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REVISITING SAFETY CULTURE: THE BENEFITS OF A NEW CULTURAL ANALYSIS FRAMEWORK FOR SAFETY MANAGEMENT

Elsa GISQUET, Sophie BEAUQUIER, Emilie POULAIN (IRSN)

Abstract

Many initiatives intended to improve safety in nuclear facilities have used the concept of “Safety Culture,” which focuses on human and organizational factors and emphasizes the importance of the perceptions, interpretations and behaviors of the individuals and groups within organizations.

Particularly when it comes to risk management, it is widely believed that safety culture can be a used as a lever to strengthen a company’s overall structure and organization. But how is it possible to ensure that a new safety policy or organizational infrastructure really will promote safe and reliable operations without unforeseen and undesired cultural consequences? Once recommendations have been issued, how is it possible to assess the extent to which safety culture has (or has not) improved?

This paper will argue that using what we call a “cultural analysis framework” can be a powerful way to identify and understand cultural elements that have an impact on reliability and safety within organizations. We will use a case study of the introduction of a safety management system in a nuclear facility to present this original approach. Because "safety culture" is a highly complex topic that can be challenging to address directly, our cultural analysis framework approaches a system at three levels, which, when explored together, can help to develop a comprehensive understanding of the cultural aspects of safety in an organization. First, at the *macro level*, this approach examines the cultural background of a system, and how it is integrated into an existing organizational culture. Second, at the *meso level* it looks at the collective aspects of a given system within an organization. Third, at the *micro level*, it investigates collective and social life (modes of socialization, relationships, trust, practice sharing), as well as the symbolic and identity-related aspects of a system.

Based on the findings of our study, this paper concludes that a socio-comprehensive approach to safety can be an effective means to identify "reasonable" actions to be taken in any organization seeking to improve risk management.

Key words: safety management, safety culture, organizational culture

I - Introduction

The concept of “Safety Culture” is a key element of many safety initiatives in nuclear facilities. Focusing on human and organizational factors, the idea of safety culture is meant to emphasize the importance of individual and group perceptions, interpretations and behavior within organizations [1, 2].

Some authors have gone further than this, arguing it may be possible to isolate “safety culture” as a lever for improving the overall performance of the facilities, particularly in terms of risk management [3, 4]. This literature deploys the concept of “Safety Culture” normatively, as a type of evaluation tool, which uses institutional standards to define what is “good” or “bad” for safety [5, 6]. A normative approach to safety culture defines in advance a set of criteria for building "good" safety culture; such an approach, for example, might list attitudes deemed necessary to workplace safety: understanding and following procedure, looking out for unexpected occurrences, stopping to think if a problem arises, seeking help, etc. [7]. From this normative angle, safety culture is a deductive approach that defines standards and then seeks to measure the extent to which they are or are not met. Employed in this way, the concept of “safety culture” ceases to be a relevant analytical approach for understanding safety-related social dynamics within a given organization [8].

This paper will argue that the concept of safety culture can be used in a different and more powerful way, to assess the reality of what goes on inside organizations, and in particular how its actors attend to safety in the course of their daily behaviors. As we will show, this socio-comprehensive approach to safety culture can offer a far deeper understanding of the dynamics of reliability and safety in the workplace than the normative approach – and thus a better tool for improving these things.

Rather than “saying what needs to be done,” a comprehensive approach to safety culture seeks to *understand* what is being done. It is an inductive approach that uses a sociological perspective to observe reality in order to understand how the notion of safety is constructed through actors’ relationships to rules, the importance they attached to safety, and the values that are defined as meaningful in an organization. For example, in nuclear facilities, safety barriers – including human and organizational barriers – are set up to protect against radiological and hazard risks. The reliability and effectiveness of these safety barriers depend on how well they are integrated into daily practices. An inductive approach to a facility’s safety culture makes it possible to identify the nature of the risks associated with the safety activities studied [9]. This may bring to light elements that cannot be perceived with a more normative approach, such as a lack of rigor in the application of procedures or inappropriate procedures which cannot be applied for organizational reasons and which may have perverse effects.

Although it may offer valuable insights, a purely inductive approach can be time-consuming and difficult. The socio-comprehensive analysis framework we propose can help to structure an inductive approach by providing a multi-level analysis grid (macro, meso, and micro) for contextualizing and understanding safety dynamics in a systemic way, since it has been highlighted that non reliable situations are systematically produced by the interconnection between environment, organizations and cognition [10].

Our proposal is based on our case study of the introduction of a new process-based management system in a nuclear facility. Instead of setting standards for specific points of safety, the goal of the facility's new process-based management system is "to ensure that safety requirements are not considered separately but put in the context of all the other requirements, for example those for security, safeguards, environment, personal safety, and economy" (AIEA).

