Universitat Autònoma de Barcelona

The organizational and safety culture of the Spanish nuclear industry
A descriptive approach based on 20 years of independent safety culture assessments

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Doctoral Thesis

-Research Compendium-

The organizational and safety culture of the Spanish nuclear industry

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el meu refugi, la meva llum.

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Acronyms

ACRONYMS	MEANING
CIEMAT	Spain's Public Research Agency for Energy, Technology and Environment
JEN	Nuclear Energy Board
CSN	Nuclear Safety Council / Spanish Nuclear Regulatory Body
ENUSA	Spain's National Uranium Company
ENRESA	Spain's National Radwaste Company
ENSA	Spain's Nuclear Equipment Company
PEN	National Energy Plan
NPP	Nuclear Power Plant
NPC	Nuclear Public Company
IAEA	International Atomic Energy Agency
INSAG	International Nuclear Safety Group (IAEA)
TECDOC	Technical Documents (IAEA)
TECH SPECS	Technical Specifications
CAMM	Adaptative Canadian Machine
AECB	Atomic Energy Control Board / Canadian Nuclear Regulatory Body
UNESA	Association of Electric Power Companies
ISCA	Independent Safety Culture Assessment (IAEA)
OSART	Operational Safety Review Team (IAEA)
SCART	Safety Culture Assessment Review Team (IAEA)

ASCOT	Assessment of Safety Culture in Organizations Team (IAEA)
NOMAC	Nuclear Organization and Management Analysis Concept methodology
HRO	High Reliability Organizations
RE	Resilience Engineering
COP	Conflicting Objectives Perspective
MMD	Man-Made Disasters
NAT	Normal Accidents Theory
SCWE	Safety Conscious Work Environment
RIS	Reporting and Improvement System
SPSS	Statistical Package for the Social Sciences

Content

Acknowledgments **3**

Acronyms **4**

1. Preface **8**

2. Introduction **11**

2.1. Development of the Spanish nuclear industry 12

2.2. Safety approaches 15

2.3. Theories of high-risk organizations 17

2.3.1. Theory of "Man-Made Disaster" *17*

2.3.2. Theory of "Normal Accidents" *18*

2.3.3. Theory of "High Reliability Organizations" *19*

2.3.4. "Conflicting Objectives" Perspective *21*

2.3.5. "Sociotechnical Model" of Rasmussen *22*

2.3.6. "Organizational Accidents" Perspective *24*

2.3.7. "Resilience Engineering" Perspective *24*

2.4. Culture 26

2.4.1. Organizational culture *27*

2.4.2. Organizational culture models *28*

2.4.3. Organizational subcultures *29*

2.4.4. Safety culture *31*

2.5. Organizational culture evaluation methodologies in the nuclear industry 33

2.5.1. IAEA methodology *34*

2.5.2. "Nuclear Organization and Management Analysis Concept methodology" *36*

2.6. Theoretical framework of theoretical reference for empirical dissertation studies 39

3. Dissertation objectives **40**

3.1. Describe the organizational culture of the Spanish nuclear industry 40

3.2. Describe the organizational safety culture of Spanish nuclearpower plants. 41

3.3. Understand the reporting and problem-solving behaviors in an organization of the Spanish nuclear industry. 41

4. Articles that form this compendium 42

4.1. Study 1: Organizational Culture and Subcultures in the Spanish Nuclear Industry 42

4.2. Study 2: Safety Culture in the Spanish Nuclear Power Plants through the Prism of High Reliability Organization, Resilience and Conflicting Objectives Theories 89

4.3. Study 3. Understanding Reporting and Problem-Solving Behaviors in a High Reliability Organization: A Case Study in a Spanish Nuclear Company 138

5. Dissertation conclusions 172

5.1. Dissertation limits 177

6. Current and future lines of research 178

6.1. Existing lines 178

6.2. Potential lines for the future 179

6.2.1. Analysis of most relevant events in nuclear power plants 179

6.2.2. Studying the impact of the energy transition context on this industry 179

7. References 181

8. Annexes 191

Annex 1. Interview to Dr. Badia 191

Annex 2. Spanish nuclear industry 192

Annex 3. The International Nuclear and Radiological Event Scale 193

Annex 4. Rasmussen's sociotechnical model 194

Annex 5. Schein's model of organizational culture 195

Annex 6. Human Synergistics, Inc. permission letter for the reproduction of the OCI styles descriptions 196

Annex 7. Organizational and safety culture assessment process outline 197

Annex 8. Mintzberg's organizational components 198

Annex 9. Dissertation sample 199

Annex 10. Dissertation methods 200

Annex 11. Study 1 data matrix 201

Annex 12. Study 2 data matrix 202

Annex 13. Historical record of events reported by nuclear power plants to the CSN (classification according to INES scale) 203

1. Preface

This doctoral thesis research, titled "The organizational and safety culture of the Spanish nuclear industry. A descriptive approach based on 20 years of independent safety culture assessments", arose from the interaction of multiple factors.

Firstly, the natural evolution of my career as a researcher for CIEMAT (Spain's Public Research Agency for Energy, Technology and Environment), where I have been working for 15 years. At CIEMAT, organizational and safety culture in High Reliability Organizations (hereinafter HRO) was my major field of study and to this date and after years of research, I still find it exciting and somewhat enigmatic. To give it an autobiographic touch, I would say I am moved by the challenge of understanding something so multi-faceted and difficult to grasp as the culture of organizations operating in high-risk environments. We are therefore talking about a research object, safety culture, which despite its apparent simplicity, is complex and diffuse and has an ever-changing and apprehending nature.

Secondly, I would like to point out that being a research team member participating in organizational and safety culture assessments in Spanish nuclear facilities, has not only allowed me to thoroughly assess and understand the industry's culture, but also opened new possibilities and approaches to studying it. In this regard, another factor leading to this doctoral thesis was my interest to further develop and give consistency to results obtained from external safety culture evaluations carried out in Spanish nuclear facilities. The large amount of available data from companies comprising the Spanish nuclear industry gave rise to the opportunity and need to analyze it from a systemic approach, which considers that the unit of analysis (individual, group or organization) is made up of a hierarchy of complex systems mutually interacting and influencing each

other (Rasmussen, 1997). From this perspective, this research aims to gain further knowledge of the main characteristics of organizational culture in this industry as a whole.

On the other hand, this work arises in a context conditioned by a change of energy paradigm to which the nuclear industry must adapt. This new scenario, within the framework of energy transition, contemplates the end of operating life for all nuclear power plants and an increasing number of decommissioning processes. This context and the pressures of environments where nuclear facilities operate will cause these organizations to face several technological, regulatory, organizational and human challenges which could impact safety. Thus, it is necessary to undertake a comprehensive analysis of safety within the nuclear industry, because having an overview of its organizational culture could contribute to improving safety levels not only in each organization, but also within the system of which it is part.

Lastly, from a more personal angle, this doctoral thesis might result (subconsciously) from the fact that I am the daughter of Dr. Josep Badia, an oncologist and surgeon whose thesis focused on nuclear medicine. His research work in the 80s revealed back then (Annex 1) that incorrect praxis with radioactive substances and lack of adherence to radiation protection regulations could lead to severe consequences, both for health professionals and patients (Bayo, 1982). In this regard, it showed how basic beliefs and assumptions around safety, that is, safety culture, did condition human behaviors. Although a lot has happened ever since, it is still clear, as shown by the analyses of the most catastrophic nuclear accidents, that organizational and safety culture are key contributors to accident occurrence.

The doctoral thesis by compendium of publications presented below gathers the results of the empirical studies in three articles published in peer-reviewed scientific journals. The first study facilitates the understanding of

organizational culture in the Spanish nuclear industry, both in terms of structure and subcultures. The second one links the reality of safety culture in Spanish nuclear power plants to three key theories within the scope of this field, namely High Reliability Organization, Resilience Engineering and Conflicting Objectives. Both studies provide, based on quantitative data, an overview of organizational culture in this industry. The third study, from a discursive and qualitative perspective, focuses on specific human behavior aspects relating to the use of problem reporting systems, with a more interpretative angle.

