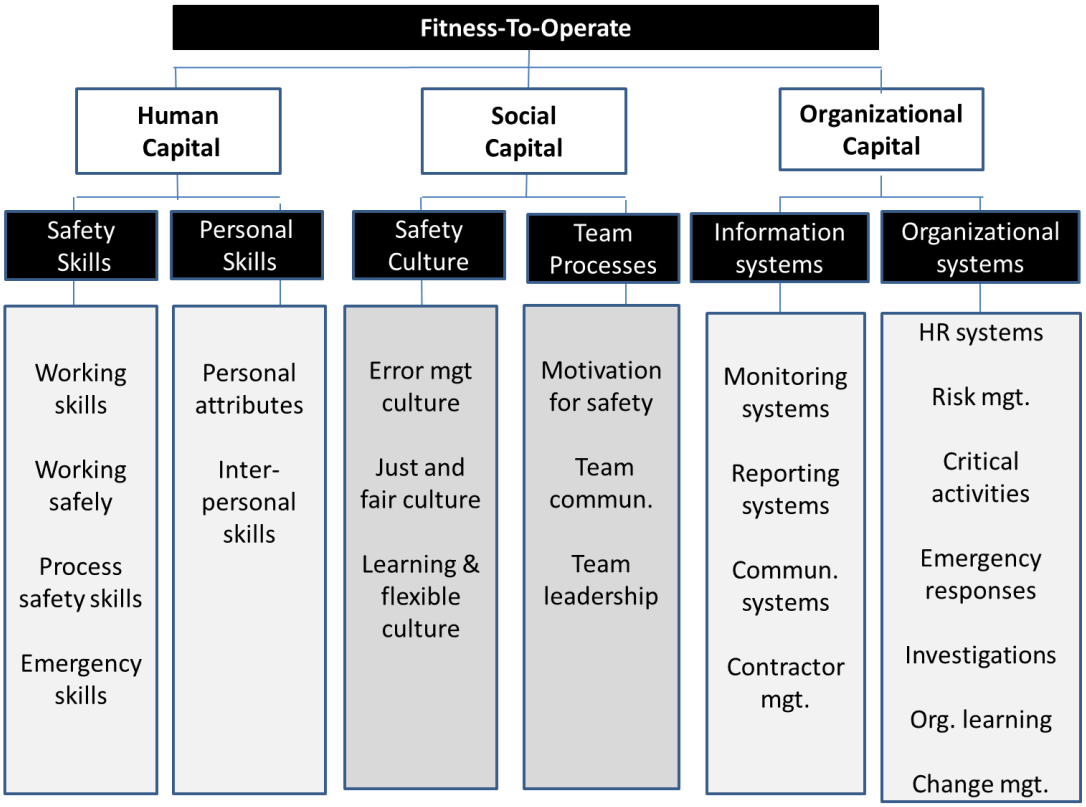

Figure 1: The Fitness-To-Operate framework (FTO) adapted from the model defined by Griffin et al. (2014): enabling capitals, dimensions and sub-elements supporting the safety capability by industrial organizations

4. Research methods and phases

To develop an assessment tool of the elements supporting dynamic safety capability by organizations, we set up a multi-phase strategy with multiple qualitative research stages (Curcuruto, 2016): a) initial item generation by a pool of researchers b) content-analysis by a pool of academic experts c) structured interviews with safety managers from a world leader chemical industrial company. These phases will be better described in the next sections.

4.1 Generation of an extensive pool of descriptive statement items

The first research phase consisted generation of a large prototype pool with about 250 contents-items covering all the twenty-seven conceptual elements of the FTO framework, as defined by Griffin and colleagues (2014). This initial pool was developed through a deductive process by a multidisciplinary team of academic research associates and assistants from different university faculties like engineering, business and organization, psychology. For each element of the FTO framework, the researchers generated an exhaustive set of descriptive statements covering all the principal characteristics of every element. Just to provide an example, the element "emergency skills" of the human capital domain was described by a set of items indicating key characteristics like: *"to know all prescribed procedures for emergency situations", "to know how to handle emergency equipment and devices in emergency situations", "to know how to coordinate their efforts with other people and teams in real emergency situations"*.