Inspired by the work of D. Vaughan [11], aiming to account for the production of deviance at three levels – structural, contextual and individual – we will show how using the socio-comprehensive analysis framework we propose makes it possible to assess the impact of this change on the cultural aspects of safety, as well as the unforeseen consequences and issues that may require vigilance going forward.

The next section begins with a detailed description of our socio-comprehensive analysis framework. We then apply this framework to our case study, analysing the effects of this new management system on the cultural aspects of safety at the macro-, meso- and micro- level. The section closes with a discussion of the relevance and the feasibility of this socio-comprehensive analysis framework in developing a systemic understanding of the cultural aspects of safety, particularly in order to bolster organizations' safety dynamics.

II - A socio-comprehensive analysis framework

In 1986, two accidents, the explosion of the Challenger shuttle and the Chernobyl nuclear disaster highlighted the potential gravity of organizational (or systemic) failures. Analyses of these two major accidents show that they were not merely attributable to inappropriate behavior among front-line operators. Rather, they had been caused by a series of organizational dysfunctions. The concept of "safety culture" originated in this idea of safety as a set of artifacts, values and beliefs rooted in organizations and shared by groups working within them, and spread through the scientific literature [12]. Over time, it became commonly accepted that "the only way to continue to improve is to address the hearts and minds of the management and workers"[13].

Several scholars in the field of risk management have rejected the view that safety culture is independent from the rest of an organization [14], arguing that any culture is embedded in structure, organizations, behaviors, and beliefs. According to their way of thinking, while culture alone cannot explain accidents, it can be the springboard for a sociological inquiry into why a practice is manifested in a certain way [15].

Using this logic, several authors have examined the links among "Organisation," "Culture" and "Safety." While this existing scholarship on safety culture has already promoted socio-comprehensive approaches to identifying the cultural aspects of safety, the core insight of this paper is that when these different approaches are gathered into a single analysis framework, it becomes possible to explore the vast topic of "culture" in a far more meaningful and intelligible way. Starting from this existing scholarship and inspired from D. Vaughan analyses framework [11], we have identified three levels of analysis – the macro, the *meso,* and the micro – that we will use to build a socio-comprehensive analysis of the cultural aspects of safety.

At the *macro level* we find broad economic, regulatory and political constraints that affect the culture within an organization in the way it perceives and manages risk. These may be national: a number of studies have sought to identify managerial modes or types of social relations specific to certain countries, and to associate them with national cultures. Notably, P. D'Iribarne [16, 17] has

emphasised the impact of national culture on corporate culture in comparative studies of 3 countries (France, USA and the Netherlands). For him, such modes and relations are not mere "cultural veneer" but instead reflect real traditions that texture social relations and collective life both inside and outside of organisations. Thus, French culture might operate according to an honor system derived from the codes of medieval knights, as opposed to a contract system would in the US and a consensus system in the Netherlands. T. Philippon [18] concurs, arguing for cultural specificity in work relations with the example of France, which he describes as characterized by a tradition of conflict between employees and employers. This win/lose outlook, he posits, generates a foul social climate that is unfavourable to employment and productivity, and which is rooted in France's history of trade unionism and family-driven capitalism, where power is held by "legacy".

Beyond such national specificities in culture, however, many scholars have noted the development of a bureaucratised and standardised approach to safety over the past twenty years or so that transcends these specificities [19-21], often called the paperwork approach of safety [15].

At the *meso level* we find organisational elements such as structures, systems, and tools, which shape culture through the meanings, beliefs, and behaviours shared by an organisation's members [22-25]. At this level, it appears than the size and age of a facility [26] and its materiality [27, 28] may be relevant to organizational culture regarding safety. As well safety requirement [29, 30] and the interpretations of these requirements [31, 32] may affect the organizational dimension to safety.

M. Bourrier [33, 34] has shown that organization plays an essential role in nuclear power plants. Using the concept of organisational reliability plans (which described the organisational characteristics of each of the plants studied) to describe their collective operations, she argued that the circumvention of rules at the Bugey nuclear plant in France in the 1990s was not primarily due to geography or national culture, but rather to the fact that actors could not adapt procedures to fit their actual circumstances. By contrast, different mechanisms at work at the Diablo Canyon or North Anna facilities allowed actors to account for the realities of plants' actual workings, and to adapt rules accordingly. This is not necessarily due to national culture: if experts are put to work with scant possibility of any formal say in the rules, the result is a model of opaque and stressed autonomy. This has advantages – autonomy can promote adaptability – as well as limitations – opacity prevents sharing and debating practices.