In short, the first two studies provide a snapshot of the industry's cultural traits, supported by the theoretical framework of social sciences. The third study complements the other two, offering a microscopic view of active culture (behavioral aspects) in a given organization.

Thus, the results of this study provide both a comprehensive and specific overview of organizational and safety culture within the Spanish nuclear industry, contributing knowledge to understand how the social and organizational reality of Spanish nuclear organizations is built. All with the aim, of course, of improving safety in high reliability organizations.

2. Introduction

The analyses carried out after the occurrence of the most important catastrophic accidents in the nuclear industry (Three Mile Island, Chernobyl and Fukushima) revealed that the causes of events relating to technologically complex systems are not only linked to technical aspects, but also to apparently intangible factors such as human behavior and organizational culture, which play an important role in their genesis (Rasmussen, 1997).

Within the Spanish context, the analysis of incidents such as the fire occurred at Vandellòs I nuclear power plant in 1989, the corrosion of cooling systems at Vandellòs II NPP in 2004 and the release of radioactive material from Ascó I NPP in 2008, also revealed the influence of organizational components in safe plant operation.

Human and organizational factors are precisely the focus of this thesis, which is comprised of three published papers that share the investigative aim of identifying typical cultural traits of nuclear organizations. Such cultural traits can help to understand human behavior within a context in which safety should be a key organizational goal.

It is important to explicitly refer to the theoretical frameworks or key assumptions of this dissertation: a) a concept of safety culture as an organizational culture facet; b) the acknowledgment that various organizational subcultures might exist within the same organization, c) some contributions developed by theoretical models of safety management within complex facilities and e) the reporting culture as a key aspect determining the safety of high-risk systems.

The most relevant information to contextualize the different studies that constitute this thesis is presented below. It starts with a historical review of nuclear energy development in Spain, followed by theories on accident

occurrence in complex organizations, the concept of organizational and safety culture, and evaluation methodologies.

2.1. Development of the Spanish nuclear industry

This section includes a short introduction on the implementation and development of nuclear energy in Spain as one of the main power sources in the country. Such model was defined into the First Energy Plan (Spanish acronym, PEN) approved in 1975. Nuclear energy was expected to become in 1985 the main power source in Spain, with a total of 13 nuclear power plants scheduled for construction (Ciemat, 2001). A brief chronology of the main facts forming Spain's nuclear industry (Annex 2) is presented below. As will be seen, safety considerations are part of the development of the nuclear industry within Spain.

In 1945 the first uranium sites were sought in several Spanish provinces, but it was not until 1951, when a legal basis for mining development in those sites was provided, when the Junta de Energía Nuclear (Nuclear Energy Board, hereinafter JEN) (Spain's Official Gazette BOE, dated October 24, 1951) was founded. JEN was a national reference center in the areas of nuclear technology research and development.

In 1968, the first Spanish Nuclear Power Plant (hereinafter NPP) was commissioned: José Cabrera. Santa Maria de Garoña NPP was commissioned two years later and Vandellòs I NPP in 1972. These were all first-generation stations. Also, in 1972 ENUSA (Spain's National Uranium Company) was founded with the aim to supply fuel to all Spanish nuclear power plants. ENUSA's mining activities took place on sites in the province of Salamanca. In 1973 ENSA (Spain's Nuclear Equipment Company) was created for the manufacturing of large nuclear components.

Later, in 1980, JEN was split into two independent bodies: the CSN (Nuclear Safety Council), in charge of regulatory functions in the area of nuclear safety and radiation protection; and the CIEMAT (Spain's Public Research Agency for Energy, Technology and Environment), with a clear research function in the areas of energy (not only nuclear), technology and environment.

In the 80s, the so-called second-generation stations were commissioned, including: Almaraz I (1983), Almaraz II (1984), Ascó I (1984), Cofrentes (1985) and Ascó II (1986). In 1984, ENRESA (National Radwaste Company) was created with the goal of managing high-, mid- and low-activity radwaste generated in Spain, as well as of undertaking decommissioning processes. ENRESA's low- and mid-activity storage center in El Cabril started its activity in 1992.

Lastly, the nuclear power plants of Trillo I and Vandellòs II, both third-generation stations, started operating in 1988.

It is important to mention that in 1983 a nuclear moratorium was integrated into the new National Energy Plan, which adapted the nuclear energy program at the time. As a result of the moratorium, construction of the nuclear power plants of Valdecaballeros, Lemóniz and Trillo II was brought to a halt, meaning only 10 of the 13 initially planned stations were actually commissioned.

There were several causes behind this moratorium (Rubio-Varas & De la Torre, 2017): The financial losses of utilities, the context of transition to democracy and the antinuclear movement, amongst other. This social opposition to nuclear energy began to spread in Spain after an accident in which two USA hydrogen bombs were dropped on Palomares in 1966 and continued to exist in parallel to the nuclear industry all these years.

Currently, 7 of the 10 reactors within the Spanish nuclear fleet continue in operation, two reactors are in the decommissioning process and one in permanent shutdown, awaiting decommissioning.

The first nuclear power plant to cease operations in Spain was Vandellòs I due to a turbine fire which led to severe site flooding and to the loss of safety systems in 1989. This event was classified as "important incident" (level 3 out of 7) in INES (International Nuclear Events Scale) (Annex 3). It was the worst nuclear accident in the history of Spain.

A subsequent analysis of this event revealed that, in addition to design flaws, there were a number of organizational irregularities (insufficient inspections program, partially tolerated equipment and system degradation, lack of operating experience use, safety design modifications not implemented and emergency response gaps) (NEA, 2014). The accident also revealed safety culture deficiencies affecting the actual regulatory agency, including a lack of critical attitude towards regulated parties and insufficient transparency or independence (Pérez, 2019).

The second station to shutdown permanently was José Cabrera, which after 38 years of operation began its decommissioning phase in 2006. One of the reasons leading to its permanent shutdown was its failure to comply with Technical Specifications (Tech Specs) during the refueling outage in 2003. Such non-compliances were classified by the CSN as Level 1 on the INES scale. That same year the regulator had opened a complementary technical instruction with the aim to improve safety culture at the José Cabrera nuclear power plant (CSN, 2003).

Lastly, in 2017, the owner companies of Garoña NPP decided to shut it down permanently due to economic reasons. The station is currently in the pre-decommissioning phase.

It is also noteworthy that within the framework of the National Integrated Energy and Climate Plan 2021-2030 (Spanish acronym, PNIEC) approved by the Government after a three-way negotiation between ENRESA, the Government and the different electricity companies, it is foreseen the gradual shutdown of the

remaining nuclear power plants between 2027 and 2035. This new scenario, within the context of energy transition, will not only imply a change in the energy model with a significant deployment of renewable sources, but also an increased number of activities and processes associated to decommissioning and radwaste management in the nuclear industry.

2.2. Safety approaches

The safety of nuclear organizations is indispensable for our society due to the severe social, environmental, and economic implications of any accident affecting the nuclear industry.

Historically safety has been addressed from different perspectives linked to the occurrence of industrial disasters (Hollnagel, 2009; Reason, 1990). Some traits of the most important safety management theories are presented below.

Efforts initially focused on the development of more reliable technologies to compensate for equipment failures, which were considered until then as the main cause of accidents. This was clearly a technology-drive approach which believed that technology could be in itself a guarantee of safety. This first period is known as the Technological phase.

During the first half of the 20th century, as the reliability of systems increased, accidents relating to equipment failure decreased and the significance of individual human errors was brought to light. Studies began to focus on individuals (ergonomics, human-machine interface, human reliability analyses…), thus leading to the Human Factors phase.