4.2 Content analysis to select a refined prototype assessment tool

In a second research phase, the large pool of items developed in the previous stage were re-examined by a new research group composed of five senior academic researchers, who assessed the quality of the large pool of items created at stage 1. All the items were evaluated in terms of adequacy, clarity, potential redundancies, in order to eventually refine the extensive version of the prototype. At the end of this stage, a reduced version of 186 items was achieved. For example, the "error management culture" was described by items such as: *"to discuss one's own errors in a "blame-free" atmosphere", "to handle the detected errors in a constructive way", "to avoid successfully the potential negative consequences of errors".*

4.3 Structured interview stage with senior industrial safety experts

In a third phase, structured interviews of six industrial experts (senior safety managers; senior executives) were conducted. The authors assessed the quality of the prototype tool developed by the academic researchers, in order to evaluate and validate all the items in term of fit and congruence with the real industrial and organizational settings. Every expert presented a specific competence in relevant areas of managerial safety systems, like process safety, behavioral safety, human resource management, organizational information systems. All the experts were currently employed a high-risk chemical plant in Southern Europe.

Interview grid. Each industry expert was asked to assess a single dimension of the FTO prototype questionnaire, using a specific quality assessment grid prepared by the authors. The grid allowed the research team to collect and order the judgement of the experts, with the final aim to rank all the items using quantitative criteria, and eventually assigning an "index of quality" to every item developed at Stage 2. Seven quantitative parameters were used to understand how much the content items presented attributes of quality in terms of : a) relevance for the organizations at different stage of maturity and safety culture b) demonstrability of the answer for the organizations and external assessors c) ease of the answer for the interviewed. Every parameter was assessed with a scale from 0 *(not at all)* to 4 *(in a great extent)*. The assessment grid is reported in table 1.

Filter questions. In addition to the quality criteria reported in table 1, the interviewees were asked to respond to three extra filter questions. These extra questions were used to identify: a) the potential best response for every item, considering different hierarchical levels in the organization b) not functional items for the goodness and economy of every single scale meant as whole indicators c) potential redundant content items that might be merged to facilitate more parsimonious scale. In other words, these last three questions were used as filter criteria for the final decision about the item retention in the final version of the FTO prototype tool. These final filter questions are reported below:

- Question filter 1 *(target of respondents at every item)*: "Who could realistically provide an accurate information on this issue?" (possible answers: 1= operator at the "bottom" organizational level; 2= supervisors & managers; 3 = only managers).
- Question filter 2 *(applicability of the assessment scale for each element of FTO)*: "Have you found some items being no relevant, ambivalent or not functional to assess this element of the FTO tool?".
- Question filter 3 *(parsimony of the assessment scale for each scale of FTO)*: "Which items with a similar content would you merge to reduce the length of the assessment scale of this FTO element?"

4.4 Evaluating and ranking the items of the FTO prototype assessment tool

Once all the items were assessed by the industrial experts, the researchers computed an overall quality index for each item in order to select a valid and parsimonious version of the academic FTO assessment tool. This general quality index was computed as statistical mean of the seven partial rates described in table 1. According to this final quality index we selected from four to six item to evaluate every single element defining the three enabling capitals of Dynamic Safety Capability (as presented in the FTO framework showed in figure 1). We used a value of 3 as cut-off value. When more than six items presented more than six adequate items, we used the filter question to select the final items to retain, giving priority to the items which showed more probability to be understandable at every hierarchical level of organizations (filter 1), and discarding the items which were indicated as potentially redundant or not functional to define a unique scale of items (filters 2 & 3).

Table 1: The Interview Grid used in phase 3 to assess the quality of the FTO prototype tool

Seven criteria of quality of the items in terms of: "relevance" *(questions 1, 2 & 3)*, "demonstrability" *(questions 4 & 5)*, "ease of answer" *(questions 6 & 7)*

Instructions given to the interviewee*: "Please, rate every item addressing each of the evaluation criteria"*. (Evaluation scale: zero = not at all; four = in a great extent)

1. How much it this content item relevant for the general organizational system of your company?
2. How much is this content item relevant for the management of safety in a company <u>at the entrance</u> in a regulatory system?
3. How much is this content item relevant for the management of safety in a <u>mature company</u> with high level of reliability and safety culture?
4. How much would be feasible for an organisation <u>to provide proof</u> that this item has been addressed?
5. How much would be feasible for an external assessor <u>to rate an organisation</u> on the basis of this content?
6. In which extent the content item was clear?
7. In which extent was easy for you to provide me with all this information on this content item?