Organizational culture has a direct effect on safety management [11]. It represents a set of shared basic assumptions learned by a group to cope with its problems [12]. K. Weick [35] used the notion of sense-making to combine notions of culture and reliability, arguing that individuals make sense of events by extracting meaningful patterns from their experiences; at the same time, the interactions between members of an organisation also produce meaning, enabling them to establish and share priorities and preferences for actions to be taken. This argument implies that understanding an organisation's culture requires us to understand how power is apportioned within it [28].

Finally, the micro level is composed the characteristics, attitudes, and professional relations within an organization's culture that come together to shape its members' perception of safety and the importance the ascribe to it. Since social reality is not an indivisible whole, and cannot be considered as such, social identity cannot be fixed once and for all. Rather, it is a constantly shifting interplay of interior identity (the identity one wants for oneself, believes in, and wishes to assert within a group) and exterior identity (the identity attributed by others, the one for which one is recognised, the one built upon by external actions). This This implies a duality between one's "reference group" – the group to which one aspires to belong – and one's "home group" – one's group of origin [36], and

means that within a given organization, different sub-cultures may coexist that do not necessarily correspond to professional boundaries [37, 38]. For a person seeking to reduce that gap, this can lead to internal tensions, negotiations and thus to strategies to be recognised and accepted the others. Consequently, "a culture that influences safety positively is not necessarily a homogeneous culture without conflict, but rather a culture in which there is enough *space to manage opposing views in a constructive way*" [39].

Taken together, these three levels make up our "cultural framework analysis," allowing us to break down the highly complex topic of "safety culture" into more accessible parts [28] and to build a comprehensive understanding of the cultural aspects of safety and their impact on risk management. The concepts and methods needed for each level of analysis will be detailed in the following paragraphs, building up a multi-level approach and a thorough and deep examination [40] of the cultural aspects of safety and their determinants within an organization.

Cultural analysis framework

Based on the literature review above, three analysis levels were selected to understand the different cultural aspects with an impact on risk management in organizations requiring high reliability. These levels of analysis reflect a research-based perspective elements affecting culture, drawing in particular on work in the fields of sociology and anthropology.

⇨ **Macro-level:**

- Economic context.
- Political, regulatory and institutional environment.
- National culture.

⇨ **Meso-level (organizational culture) :**

- **Collective aspects of the activity**: role distribution, management system, cooperation/conflicts, etc., player games (uncertainties, strategic resources, etc.), balances of power (strong players, etc.), relationship to the rules, formal and informal social hierarchy.
- **Values and symbolic aspects** that help to give meaning, to operate, to motivate staff, to unify practices, to create adhesion: standards, generic values, identification spaces (status, enterprise, occupation, etc.) and recognition arrangements (by hierarchy, by structure).

⇨ **Micro-level**

- **Professional culture:** professional socialization, work identities, expertise and "work well done" criteria, peers recognition, professional education.
- **Collective life and social relations**: socialization methods and their impact on trust and practice-sharing, symbolic status, rituals, representations, myths, involvement and motivation.

In the study below, we have examined the 'before' and 'after' the implementation of the new system to identify difficulties and tensions, as well as adjustments that may be favourable to risk management.

III - Case Study Methodology

The relevance and feasibility of this "cultural framework analysis" were tested using a case study of the introduction of a new safety management system in a nuclear facility. This case study should be seen as a tool for experimenting with the cultural analysis framework we propose [41].

Following international recommendations (IAEA Safety Standards Series No. GS-R-3), French regulations for nuclear facilities (Order of 7 February 2012 setting the general rules relative to basic nuclear installations) now require that all environment, security, and safety policies be integrated into a single system of management.

Under this new system, activities involving risk and safety must be identified and given special attention using by separating them from other activities. They require extra oversight in the form of more validation (and signatures) from stakeholders, a higher level of detail in the writing of procedures, breakpoints with third-party verification, and special training.

Once this new system had been implemented, the regulator and its technical support organization (TSO) wished to evaluate and analyze the cultural impact of the required change, as part of the obligatory 10-year safety assessment to which French nuclear facilities are subject. This kind of external safety assessment may lead to the recommendation of certain actions that facilities are unable to implement, even if the difficulties they seek to correct had already been identified internally. This type of third-party evaluation can be useful because while identifying some of the consequences of change may be possible internally, it can be difficult to maintain a properly objective perspective on a situation when one is immersed in it. All along the hierarchy, it is easy to cast doubt on internal assessments, particularly in cases of conflicts among stakeholders.

As Human and organizational experts from the TSO we identified and analyzed consequences of the change in system using our "cultural analysis framework". We remind the reader that the focus of our study was not to assess the efficacy of the new safety management system, which is required for all nuclear facilities in France and recommended internationally [6]. Instead, we wished to test our **"**cultural analysis framework" as an appropriate way to understand the concrete consequences of implementing a new safety management system in terms of practices, norms and values. What is its cultural impact? How are safety operations affected? Can the cultural analysis framework be used to highlight certain key safety issues; for example, unforeseen consequences or previous problem that remained unresolved following the implementation of the new management system and that require further attention going forward?