Investigations following industrial disasters such as Three Mile Island (1979), Chernobyl (1986) and Goiania (1987) questioned approaches which saw engineering failures and individual human errors as the origin of accidents, identifying instead that organizational failures also played their part. They referred to factors not addressed until now, such as non-compliance with

regulations, tolerated degradation of safety systems, self-complacency, or lack of leadership. It was revealed that accidents rarely resulted from single failures of equipment or human errors, and that some organizational deficiencies could trigger their occurrence. This new vision was called the Organizational phase and dealt with other less tangible aspects relating to safety. From this organizational approach, human errors are considered a symptom of latent organizational and managerial gaps. In other words, organizational factors have an impact on human performance. It is during this period that the 'safety culture' construct arises as a principle to understand the influence of cultural elements within the organization on safety.

A new period was added to the approaches proposed by Reason, which was called Inter-organizational phase (Wilpert, B.; Fahlbruch, B.; Miller, R.; Baggen, R.; Gans, 1999). These authors believed that accidents should be assessed taking into account not only existing relationships within the organization, but also how the latter interacts with other key, external stakeholders.

As for Glendon, Clarke and McKenna (2016), they considered that previous approaches should not be discarded, but rather integrated. Under an idea of integration, they pointed out the importance of addressing safety management from a holistic approach with the aim to understand the complex relationship between technology, humans, and the organization.

Aligned with the idea of not replacing previous approaches, Borys, Else and Leggett (2009) introduced the concept of adaptation, considering that organizational leaders need to accept that groups of workers might create their own shared meaning of what it means to work safely. Thus, management should try to understand and influence these differentiated cultures so that they are aligned to the corporate culture as much as possible (Martin, 2002). Therefore, the adaptation phase challenges the vision of a single organizational culture, acknowledging the existence of socially-built subcultures (Gherardi & Nicolini,

2000) and considering that organizations should have adaptative cultures to deal with performance variability and uncertainty. This adaptation requires taking more than one perspective into account to prevent event causes.

In short, safety management in high reliability organizations has changed throughout the years, with focus shifting from technical aspects and human behaviors to more managerial and organizational aspects. When an accident occurs, contemplating these variables separately seems insufficient to consider the multiple causes involved. A complete and integral view of safety will be beneficial from a preventive perspective. Operating experience and research have revealed that bringing about behaviors and attitudes which reflect a high level of commitment and responsibility towards safety is an indispensable task to prevent catastrophes.

2.3. Theories of high-risk organizations

Over the last 40 years, a number of theories on the contribution of organizational factors to safety within complex systems has been developed.

The main approaches supporting the empirical studies of this dissertation are included below.

2.3.1. Theory of "Man-Made Disaster"

In 1978, Barry Turner (1978) published the book "Man-made disasters" (hereinafter MMD), in which he linked organizational culture aspects to the safety of facilities. After a qualitative analysis of research reports from various accidents, Turner pointed out that catastrophic events were not fortuitous events, "acts of God" according to him, or the sole consequence of technological failures, but that they were actually caused by the interaction between organizational and human aspects (Turner & Pidgeon, 1997).

This approach considered that human errors were a consequence rather than a mistake. In other words, errors are a symptom of the existence of inadequate, latent conditions within the system.

One of the contributions of the MMD theory was to reveal the link between the occurrence of significant accidents and basic organizational processes such as organizational culture, communication mechanisms and power relations. In that regard, one of the pillars of this theory is the concept of 'incubation'. MMD considers that accidents incubate before they occur, with the organization being unaware that they exist, and their severe operational complications will surface. The accumulation of inadvertent events, the lack of information and the underestimation of risks, are all components developed during the incubation period of a disaster. It is a paradox inherent to culture, which is both a "way of seeing and a way of not seeing" in the form of blind spots within the organization (Turner & Pidgeon, 1997, p. 49).

From the perspective of MMD, the challenge for organizations is to ensure early detection of conditions which could lead to a disaster, even if they are not evident. MMD considers that organizational learning is paramount to improvement because it favors the review of beliefs which affect behaviors and reduces organizational vulnerability through resilience.

2.3.2. Theory of "Normal Accidents"

In 1984, Charles Perrow (1984) developed the theory of "Normal Accidents" (hereinafter NAT) after analyzing the nuclear accident at Three Mile Island in 1979. This theory, together with that of "Man-Made Disaster", are the origin of an organizational approach to safety (Reason, 1997).

It is considered that NAT has a pessimistic vision as its states that accidents and failures of complex systems employing technology and humans cannot be prevented, regardless of their operational and managerial effectiveness. Perrow's

argument, based on human error, is that significant accidents tend to escalate and that the problem is not technology, but organizations.

Perrow also says that complex systems such as nuclear power plants have two properties making them susceptible to having an accident: complex interactions and high coupling. Complex interactions are caused by multiple components interacting with one another and impossible to predict because they are not visible or immediately understandable (Perrow, 1994). In organizations with high coupling, failure in one part can quickly and almost invariably spread to other parts, with little chance for human intervention. These characteristics imply that there is not sufficient knowledge to understand, intervene and stop potential failures.

Thus, Perrow states that the immense complexity of these systems makes it inevitable for high-risk organizations to be impacted by what he calls "normal accidents", suggesting that it would be better to consider a radical redesign and, if that were impossible, to drop this technology altogether.

2.3.3. Theory of "High Reliability Organizations"

The theory of "High Reliability Organizations" (hereinafter HRO) was created by a group of researchers from the University of California in Berkeley (Rochlin, La Porte, & Roberts, 1987), in contrast with the "Normal Accidents Theory". It was not developed with the aim to study accident causation, but to focus on what supports the performance of complex organizations. To do that, their research tried to determine which factors allowed complex high-risk systems (aeronautics and nuclear industries) to obtain a good safety performance.

According to this theory, severe accidents in dangerous, high-risk operations could be prevented through a combination of strategies such as redundancy, organizational learning, ongoing technical qualification, promotion

of communication and existence of reporting mechanisms (La Porte & Consolini, 1998; Roberts & Bea, 2001).

Scientific literature includes multiple definitions of the concept of high reliability organizations. Although all of them have some aspects in common, no fully-agreed definition has been established yet (Enya, Pillay, & Dempsey, 2018). As for Roberts and Rousseau (1989), they identify a set of characteristics for an organization to be considered an HRO: organizations of high complexity and interrelations; existence of highly hierarchical structures with clear roles and responsibilities; redundancy; high levels of responsibility and tight timelines. Sutcliffe (2011) suggests that the common attribute of HROs is that their daily operations are carried out in an environment full of risks and uncertainty where failures rarely occur due to the existence of complex processes used to manage complex technologies.

Hopkins (2007) points out that researchers recently stopped focusing on the criteria that facilitates the identification of high reliability organizations to focus on determining which type of practices allow organizations to reach and maintain high levels of reliability.

Along these lines, Weick, Sutcliffe and Obstfeld (1999), after reviewing literature on HRO, define five characteristics which increase organizational reliability: preoccupation with failure; reluctance to simplify interpretations; sensitivity to operations; commitment to resilience; deference to expertise. These refer to behaviors such as quality of attention, state of alert and awareness of details (collective mindfulness) exhibited by organization members and needed to manage unexpected situations and attain organizational reliability.

In short, the approach of both HRO and NAT highlights the contribution of organizational and social factors to safety, as well as their role in accident causation. However, although they coincide in the belief that the complexity of high reliability organizations could lead to system accidents, the HRO theory

shows a more optimistic vision by supporting the idea that facilities can perform safely despite the dangers faced by complex systems.

2.3.4. "Conflicting Objectives" Perspective

The "Conflicting Objectives" perspective by Rasmussen (1997) is supported by the basic idea that human activities are characterized by an ongoing search for adaptation against partially conflictive needs and pressures. This conflict could take the organization to a state of dilemma due to the impossibility of balancing goals correctly.