5. The final "Fitness-To-Operate" prototype assessment tool

Following the several research stages recommended in literature to develop new assessment survey tool with a qualitative methodology (Curcuruto, 2016; Curcuruto et al., 2016), we were eventually able to achieve a final version of the FTO assessment tool consists of 130 items, covering twenty-three of the elements defining the human, social and organizational capitals supporting dynamic safety capability in industrial setting (Griffin et al., 2016; Griffin et al., 2014). Given the complexity of the overall conceptual framework it is not possible to show an extended version of the overall prototype tool. However, tables 2, 3 and 4 present three examples of assessment scales for single element from each one of the three main enabling capitals. More information about the complete version of the FTO tool are available contacting the authors of the present manuscript.

Table 2: The assessment scale for the element "Process safety skills" (from the "Human Capital")

Instructions: *"Please, consider people in your team or organizational unit …"*

1. As the operating context changes, do individuals know when to ask for external technical assistance?
2. When individuals are engaged in new activities/ changes, are you confident that risks are understood?
3. Are you confident that they have the breadth and depth of knowledge of major accident risks appropriate to your facility?
4. Are you confident they would know when to stop the operation?
5. Do you trust them to manage the response to an incident (such as a gas leak)?
6. Are you confident the people that plan and manage the operation of your facility understand the factors that influence risk?

Table 3: The assessment scale for the element "Learning & flexible culture" (from the "Social Capital")

Instructions: *"Please, consider your team or organizational unit …"*

1. Does the team discuss how potential problems *(e.g. near-miss, errors…)* might be managed?
2. Are unusual events used as sources for learning?
3. Do team members discuss errors and mistakes, and how they could have been prevented
4. Can the team do things differently if they think it is necessary without waiting for the approval of higher authorities?
5. Can the team regroup and restructure its work if needed?
6. Are team interactions effective when responding to unexpected events?

Table 4: The assessment scale for the element "Risk management" (from the "Organizational Capital")

Instructions: *"Please, consider your department or your organization …"*

1. Are activities of risk and hazard identification conducted by specific qualified teams?
2. Are activities conducted to identify control measures, in order to reduce every risk factor to the lowest level reasonably practicable?
3. Are worker opinions and evaluations on risk factor attributes collected? *(i.e. estimation of accident likelihood; personal exposure; consequence severity)*
4. Are workers involved in proactive activities of risk prevention and monitoring *(i.e. job safety analysis; peer-to-peer observations; safety committee)*?
5. Are workers actively involved in the ergonomic and usability review of risk control measures *(i.e. procedures; tools and devices*)?
6. Are workers encouraged to report any incongruences with existing EHS regulations *(safety omissions, risky conduct and violations)* to their direct supervisors or to the EHS office?

6. Conclusions

The study reports systematic development of a set of items that capture the way organisations achieve safety capability. The items reflect processes at the individual, social, and organisational level that are important for ensuring organisations can manage safety in dynamic and unpredictable environments. The FTO assessment framework presented in this paper might support a systemic and comprehensive approach to safety over the life-time of an industrial 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.

In order to provide further evidences of validity, the next logic research steps should set up experimentations of the FTO assessment model in specific industrial contexts using a confirmative oriented approach (Mariani et al., 2016). In which extent the validation of our assessment model can be generalized in other industrial business sectors and in different national regulation systems? Moreover, beyond the instances of generalizability and contextual validity, it would be certainly relevant for research advancement purposes to try to address specific conceptual key questions, concerning the internal structure of our framework and the alignment among subcomponents. For instance, which typology of relationship exists between the different enabling capitals of the FTO framework and between their elements? How these relationship may change in a long term cycle of life? The systemic nature of the framework certainly encourages integration of safety culture and human skill with the organizational procedures and processes that enable reliability and adaptability. We hope that our assessment framework might help to identify the causal links between organizational, social, human factors that combine to create the safety dynamic capability of industries.

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