An inductive approach using qualitative ethnographic methodology that fully accounts for people's interpretations and the sense they give to what they do [42] is required to examine cultural issues such as those raised at the three levels of our "cultural analysis framework."

To identify the environmental, organizational and professional context of the safety management system in question, we paid particular attention to such elements as the structure type (entrepreneurial, professional, bureaucratic, mechanistic, innovative, missionary, or politicised organisation), division of labour, subcontracting policies, etc. [43]. With regard to the management policy, we took care to distinguish between the management system (action-related questions) and assessment tools (reporting) [44]. We explored relationships to rules by looking at latitude for changing the rules and the degree of worker involvement in the process of creating rules, including event management arrangements when actions didn't strictly follow rules and the procedures.

We also took account of the values inside the organisation and its different groups of actors: its generic, “declared” values (texts, institutional discourses); its "operating" values (expressed in management systems, decision-making methods, and procedures such as recruiting, budgeting, etc.); its underlying value systems as expressed through discussions of safety-related values (what is considered "good" risk management/"bad" risk management, etc.).

To this end, we interviewed eighteen people at the different hierarchical levels of the nuclear facility: the head of the facility and his deputy, two unit heads, three people from the department responsible for the creation and deployment of the new based management system process, a safety engineer, three radiation protection officers, four operators, and three electrical technicians.

The topics discussed were as follows: the design of the new management system, the appropriation of this system by different actors, its effects on the activities and procedures implemented, and assessments of this change. Questions were also asked about the nature of the relationships among actors and their exchange modalities (see annex). In addition, we observed coordination meetings and risk-related activities.

The field material, once collected, was sorted and analyzed following the three levels of our analysis grid. We used an inductive approach to analyze the field notes, interviews, and documents we collected. Line by line as well as paragraph by paragraph, we coded all conversations, activities, and documentation related to each of the changes people experienced following the implementation of the new management system. We then sorted these codes according to our three levels of analysis (macro, meso, micro).

After performing this analysis, we re-read and compared all the data gathered to see if the data brought together under the main codes were compatible and if more detailed subcodes could be identified through the three levels. We continued this iterative process until we had classified all of the corpus.

IV – The case study: effects of a new management system on the cultural aspects of safety

IV.A - The macro level: a formal context to ensure safety

The *macro level* of our “cultural framework analysis” takes into account the national regulatory context, which can affect the cultural dimension of safety within an organization. The people interviewed identified two justifications for the adoption of the new management system required by French regulation (in line with international standards): The first was to improve formalization and traceability, which would benefit newcomers. This justification was cited often by front-line managers, who thought it would be easier for the newcomers to follow safety procedures if they were more detailed and formalized. The second was their obligation to comply with the regulator.

Institutional discourses very explicitly illustrated these two registers of legitimization within the facility. According to the facility’s director, for example, the new management system was both an opportunity to align with current management trends and a legal obligation.

Some experienced the new management system as an obligation for more formalization and formalism, but not as an opportunity for re-thinking the facility's approach to safety. For them, it generated a greater volume of procedural activities that took time away from the field to conduct risk analyses.

The *macro level* of our "cultural analysis framework" thus helps to highlight how national regulations affect organizational culture by increasing formalism and formalization by implementing what is sometimes known as the "paperwork approach" to safety [15]. Other scholars have already noted this trend toward bureaucratised and standardised approaches to safety, which has been prevalent in companies for over twenty years now [19-21]. A control logic which is particularly present in the nuclear sector [9, 45].

For this nuclear facility, however, the change represented a real revolution in culture. Specifically, staff were concerned that their spontaneous and highly responsive horizontal arrangements would be replaced by slow vertical procedural adjustments. Before, they saw themselves as a "big family," where it was easy to ask for things. By contrast, under the new management system one was "forced to wait" because requests and responses had to follow a formal procedure that ran the risk of being ill-adapted to the facility's specific features. This might incite actors to circumvent [46], or cause organizational inertia that might prevent proposed modifications and modernizations or cause the nuclear power plant to close its doors to the outside world [9, 45].

IV.B - The meso level: the fluidity of activities within the organization to ensure safety

At the *meso level* of our "cultural framework analysis" we assessed how changes made at an organizational level affected the cultural dimension of safety, based on the assumption that "people in organizations do not learn `safety'; rather, they learn safe working practice"[47].

IV.B.1 - The work of organizing activities

Risk management takes place at all levels of an organization. Most attention to human and organizational factors has been focused on operators, particularly through the prism of human error, but it is now accepted that safety is anchored in the process of organizing and scheduling activities.