Large technological systems are subject to multiple pressures: operations need to be profitable and safe, and the workload for personnel must be feasible. Failure could be the result of a normal organizational behavior that is influenced by environmental pressures, complex technology, and social system processes.

When individuals and organizations constantly make compensatory decisions to deal with the pressure resulting from differing goals, activities tend to migrate towards potentially unacceptable behavioral limits. In that sense, decisions in the face of conflicting goals can push systems towards safety limits, meaning this confrontation between conflicting organizational decision-making processes can lead to accident.

In a dynamic, complex, sociotechnical system, safety and quality could be gradually relegated in favor of other goals such as production and time. It is worth noting that, at every hierarchical level, people respond to pressure and make compensatory decisions without considering how such decisions will influence and mutually interact with decisions made by others (Woods, Dekker, & Cook, 2010). In the case of complex systems, these decisions and adaptions to balance all types of pressure are made locally, without central coordination or understanding their impact on safety (Dekker, 2011). Rasmussen stated that these uncoordinated adaption attempts could accumulate in time, taking the system

away from its design parameters. That would mean that systems might slowly and inadvertently move towards catastrophe. Dekker adds that some organizations seem to head for failure even if they appear to operate well and have success, whereas others seem to avoid significant organizational accidents even if they have faced similar risk situations which could have ended in a disaster.

Based on the "Conflicting Objectives" perspective, Rasmussen develops the "Drift to Danger" model or the "Systemic migration of organizational behavior toward accident under the influence of pressure toward cost-effectiveness in an aggressive, competing environment" (Rasmussen, 1997). This model seeks to effectively manage conflicting goals, making unacceptable risk limits both explicit and known. That implies organization members can control their behaviors to remain within safe limits, meaning organizations have to formulate and justify precise criteria to manage critical decision-making processes.

2.3.5. "Sociotechnical Model" of Rasmussen

In addition to the "Drift to Danger" model, Rasmussen also developed the sociotechnical model, which highlights the importance of human and organizational factors in the safety of complex systems such as nuclear power plants.

The sociotechnical model (Annex 4) also identifies multiple stakeholders, both inside and outside the organization, which play a key role in safety through control and decision-making process mechanisms. Rasmussen arranges these stakeholders hierarchically, pointing out how the decisions made by some individuals limit the decisions of others through laws, norms and rules which set the guidelines to follow.

Interaction (top-down and bottom-up) and adjustment between government, regulator, organization, management, and personnel, as well as technology and the environment, contribute largely to system safety.

Decisions made in high hierarchical levels condition the safety measures implemented in lower levels, meaning safety is determined by the decisions of some stakeholders, politicians, managers, and safety experts, and not just by nuclear technology or the actions of production line workers. Therefore, accidents and threats to safety might result from gaps in the vertical integration of abovementioned levels, and not only from deficiencies in one single level.

That means that within the nuclear industry context, safety emerges from the interaction of all stakeholders inside and outside the organization, and from the system's response to environmental pressures.

Quite often, the analysis of incidents tends to focus on the factors closest to occurrence, space, and time, without considering the relevance and interdependence of all stakeholders abovementioned. That is exactly one of the main contributions of Rasmussen's model.

In short, safety is an emergent system property which results from interrelations between the social and technological system. Thus, human, technological, and organizational factors, their interrelation and their interaction with the environment are paramount to safety. It is necessary to take into account that the context in which activities are developed has an influence on the decision-making process and conditions the application of norms and regulations. Therefore, the development of more effective safety culture policies requires, according to this model, adopting a multidisciplinary approach which considers the system's dynamism and interactions.

2.3.6. "Organizational Accidents" Perspective

According to Reason (1997), there are two types of accidents: those affecting individuals and those impacting organizations. Compared to individual accidents, organizational (or system) accidents are infrequent but when they occur their nature is catastrophic, especially in nuclear power plants, commercial aviation, or chemical and petrochemical industry.

Reason believes that accidents are not only caused by the individual mistakes of operators (active errors), but also by broader organizational, systemic factors (latent conditions) in higher hierarchical levels within the organization. Reason defines active errors as those "where the effect is felt almost immediately" whereas latent errors "tended to lie dormant in the system largely undetected until they combined with other factors to breach system defenses." (Reason, 1997, p. 173). He also thinks that active errors are symptoms or signs of a defective system.

With this perspective of accident causation, the focus is transferred from individual blame, personal approach, and active errors to blame-free investigation, a systemic approach, and latent errors. In this regard, one of the implications of this organizational view is the search for latent conditions leading to accident.

2.3.7. "Resilience Engineering" Perspective

Hollnagel describes two different modes through which safety can be attained. The first approach, 'Safety-I' or centralized control is associated to a concern to understand things that go wrong. The second approach, 'Safety-II' or guided adaptability, focuses on how and why things go well, and is defined as the capacity to be successful under changing conditions (Hollnagel, 2008). The term 'Safety II' is also used to refer to "Resilience Engineering" (hereinafter, RE).

Hollnagel, Paries, Woods and Wreathall (2011) define resilience as "the intrinsic ability of a system to adjust its operation before, during or after changes or disturbances, so as to ensure the operations required, under expected or unexpected conditions." It implies variability in the performance and capacity of individuals and organizations to adapt continuously to situational changes in their daily work with the aim of ensuring a good outcome. Therefore, resilience includes the capacity to respond, monitor, anticipate and adapt to or recover from accidental events.

According to Grabowski and Roberts (2019), high-risk complex systems need to have two main features to ensure safety: being reliable and being able to adapt to variability.

In some organizations that adaptation could be a prerequisite of safe performance, whereas in others it might lead to significant damages (Dekker, 2006). Thus, performance adjustments are seen as a precursor of both success and failure. It is considered that the more tightly coupled (inter-dependence between parts of the system) and intractable (complex systems subject to change) performance is, such as in the case of nuclear power plants, the more necessary it is to have an adaptive response because the risk of adverse results is high (Hollnagel, 2009). RE points out that organizations need to strive to ensure the safety of risk variations.

The theory of HRO and RE have eventually converged in some features, thus integrating an adaptative approach into safety management. Both approaches advocate that organizational reliability requires resilience to handle organizational variations while maintaining systems stable (Schulman, 2004; Weick et al., 1999).

2.4. Culture

A core element of this dissertation is the notion of culture. Some definitions of the concepts of culture, organizational culture, subcultures, safety culture and culture models supporting this study, are presented below. As will be seen, the relevance of the term 'culture' is justified by the fact that it is essential to understand human behavior in multiple facets.

There are many definitions of culture, especially in the areas of social sciences, such as social anthropology, sociology, and psychology. The studies carried out by Malinowski (1984) are considered as fundamental background in the area of culture, as they try to identify collective meanings which consider culture as a set of norms, ideas, beliefs and habits governing a social group. From the field of sociology, the nature of social interaction in culture has been emphasized. For example, Rocher (1979) considers that it is part of the set of ways in which a specific group thinks, feels and acts. The contribution of psychology was also very important, as it added aspects relating to individual knowledge, values, and beliefs with the aim to ensuring their adaption to their environment. One of the most commonly used definitions of culture within the framework of organizational studies is that of Schein (2004, p. 17), who defines culture as "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems." Thus, culture can be considered as a complex, difficult-to-interpret concept which has been addressed from different disciplines and whose multiple approaches are complementary.

2.4.1. Organizational culture

Scientific literature on organizations reveals that the culture of an organization affects efficiency and performance levels, even when personnel are committed and competent (Balthazard, Cooke, & Potter, 2006).

An organization's culture can be conceived as a set of common norms, values and world visions that develop within the organization when its members interact with each another and their context (Bang, 1995). Hofstede (1997) believes that shared perceptions on daily practices should be considered as the organization's core culture. Thus, the organizational culture models the possibilities for action, entrenched in "the way we do things around here" (Deal & Kennedy, 1982, p. 4).