When it comes to the planning, scheduling and implementation of activities, it has been widely demonstrated that fluidity is a factor of reliability [48-50]. Constant organizational adjustment helps keep the flow of activity fluid, making it possible to maintain safe conditions [48]. To be effective, a management system ought to foster fluidity in activities, rather than hindering it.

It appears, however, that both in the preparation phase and in the implementation phase of this new management system, rigidity and verticality increased, affecting the culture of the organization. During maintenance phases in which facilities are not in operation, work is very dense, and organizing activity effectively is crucial. Group leaders, work supervisors, shift managers, and safety engineers attend a daily coordination meeting during which they organize and schedule the day's activities and detail work orders for the following day. This meeting provides one final opportunity to check activities with a potential safety risk, including possible situations of co-activity: the electrical group might announce that a sub-contractor will be working in Zone A while the maintenance group is finishing its work in zone B, and so on. The coordination meeting offers these groups a last chance to make sure that their different planned interventions are compatible with each other and will not generate risks for others. Should unexpected events occur, such as a delayed delivery, equipment

failure, or testing, the order and scope of planned activities can be modified. This organizational work [51, 52] helps to maintain a continuous flow of activities. Autonomous regulations are put in place, which further contribute to operational reliability [53].

This organizational work was strongly affected by the new management system. Activities involving safety had to be flagged for further attention and placed in a separate circuit with greater oversight (and signatures) from more stakeholders, more closely-written procedures, and third-party verified breakpoints.

While safety-related activities received more attention, their codification changed the way actors related to them. Despite extensive training in the new system, the new language it generated remained difficult for operators to master. While it was easy enough to identify whether or not an operation was sensitive, figuring out how to classify it was another matter, one actor reported, explaining that it was difficult to figure out which procedure number to attribute. As an example, he pointed out that there were three ways to code the procedure for replacing nuclear material in a machine, depending on which action he chose to focus on: was it maintenance, handling or the use of a lifting tool? For him, coding was not clear.

In concrete terms, this means that the procedure number assigned in the work orders is often wrong. This in turn pollutes exchanges among actors and disrupts fluidity at the planning phase. To resolve this issue, preparatory meetings were organized before each "coordination meeting," allowing arrangements to be carried out horizontally without hierarchy intervening [54].

Although time-consuming for operators, this high level of detail and formality in the new system made the additional meeting necessary "to ensure that all boxes are well ticked." Put another way, the implementation of the new system caused actors to spend more time and effort on coordinating something they felt slowed the pace of activity unnecessarily and even harmfully, since a delay in the restart date of a reactor can increase time pressure, which is known to have negative impact on the reliability of operations.

IV.B.2 - Impact on the application of procedures: the increase in breakpoints

The most destabilizing consequence of the change for operators and group leaders appeared to be the required breakpoints, during which activity is suspended and actors must wait for third-party verification before resuming work.

Two kinds of breakpoints exist. The first are provided for in procedures for activities involving risk and safety to ensure that all correct arrangements have been made. The second are required when there is a gap between an activity as it is carried out in context and as it is supposed to be carried out according to formal procedure. This second type of breakpoint is most often identified as problematic, as it interrupts activity in unforeseen ways, requiring workers to evacuate the area and locate the person responsible for the third-party verification. The more detailed and formalized procedures are, the greater the risk that actors will deviate from practices that might force breakpoints. Operators experience these breakpoints as undermining their authority and denying their ability to assess a situation and make appropriate decisions. Actors, including managers, have expressed these enforced breakpoints as a painful loss of agency. As one operator recalled, before the new management system, when a nut was stuck, you could simply heat it up and get on with things. Now, by contrast, operations must stop, and no matter how many people he can explain the

solution to, he must wait around for the right person to confirm that it can be carried out. For him, the procedure is demeaning and even dangerous, in that it wastes time before action can be taken.

This illustrates how breakpoints with third-party verification can affect organizational safety dynamics. For D. Cru [55], "prudence ability" covers all procedures, gestures and ways of doing things that are not officially recognized but help to protect against workplace danger. Based on memory, practice and collective action, "prudence ability" makes activities more reliable and operators more secure. Any procedures, in their level of detail and application, must be compatible with these "prudent abilities" if they are not to hinder the fluidity of activities or run counter to human safety and security.

In the end, too much formalization of activities leads to too many breakpoints, causing the fragmentation of activities, which is detrimental to operational reliability [56]. For example, operators reported a situation where they had a problem with a procedure. They had to leave a controlled radiation area in order to get the signoff needed to rectify the situation and then return to the controlled area to finish the job. They felt that the situation could have been dealt less formally and more directly, preventing double exposure to very low doses of radiation.

Another operator described a situation where a small amount of water retention in a pocket caused an alarm to sound before he was able to wipe it off. Because the alarm sounded, a breakpoint occurred, requiring a report procedure for the regulator. The operator was both observant enough to perceive the excess water and already equipped to wipe it away – if the alarm hadn't sounded, he would have simply circumvent the procedure without saying anything, creating the dark side of organizations [10].

The *meso level* of this analysis thus highlights that organizational change may have unintended consequences on the cultural aspects of safety. Here, breakpoints that require external assistance should be carefully implemented to ensure the right balance is struck between formalization and individual autonomy, as too much formalization and bureaucracy may cause actors to circumvent rules and operators to avoid transparent communication in order protect themselves from too much oversight. To prevent this deviance, it is important to report any difficulties encountered in the field to the managerial level, in order to adjust the system accordingly.

IV.C - The micro-level: relationships and collective work to ensure safety

At the *micro level* of our "cultural framework analysis," we assessed how changes made by the new management system were experienced by operators and actors on the field, and how they affected the cultural dimension of safety: how did operators intimately and personally appropriate the new circuit of procedures? Did it affect their relationship to work and safety?

IV.C.1 - Impact of involvement in the writing of procedures, on the work collective

Previous sociological work has highlighted the importance of operators' participation in the development of procedures: participation makes it easier for operators to appropriate them, to feel more involved in their application, and to update them regularly [34].

In the case of the implementation of the new system, operators were involved in the writing of the new procedures, and they reported that it was interesting to be able to clarify or update certain sensitive procedures. Furthermore, newcomers appreciated being involved in the writing, as it was a way for them to appropriate the procedures as they went.

However, some of them complained that this task significantly increased their workload. Others questioned whether their involvement left too much room for individual interpretation. One radiation protection operator, observing that a same procedure might lead to very different recommendations, gives this example: facing a same situation, workers may ask to wear either a mask or a full suit for respiratory protection. The protection is the same, but the approaches are different - one promotes comfort, while the other one tries to limit waste.

Finally, involvement in the writing of the procedures may have been painful for some: in many cases, rewritten procedures must be corrected by specialists, such as radiation protection engineers, who expressed feeling like school teachers correcting homework: operators authors of the procedure came to see them proudly with their updated procedures, but were mistaken in identifying the type of procedure or the procedure allocation number, forcing the radiation protection engineers to ask them to come back the next day with a correction.

It therefore seems essential to define the appropriate level of involvement of operators in the writing and updating of procedures, particularly because of the activity's impact on work collectives, given the importance operators ascribe to these. Notably, operators in charge of high-risk operations described themselves as a very supportive group, even sharing convivial, family-like moments outside of work. They reported helping one another and feeling no competition among themselves. In one of our observations of a risky operation, for example, operators took turns on the bridge handling the remote control. Without prior planning and without even waiting to be asked, operators recognized signs of fatigue in their colleagues and stepped in to ensure a constant state of awareness was maintained, "because we don't work in a chocolate factory". With less difficult, lower-risk tasks, senior operators step aside so that newcomers can try their hand. The strong inter-knowledge between operators contributes to the fluidity and reliability of operations.

At the *micro level* of our "cultural analysis framework" we can see that placing the writing of procedures in the hands of the operators saves time and increases efficiency for the multiple updates that need to be done. However, if this choice is to be a productive one, it must be acknowledged that it has real professional and cultural impact [38]. So far, the choice has been made to maintain a high level of operator involvement in the writing of procedures, to the point of adapting recruitment policies accordingly. Nowadays, recruitment no longer focuses exclusively on the technical skills of operators, but also on their writing skills, meaning that a higher level of qualification is now required. Professional profiles are becoming more heterogeneous as the recognition of technical skills ceases to be the sole criterion for hiring. This may have an impact on the social dynamics of professional groups, which may require specific support - or at least reflection - on the collective skills expected in relation to safety issues.

IV.C.2 - Impact on professional activity, the field reality issue

The new management system increased the volume of work and was a source of stress and uncertainty for operators who expressed a fear of being blamed for errors that were once considered minor. For change to make sense to and be appropriated by actors, it seems essential that they not be forced to bear the consequences of the new management system. Operators must feel they are supported and listened to, which requires feedback. This double movement of "descending" and "ascending" information to and from the field level, accompanied by support, is what makes it reliable [48].

The naming of a reference person for the new management system within each professional group has helped to inform and reassure operators and group leaders about certain decisions, and interviewees expressed their appreciation of this aspect. This local support is a real added value, making it possible to detect and react to difficulties in the field more quickly and to help agents learn and react to difficulties encountered. As yet, it is unclear how these reference people will exchange with one another in order to achieve an overall vision of the system's implementation, without being unduly influenced by problems encountered by their own teams. At the same time, although it does not seem to be under consideration at the moment, it should be noted that these reference people could help circulate information from the bottom up, particularly feedback with regard to operating experiences.