In fact, the definitions of culture are multiple and vary in content, scope of aspects addressed and depth of their analyses (Martin, 2002). One of the most relevant differences is that culture could focus on both observable aspects and others of a deeper nature with no evident manifestations. Within organizational studies, it is possible to differentiate two types of works (Cooper, 2000): those focused on identifying basic assumptions (the way people think) and those focused on consequences (the way people behave).

On the other hand, the analyses of catastrophic accidents such as Fukushima or Chernobyl have favored the acknowledgment of how organizational aspects affect safety (Antonsen, 2009; IAEA, 1991, 2014).

Organizational culture reveals itself as a crucial aspect for the safety of complex technological installations, as it has a strong influence on human behaviors (Sagan, 1993). Therefore, that means the safety of an organization could be improved by intervening on its organizational culture (Mariscal, Herrero & Toca, 2012).

2.4.2. Organizational culture models

Various organizational culture models coexist nowadays. This thesis does not aim to thoroughly review them, but rather to present two approaches of interest for the study.

The first one is Schein's culture model (Schein, 1985), which as above-mentioned, is one of the most widely accepted and considers that culture is comprised of three levels: artefacts, espoused values and basic assumptions (Annex 5).

The level of Artefacts is the most superficial, tangible and observable of culture, and it includes the physical and social environment (express behavior, language, habits, symbols, physical spaces…), that is, things which can be seen, heard, or felt in an organization.

Espoused Values include the appreciative and appraisal levels of culture, which show how individuals should relate to one another and where power is exercised. It includes norms, ideologies, and attitudes, and can be expressed in public statements and written documents.

The last level is Basic Assumptions, which refers to the strong, deep beliefs that arise when values are accepted as valid and correct. This level includes the most essential aspects of culture.

The second model of relevance for this study is that of Cooke and Lafferty (1987), authors who differentiate three cultural styles related to behavioral norms and expectations considered acceptable by the organization, and referred to task performance and interpersonal relationships at the workplace (Cooke & Rousseau, 1988). These are the constructive, passive/defensive, and aggressive/defensive styles of culture (Annex 6).

The style of constructive culture reflects that the organization strikes a balance between being task-oriented and promoting good interpersonal

relationships at the workplace. This style aims to lay the foundations for professional development of individuals, while simultaneously seeking the goals of the organization and promoting good work-related relationships. This style is expected to be associated to increased organizational effectiveness. Furthermore, it is also expected to provide workers with more professional satisfaction, as it makes it possible to indulge important individual needs such as the sense of achievement, self-innovation and feeling of affiliation.

The passive/defensive style promotes workforce submission to organizational guidelines, causing workers to act defensively in order to feel safe and behave predictably. This style encourages an orientation towards self-protection, whereas task-orientation is relegated. It can also stress individuals, lead to organizational stagnation, hamper learning and the capacity to adapt and, ultimately, threat the survival of the organization.

The aggressive/defensive style is more orientated towards tasks than to interpersonal relationships. It emphasizes individual needs over group needs, and its decision-making process is more based on status than on expert knowledge. Opposition and search for perfectionism are also typical of this culture style, which despite its potential to be effective in the short term, can generate stress, create conflict, and discourage collaborating attitudes.

2.4.3. Organizational subcultures

Another aspect explored by this dissertation relates to the term subculture, which has sparked major scientific debate within organizational literature. Both the uniformity of organizational culture and the desirability of such uniformity due to its impact on efficiency, have been contested.

Considering a broader perspective, Hofstede (2004) conceptualizes the existence of different culture levels based on aspects relating to nation, region, ethnicity, religion and gender.

Within the scope of organizational culture studies, the existence of sub-specific features in small groups, known as subcultures, is acknowledged (Martin, 2002; Pidgeon, 1997; Trice & Beyer, 1993).

Martin (2002) considers that the culture of an organization is not only comprised of elements shared by its members, but also of ambiguities and inconsistencies which form groups of people with similar practices, values and assumptions (subcultures) not necessarily coinciding with those of the organization to which they belong.

According to literature, some organizational characteristics could promote the emergence of subcultures, with their existence being linked to social, organizational or individual characteristics (Day, 2014; Jermier, Slocum, Fry & Gaines, 1991; Schein, 2010). That means subcultures may arise from professional groups (Helmreich & Merritt, 2019; Parker, 2000; Rollenhagen, Westerlund & Näswall, 2013) or occupational traits (Black, 2003; Johnson, Koh & Killough, 2009).

Schein (1985) explains that they tend to appear in large, complex organizations, whereas Trice and Beyer (1993) add that they are most likely created in bureaucratic organizations. Koene, Boone and Barley, (1997) think that subcultures are associated to a lack of contact, to differentiated tasks and to a lack of interdependence, whereas Rose (1988) considers that depending on the level of satisfaction with the values of the dominant culture, the likelihood of people joining a subculture might increase.

Copuš, Šajgalíková and Wojčák (2019) point out that it can be generally said that organizations of the same type include similar subcultures. Within the area of healthcare, it is possible to include a subculture of doctors and nurses, in education one can talk about the subcultures of teachers and non-teachers, whereas in other industries it is possible to refer to the subcultures of production vs. non-production personnel.

The importance of studying subcultures is determined by their impact on the organization. Some authors think that the existence of various subcultures with different priorities could lead to serious problems within the organization, while others believe that the presence of these subcultures is beneficial as they provide different perspectives (IAEA, 2002). Rollenhagen, Westerlund and Näswall (2013) highlight that in order to operate nuclear power plants in a safe and effective manner, a high level of integration between different sub-processes is required. The creation of a unified safety culture might be hampered by specific subcultures. They consider that the existence of differentiated professional subcultures hampers cooperation and negatively affects safety. On the contrary, Boisnier and Chatman (2002) suggest that subcultures can develop within a strong, integrated culture without weakening it and with the aim of strengthening organizational flexibility to change and adapting to external contingencies. In that sense, organizations with more variety are better prepared to respond to complex environments.

2.4.4. Safety culture

The investigation report INSAG 4 (IAEA, 1991), following the Chernobyl accident on 1986 is often cited as the origin of the term 'safety culture' (Cox & Flin, 1998). In this explicative analysis of the catastrophe, it is made evident that organizational and cultural aspects in high-risk systems can trigger events of disastrous consequences. In this report, safety culture is defined as "that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance." (IAEA, 1991, p. 1). It is worth mentioning that the actual view of the IAEA on the concept of safety culture has extended significantly over the years as associated complexities were better understood. (Mengolini & Debarberis, 2008). The concept is now conceived as a specific type of organizational culture in high reliability organizations.

Following the Fukushima accident (2011), the International Atomic Energy Agency (hereinafter IAEA) promulgated a holistic view to strengthen safety culture during an international meeting of experts (IAEA, 2014). In its report, the Agency mentions that the interaction between human, organizational and technical factors of all organizations involved (social stakeholders) and of various levels within each organization, should be assessed and understood for each phase of nuclear facility cycles.

However, despite everything written about safety culture, a clear consensus on the areas covered by this concept does not exist to date. According to some authors, each organization has some kind of a safety culture which can be described as strong or weak, positive or negative. According to others, only an organization with an overriding commitment to safety can be considered to have a safety culture. This crucial ambiguity leads to confusion.

Despite this lack of consensus on safety culture definitions and models, there is a certain level of agreement that a solid safety culture is an organizational culture which prioritizes beliefs, values and attitudes relating to safety (Cooper, 2000; Guldenmund, 2000; Short, Boyle, Shackelford, Inderbitzen & Bergoffen, 2007).

Clarke (1999), for example, defines safety culture as a set of beliefs and values specifically related to the health and safety of a subset of organizational culture. As for Richter and Koch (2004), they define it as "the shared and learned meanings, experiences and interpretations of work and safety which guide peoples' actions towards risks, accidents and prevention."