The strong involvement of safety engineers during the execution of operations could be particularly relevant to the procedure-writing process for two reasons. First, safety engineers could contribute directly to the development of procedures while guiding operators in their responsibilities at the same time. Second, safety engineers could provide feedback based on their knowledge of the field during "process reviews" or during meetings to prepare for operations involving safety risk.

It is also essential that operators feel confident enough to report any difficulties and malfunctions they may encounter. For example, operators described an event in which a fastener was torn off when a too-powerful machine was used to unscrew it. Management identified the operator responsible for this human error without trying to understand the reasons for his action, causing the operator to feel threatened in a way that impeded understanding what had actually caused the event. This highlights the importance of developing a non-punitive approach, which is currently in its infancy: rather than simply identifying the person responsible for a given problem and applying a corresponding sanction, it is important that organizations investigate the circumstances leading up to the problem. The problem with the fastener underscores the importance of human factors in an organization, and makes a strong case for a comprehensive rather than a controlling approach.

The *micro level* of our cultural analysis highlighted the need to support operators in the field to ensure that the change in the safety management system be optimally adapted to actual working conditions. For the moment, safety engineers regret that they are too absorbed by their procedural activities to be able to fully dedicate themselves to accompanying the operators in the field.

IV.C.3 - Impact on the occupational culture, specificities according to the professional groups

A profusion of managerial literature has shown the relevance of managerial modalities that generate autonomy and empowerment. Allowing for the decentralization of decisions by making it possible to move back and forth between centralized and decentralized organizational modalities functions particularly well for hazard management [57].

It is therefore important to start by considering the actual work situation on the ground before thinking about the development of procedures. Occupational safety rules should be developed in this way [58], rather than institutionalizing rules from the top down, based on an engineer's belief that an organization ought to impose well-designed rules to preserve safety and security in a certain way, as is so often the case [59].

The micro-level of this case study also makes clear that breakpoints must be adapted to work situation ergonomics. Breakpoints provided for in procedures must be designed with the help of safety engineers to be relevant not only inside offices but in the field, as well. Conditions for restarting a procedure must be examined in order to identify the correct level of oversight, since a person at a high level of the hierarchy may be difficult to reach, meaning they are not necessarily in an ideal position to assess a situation and give permission to restart an activity. For example, if a safety engineer is called in for third-party verification on a procedure with which she is not familiar, her signature is little more than a formality.

As the concept of "prudence ability" [55] passed on from actor to actor has shown, not everything can be written into a procedure. As one safety engineer noted, each occupational group has its own set of skills, meaning that written procedures are not the same as a manual, and cannot replace know-how. It is impossible, he explained, to specify every place one should or shouldn't step, or whether, at a given moment, one should look up and to the right, not down and to the left. Not everything, he concluded, can be written.

Furthermore, reviewing the ergonomics of procedures does not necessarily mean standardizing them among all professional groups. To the contrary, in fact: it may also mean taking into account the specificities of each group in an organization [59], particularly in cases where the appropriation of procedures and relationships to rules varies from one professional group to another. Professional systems are not homogeneous within an organization [60]: for example, electricians are accustomed to taking measurements and acting in consequence, whereas material handlers are not. Thus, formalization of procedures and the transition to a culture of traceability was an easier experience for electricians than it was for material handlers, because they fit into the electricians' existing work practice. In situations where the interplay of rules within the structure of an organization is significant, differences occupational groups may appear and even bring into conflict [60].

As this section has documented, the *micro level* of our "cultural analysis framework" allowed us to analyze the impact of the new safety management system on the occupational culture of the operators. This suggests that organizational and cultural change must incorporate familiar and effective occupational norms about work objectives and skills in order to build a safety culture [35]. This implies taking into account the specificities of the professional groups, not only in the SMI training sessions - as is already the case - but also in the process of reviewing the procedures to consider their operationalization and their singular appropriation modalities.

V - Assessment of the cultural analysis framework proposed

Working from the field of social sciences, we were able to build a socio-comprehensive analysis of the cultural aspects of safety in line with the existing literature [11, 28, 34]. The "cultural analysis framework" proposed here helps to develop a comprehensive approach to the cultural aspects of safety – not what ought to be done, in other words, but *how* it is done. The cultural aspects of safety are embedded in the different levels of an organization as well as in its environment. Safety is thus highly contingent and requires the kind of case-by-case analysis that the analysis framework proposed in this paper makes possible.

As our case study showed, analyzing the *macro level* helps to reveal how the national regulatory context affects the internal dynamics of an organization. Exploring the *meso level* makes it possible to highlight the risk of excessively strict and rigid formalization of processes relating to high-risk

operations, both in the preparation phase (scheduling of activities), and in the implementation phase (application of procedures). Finally, examining the *micro level* shed light on the importance of formalizing procedures while preserving the autonomy and know-how of operators and fostering the flow of information.

The core advantage of our socio-comprehensive framework is the way in which it identifies and helps to explain the impact of change on the cultural aspects of safety – and the gap between expectations and reality when it comes to this impact. It therefore likely offers challenges to both regulators and academics in the field of nuclear engineering. In cases such as this one where the gap between regulatory expectations and organizational performance is frequent or significant, our framework allows us to explain not only "why" but also "how" [54].

In our case study, the regulator's goal was to integrate all environmental, security and safety policies into a single system of management. Our analysis framework reveals an unforeseen consequence of the change required to achieve this goal: the new management system generated a greater volume of procedural activities without actually creating a new and more integrative safety approach.

Our analysis framework also makes it possible for practitioners to identify the impact of change and to highlight key points where particular vigilance is required. These points include: developing a management system that can be easily appropriated by the actors involved, providing staff to safety engineers to handle their increased volume of administrative work, limiting the level of detail included in procedures, and adapting breakpoints to work situations. The framework makes it possible to see that while it may be true that operators are not yet sufficiently trained and continue to experience difficulty applying the procedures, the procedures themselves are also too detailed and too rigid. The more detailed and rigid the procedures, the more likely it is that breakpoints will affect the reliability of operations.

There are certain constraints to implementing this kind of socio-comprehensive approach to safety assessments. The first constraint is feasibility: this kind of study underlines the importance of a qualitative methodology based on observations and interviews; in practical terms, this means having access to the field and being able to interview people who feel confident to talk about their activity and experiences. However, restrictions set by the Operator in terms of access to the field may leave little place for this kind of thorough analysis. This approach, furthermore, may also require more time than a simple questionnaire, especially when it comes to accurately recording the perceptions and beliefs of the actors.

The second constraint relates to skills and professional background: a socio-comprehensive approach analyzes the knowledge produced by actors in a given activity, as well as their representations and the way they give meaning to what they do, which in turn reintroduces rules and norms. It therefore requires a background in the social sciences, something that may not be available to an organization internally. This is further complicated by the fact that it is imperative for social scientists working in this kind of field avoid bringing with them a pre-established, scripted approach to safety culture. Instead, it is essential that they learn to develop a comprehensive approach to the phenomena they wish to observe, within their own and in other organizations.

VI – Conclusion

For those wishing to go beyond very vague general assessments, the broad topic of "safety culture" appears far too complex to be addressed comprehensively. Our paper has shown how a socio-comprehensive approach that uses a “cultural analysis framework” offers an appropriate way to meet this challenge by providing a more thorough understanding of what goes on inside an organization with regard to safety. In the case study presented here, interviews and observations showed how a change in safety management systems in a nuclear facility did not produce the effects expected or intended by the regulator in terms of safety management.

The logic of safety assessments as they are usually conducted by Regulators and their Technical Support Organizations is based mainly on formal material (procedures, writings, data, etc.), which may be clarified and reality-checked by operator narratives collected in interviews. However, these narrations are all too often seen as unreliable or untrustworthy in their ability to provide opinions, advice, or perceptions.

As this case study has shown, if we are to expand and deepen our understanding of safety culture, it is imperative that actors’ words be considered as both necessary and sufficient to decoding safety in its cultural dimension. This implies building training programs that teach a comprehensive approach, as well as expanding the use of comprehensive studies such as this one.

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APPENDIX – Interview questions

This table presents the list of questions to be asked to respondents during the survey

Safety	1 - In your opinion, what are the ingredients essential for "good safety control"? Please explain and give examples. 2 - What makes sense for you at work, what is most important on a daily basis? Are you happy at the end of your day if...? How is the transmission of field practices between operators carried out? (companionship, validation of knowledge acquisition, etc.) Have you experienced situations where compliance with procedures conflicted with safety/operations? Are there cases in which compromise is impossible to reach?
The new management system	What is the story behind the establishment of the new management system?
	What are the objectives you are pursuing through the deployment of the new management system? What objectives do you personally consider or would you have liked to associate with it?
	How did you perceive this new management tool? With whom did you agree/disagree?
The consequences	How has the implementation of the new management system impacted your activities?
	Do you consult the procedures in your operating process?
	What impact does the new management system have on the flow of activities: activity scheduling, issuance of work orders, coordination meetings, etc.
	What (who) is helpful/ a hindrance in the implementation of this new system?
Experience Feedback	Are there professional characteristics that facilitate the appropriation of SMI?
	Have you noticed any impact of new management system on departures/hiring?
	Do you have any concrete examples of recently implemented measures that have been supportive of safety, whether or not they are related to the new management system?