Along this line, most authors consider that safety culture is a facet of organizational culture (Choudhry, Fang & Mohamed, 2007; Guldenmund, 2000; Hopkins, 2006) focused on aspects relating to health and safety. Thus, some authors (Guldenmund, 2000; Hale, 2000; Hopkins, 2006), with the aim to prevent such chaos, have expressed strong arguments to move attention away from the

concept of safety culture towards a concept of organizational culture. From this perspective, although this research paper uses the term 'safety culture', it is actually applied as a conceptually useful label that links the organization's culture to its safety focus. In this sense, it is worth mentioning that the IAEA uses the term 'organizational culture for safety' as an equivalent of safety culture (IAEA, 2016).

2.5. Organizational culture evaluation methodologies in the nuclear industry

As abovementioned, the analyses of the most severe accidents in high-risk organizations have contributed to acknowledging that the cultural context of work practices can influence safety similarly to technology (Antonsen, 2009).

Each organization has a culture or multiple subcultures, which will most likely influence safety. Thus, the study of safety culture can contribute to understand what needs to be modified in order to further prioritize safety (Hopkins, 2006).

Some types of organizational culture are associated to positive and negative outcomes, either in terms of organizational effectiveness or of individual performance (Balthazard et al., 2006; Schein, 1996). Motivation and satisfaction are amongst the positive outcomes, whereas job insecurity and stress are amongst the negative ones (Cooke & Szumal, 2000).

According to Mariscal et al. (2012), a modification of organizational culture aspects can improve safety culture. That means that knowing which is the organization's culture can be very useful to enhance safety performance within organizations.

There are significant differences in the approaches to the evaluation of safety and organizational culture (Rousseau, 1990), which can be analyzed at

different levels of depth. Some authors focus their analysis on observable aspects, whereas others try to arrive to basic assumptions which are the essence of culture, or study behavioral norms which they share with different members of the organization.

It is worth mentioning that the ultimate aim of a safety culture evaluation is to use information to draft an improvement action plan.

This section includes two of the most used methodologies within the nuclear industry: Independent Safety Culture Assessment (ISCA) by the IAEA and Nuclear Organization and Management Analysis Concept methodology" (NOMAC). The latter is the methodology implemented in the Spanish nuclear industry, meaning it is the one used to collect the data analyzed in this study.

2.5.1. IAEA methodology

The IAEA has an operational safety review team (hereinafter OSART) which provides assistance and consultancy services to Member States. OSART is aimed at improving safety in nuclear power plants during commissioning and operation (IAEA, 2016).

The OSART program includes an "Independent Safety Culture Assessment" (hereinafter ISCA). Under a systemic approach to safety, this safety culture evaluation is carried out together with an operational safety evaluation, with the aim to better understand existing relationships between technical, human, organizational and cultural aspects, and to get to the fundamental causes of identified problems.

The methodology used for safety culture evaluation seeks to identify the basic culture assumptions which drive organizational behaviors.

ISCA is comprised of the following steps:

- Administration of a safety culture survey onsite prior to the start of the OSART mission.
- Survey data analysis.
- Documentation review and analysis.
- Delivery of training on safety culture evaluations to OSART team members which are not culture specialists.
- Collection of data over the first five days of the mission with the aim to have an overview of organizational culture. Data is collected during interviews, observations and focus groups.
- Revision of OSART team conclusions during the last three days to determine underlying cultural aspects driving such conclusions.
- Analysis of results, including the descriptive and regulatory parts. The first one addresses the "what is" and includes cultural expressions. The second one addresses the "what should be" and assesses cultural conclusions according to the 5 safety culture principles of the IAEA (2006): Safety is a clearly recognized value; Leadership for safety is clear; Accountability for safety is clear; Safety is integrated into all activities; Safety is learning driven.

Safety culture evaluation conclusions are integrated into the OSART report through the establishment of safety culture strengths and areas for improvement. These results are presented verbally to senior management.

The OSART Independent Safety Culture Assessment (ISCA) from 2016 updates the guidelines of the Safety Culture Assessment Review Team (SCART) service from 2008 (IAEA, 2008), which in turn updated the guidelines of the Assessment of Safety Culture in Organizations Team (ASCOT) service from 1994 (IAEA, 1994).

2.5.2. "Nuclear Organization and Management Analysis Concept methodology"

The "Nuclear Organization and Management Analysis Concept methodology" (hereinafter NOMAC) was developed within the framework of a research project between the Nuclear Regulatory Commission (NRC) and the Brookhaven National Laboratory (BNL) in 1991. The fundamentals of this methodology were included within NUREG/CR-5538, Vol. 1. (Haber, O'Brien, Metlay & Crouch, 1991).

The Canadian Nuclear Regulatory Body (Atomic Energy Control Board, AECB) implemented the NOMAC methodology to assess organizational aspects of nuclear organizations and established a conceptual framework called Adaptative Canadian Machine (CAMM). The results attained during this project were positively perceived by the regulatory bodies (NRC, AECB) and station managers.

Within the Spanish nuclear context, CIEMAT validated and implemented this methodology within the framework of the IOS-I and IOS-II research project, funded by the CSN and the Association of Electric Power Companies (UNESA) (2001-2002 and 2003-2005). This project was conducted in international collaboration with one of the coauthors of the NOMAC methodology, Dr. Sonja B. Haber (Human Performance Analysis Corp).

After some changes, this methodology continues to be used in the international nuclear industry and is the reference methodology for the Spanish regulator (CSN) during safety culture assessments of organizations within the Spanish nuclear industry (Annex 7).

NOMAC is based on two theoretical proposals: the model of organizational culture defined by Schein (1985) and the concept of organizations based on organizational components, as defined by Mintzberg (1989). In this regard,

Mintzberg conceives organizational structure as a critical element of organizational safety and thinks that for an organization to be effective there needs to be a high level of coherence between its organizational components.

According to this model, the main organizational components are Strategic Apex, Middle Line, Operating Core, Technostructure and Support staff. Sample selection and results presentation are carried out according to this model (Annex 8).

People whose work is directly related to products and services are at the base of the organization (Operating Core). In the upper part we can find the Strategic Apex, responsible to overview the entire organization, ensuring its mission is met and owners' needs are satisfied. Between the Apex and Operating Core sits the Middle Line, a chain of managers with formal authority in productive processes. There are two additional components outside the line of authority. The Technostructure, focused on the design and performance of process standardization, and the Support staff, which provides specialized support in administrative or financial aspects, amongst other.

It is important to emphasize that, based on the analysis of incidents, methodology authors identified 37 safety-relevant organizational factors (Haber et al., 1991). The methodology requires collecting data on the perceptions that individuals within the organization have of these factors and of the behaviors of individuals throughout their professional lives. In this regard, these perceptions generally coincide with the reality of assuming them as 'objective facts' which have an impact on individual behaviors.

Similarly to the IAEA methodology, data collection is based on research techniques of a quantitative (survey) and qualitative (interviews, observations, focus groups and functional analysis) nature. The techniques comprising NOMAC are the following:

- Functional Analysis: Documentation review to identify different organizational elements, analyze information and communication flow, identify the chain of command and the critical roles and responsibilities, select organizational behaviors to be considered during the evaluation, identify specific traits which should be considered during design and plan data collection.
- Organizational Culture Survey: An organizational culture survey is administered, together with an additional survey focusing on a set of complementary scales validated in scientific literature.
- Semi-Structured Interviews: They are used for personnel at all organizational levels and components. To ensure representativeness, about 15% of all organization employees are interviewed.
- Behavioral Anchored Rating Scale (BARS): Continuous scales for explicit behavioral norms which include the definition of an attribute followed by five graded behavioral scenarios; individuals are asked to choose only one. They are administered to interviewees and focus group participants to measure and quantify the perception of organizational behaviors considered key according to the functional analysis.
- Focus Groups: They are designed to generate qualitative information on organization members. They are based on a search for strengths and particular traits of the organizational and safety culture.
- Observations: These are structured, qualitative observations of meetings, routine activities, and non-scheduled activities with the aim to access culture "in action".

Based on the analysis of data obtained through the different techniques, a report identifying strengths and areas for improvement is drafted, assigning them to the traits of the organization's safety culture model. This information is presented to the management board.

2.6. Theoretical framework of theoretical reference for empirical dissertation studies

As a summary, the main theoretical aspects taken as reference framework for carrying out the empirical studies comprising this dissertation, are presented.

Firstly, organizational culture is conceived as a factor determining human behavior and impacting safety management within organizations. That means safety culture is conceived as an inseparable part of organizational culture (Antonsen, 2009).

Secondly, Martin's differentiation perspective (Martin, 1992), which considers that the working environment could be comprised of groups with different subcultures, is assumed as valid.

Thirdly, Mintzberg's approach (Mintzberg, 1989) regarding the relevance of organizational structure and its different organizational components in the generation of cultures is taken as a reference.

Fourthly, the multidimensional nature of safety paves the way to implementing an eclectic theoretical perspective based on the complementarity of theoretical approaches (Theory of HRO, Resilience Engineering and Conflicting Objectives Perspective). These theories highlight how important aspects such as reliability, resilience and decision-making are for the safety of complex organizations.

Lastly, it is considered that behaviors relating to problem notification and reporting are paramount in terms of safety at high-risk organizations (Reason, 1997; Weick & Sutcliffe, 2001), meaning the participation of personnel in these reporting systems could be considered as a seismograph of safety culture health (IAEA, 2002).

3. Dissertation objectives

The general purpose of this thesis is to identify some of the characteristic features of the organizational and safety culture of the Spanish nuclear industry based on the analysis of the results of the safety culture assessments of the sector. To this end, three specific objectives are proposed in the three empirical studies that comprise this thesis: 1) describe the organizational culture of the Spanish nuclear industry and identify the possible existence of different subcultures within the industry (quantitative study); 2) describe some of the relevant factors for the development of safety culture characteristics based on three scientific theories on complex organizations (quantitative study); and 3) identify, in a case study, the factors that determine personnel's participation (or non-participation) in the problem notification system (qualitative study).

Information about the sample, methods and quantitative studies data matrix is included on Annexes 9, 10, 11 and 12, respectively.

Each of the objectives is detailed below.

3.1. Describe the organizational culture of the Spanish nuclear industry

The first objective was to describe the organizational culture of the Spanish nuclear industry based on the results of the organizational culture surveys (Cooke & Lafferty, 1987) administered to the sector. The activities carried out were as follows:

a. Describe the styles and normative patterns of the organizational culture of the Spanish nuclear industry.

b. Identify the possible existence of organizational subcultures according to the type of organization, sociodemographic variables, and organizational structure.

3.2. Describe the organizational safety culture of Spanish nuclear power plants

The second objective has been to describe the organizational safety culture of Spanish nuclear power plants, based on three relevant theoretical approaches in the field of high reliability organizations. This study has been obtained from the analysis of the safety culture surveys and the behavioral anchored rating scales (Haber & Shurberg, 1996) administered to the nuclear power plant personnel. The aspects analyzed were: Attention to safety; Hazard perception; Safety conscious work environment (SCWE); Organizational resilience; Degree of formality; and Resources allocation. The activities carried out were as follows:

a. To describe the characteristic features of the safety culture of the Spanish nuclear power plants.
b. To identify the possible existence of subcultures according to the organization and sociodemographic variables.

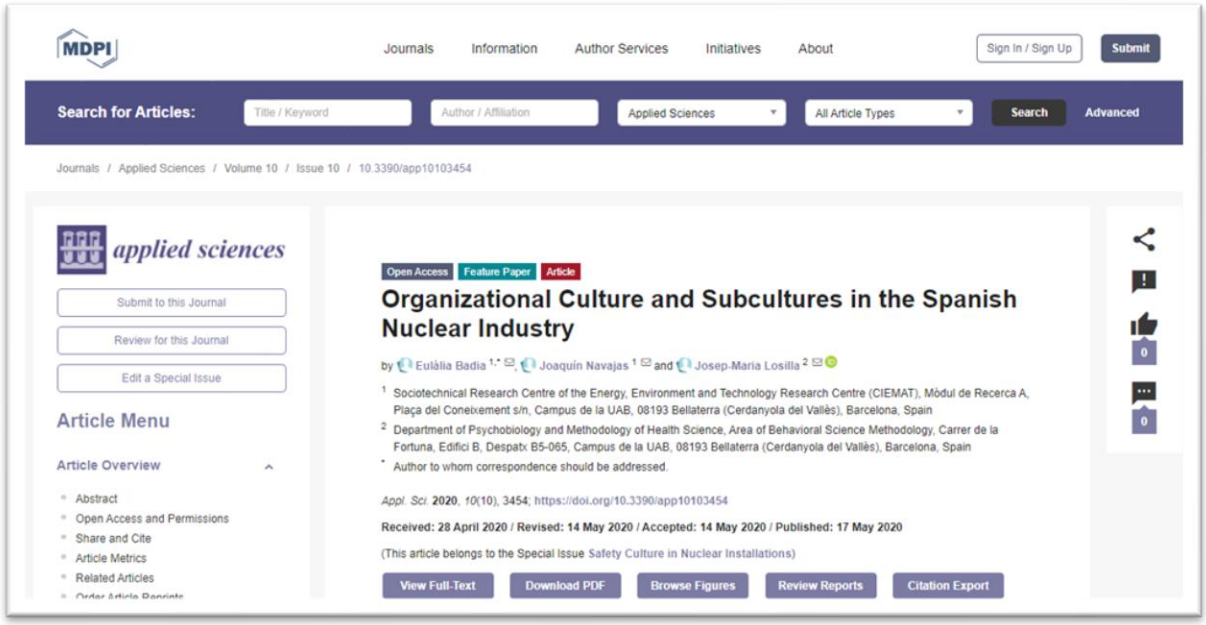
3.3. Understand the reporting and problem-solving behaviors in an organization of the Spanish nuclear industry

The third and last objective was to understand how the event reporting system is perceived in an organization of the Spanish nuclear industry and to improve the knowledge about the factors related to the perception of the reporting system and the approaches to problem solving.

For this purpose, a case study was carried out in a nuclear organization, analyzing from a qualitative approach, the discursive content obtained through discussion groups. The goodness and relevance of the reporting system according to nuclear industry standards has been considered.

4. Articles that form this compendium

4.1. Study 1: Organizational Culture and Subcultures in the Spanish Nuclear Industry



(Badia, Navajas & Losilla, 2020).

Organizational Culture and Subcultures in the Spanish Nuclear Industry

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Featured Application: The description of organizational culture within the nuclear industry, as well as the identification of specific subcultures, favor the adaption of organizational intervention and improvement programs, thus benefiting safety culture.

Abstract: Organizational culture determines the norms, values and behaviors of an organization, playing a key role in the safety of high-reliability organizations (HRO). Previous research has shown that differentiated subcultures can coexist within organizations, sharing some norms and values but not necessary everything. From this perspective, this study was aimed at (1) describing the organizational culture of the Spanish nuclear industry and (2) determining the potential presence of organizational subcultures. To do that, a statistical analysis of organizational culture surveys (Organizational Culture Inventory®, N = 5825) handed over to all organizations within the Spanish nuclear industry, was carried out. Results allow us to accurately characterize the industry's organizational culture, which is made up of predominant "Constructive"-style behaviors together with "Defensive" normative patterns of the "Conventional", "Dependent" and "Perfectionistic" styles. Indications about the existence of

various subcultures associated to the nuclear organization type, the sociodemographic aspect and the organizational structure component were also found. Certain safety implications potentially linked to the existence of subcultures and to the industry's organizational culture are discussed.

Keywords: organizational culture; organizational subcultures; safety culture; nuclear industry; organizational culture inventory; organizational components of Mintzberg

1. Introduction

This paper aims to describe the organizational culture of the Spanish nuclear industry and to identify the existence or nonexistence of different organizational subcultures. To do that, three theoretical elements were taken as the reference framework for this research: (a) a concept of culture as a decisive factor determining the behavior of individuals within the organization; (b) the acknowledgment that multiple subcultures might exist within the same organization and (c) the need to consider organizational structure as an element potentially contributing to the creation of subcultures.

1.1. Organizational Culture

Culture studies have become a crucial part of the behavioral landscape of the organizational sciences [1]. It is worth mentioning the interdisciplinarity of the term 'culture' and the multiplicity of approaches. In that sense, anthropology has focused mainly on the knowledge of collective meanings, within which culture would be comprised of "the body of norms regulating a number of social groups" [2] (p. 56). Sociology has highlighted the nature of social interaction which eventually causes groups of individuals to create a particular different collectivity [3]. As for psychology, the term was linked to external adaption and internal integration [4], focusing on its influence on behavior and on interpreting how others behave [5].

An organization's culture could be conceived as a set of common norms, values and world visions that develop within the organization when its members interact with each other and their context [6]. Organizational culture restricts the possibilities of action, entrenched in "the way we do things around here" [7] (p. 4). In fact, the definitions of culture are multiple and vary in content, scope of aspects addressed and depth of their analyses [8]. One of the most relevant differences is that culture could focus on both observable aspects and others of a deeper nature with no evident manifestations. Within organizational sciences, it

is possible to differentiate two types of studies [9]: those focused on identifying basic assumptions (the way people think) and those focused on consequences (the way people behave). Hofstede [10] believes that shared perceptions on daily practices should be considered as an organization's core culture.

In organizational literature, it is recognized that the culture of an organization may imply dysfunctional outcomes that lead to low efficiency and performance levels, even when personnel are committed and competent [11]. Some types of organizational culture are associated to positive outcomes, either in terms of organizational effectiveness or of individual performance [7,12]. Culture determines the quality of working life and professional performance [13,14], impacting organizational change and transformation [15].

On the other hand, the analyses of catastrophic accidents such as Fukushima or Chernobyl have favored the acknowledgment of how organizational aspects affect safety [16–18]. Therefore, this means the safety of an organization could be improved by intervention of its organizational culture [19].

1.2. Organizational Subcultures

The second aspect addressed by our study is related to the term 'subculture', which has sparked major scientific debate within organizational literature. Both the uniformity of organizational culture and the desirability of such uniformity due to its impact on efficiency, have been contested.

Generally speaking, it seems commonly accepted that there are only a few organizations with a homogeneous, compact culture [20,21]. According to Reason [22], culture is not a single construct, but the combination of multiple organizational elements continuously interacting, such as problem reporting and organizational learning, amongst others. As for Schein [20], organizational subcultures may share some values but not others; in fact, they could completely differ in terms of basic organizational values.

Martin [23] identifies three perspectives in the study of organizational culture: (a) Studies postulating a uniform, consistent organizational culture throughout the organization (integration). These are the most common studies. (b) Studies which identify differentiated cultural manifestations within the organization (differentiation). (c) Studies considering that it is not possible to reach a culture agreement due to the existence of multiple and at times opposed visions (fragmentation). From Martin's differentiation perspective, the working environment can be conceived as a combination of different groups—subcultures—with specific characteristics [8,9,24,25].

Many studies have tried to identify which group features or factors determine the setting of possible subcultures. Some of the aspects considered relate to structure (departments, work groups, place in the organization), task features, occupational levels, work experience and affiliations [20,21,26,27]. Considering a broader perspective, Hofstede [10] conceptualizes the existence of different culture levels based on aspects relating to nation, region, ethnicity, religion and gender.

Some studies link the existence of subcultures to aspects relating to traits either professional [28–30] or occupational [31]. According to Koene et al. [32], subcultures are associated with differentiated tasks and to a lack of contact and interdependence. Similarly, Black [33] thinks that training-related occupational subcultures may exist, as well as departmental subcultures.

Likewise, when task characteristics (production group) and organizational seniority are considered, differences in occupational satisfaction and motivational aspects were identified in specific groups within the industry. For instance, the longer workers are in the organization, the lower the motivation [34]. Studies of subcultures in healthcare organizations have found satisfaction differences related to work-related autonomy and wages [35]. Rose [36] adds that the level of satisfaction with dominant culture values may increase the likelihood of individuals joining specific subcultures.

Copuš et al. [34] point out that it can be generally said that organizations of the same type include similar subcultures. Within the area of healthcare, it is possible to identify a subculture of doctors differentiated from the subculture of nurses, whereas in other industries, the subculture of production personnel can be found. Similarly, Park and Jung [37] point out that operators from different Korean nuclear power plants share a similar cultural profile, different from the rest of the organization.

In short, previous research shows that organizational subcultures can be created as a result of multiple and differentiated elements.

1.3. Subcultures and Safety

A relevant aspect of our study is related to the existence of subcultures and their potential impact on safety. In fact, the interest in subcultures within high-risk organizations is determined by their potential influence on safety. This leads to the following critical question: How does the existence of different cultural groups within high-reliability organizations impact safety? In other words, can the existence of different subcultures within an organization be a risk factor for safety?

According to the International Atomic Energy Agency (IAEA) [38] (p. 7), the existence of subcultures is not an element that has a positive or negative impact per se:

> "Is the existence of subcultures likely to be harmful? One viewpoint is that, unless the different subcultures all contain something that results in a common sense of purpose, different priorities and agendas can arise and this can create serious problems. The counterargument is that different subcultures give different perspectives, and this is advantageous."

The literature of organizations does not seem to provide a clear answer either. Some theoretical approaches to the study of complex, high-risk organizations acknowledge subcultures and their potential strength for safety as a key element. From the perspective of the man-made disaster theory [39], accidents are caused by a lack of information flow. This perspective considers that within an organization, there are warning signs that, if detected, could prevent accidents. Signs which are most likely known by an organizational subgroup. Therefore, the existence of subcultures is not necessarily negative; in fact, acknowledging and managing them could contribute to preventing "safety blind spots" [40]. Boisnier and Chatman [41] also consider that subcultures can develop within a strong, integrated culture without weakening it and with the aim of strengthening the organization's flexibility to change and adapt to external contingencies. In that sense, organizations with increased cultural variety are better prepared to respond to complex environments. According to Wahlström [42], cultural differences should be considered key factors of safe evolutions in nuclear facilities, meaning research should focus on how safety is built as a result of cultural interactions.

On the contrary, other authors defend the need of cultural integration as a way to ensure organizational reliability and safety. Rollenhagen et al. [30] consider that the existence of differentiated professional subcultures hampers cooperation and negatively affects safety. In their study, they analyze differences between three groups (maintenance, operations and engineering) of three Swedish nuclear power plants, focusing on key safety climate aspects such as safety management, occupational safety and resources. Similarly, another study in the Norwegian oil and gas industries reveals the existence of different ways to interpret safety rules. Such interpretation varies depending on whether personnel belong to management, engineering or operations, thus impacting differentiated regulatory compliance [43].

1.4. Organizational and Cultural Structure

Thirdly, this study believes it is relevant to analyze the relationship between organizational structure and organizational culture. It is important to mention Mintzberg's paramount contribution, in which he conceived organizational structure as "the total of the ways in which labor is divided into distinct tasks and then its coordination achieved among those tasks" [44] (p. 100).

According to Mintzberg [45] (p. 99), there are six clearly differentiated organizational components within organizations, as shown in Figure 1.

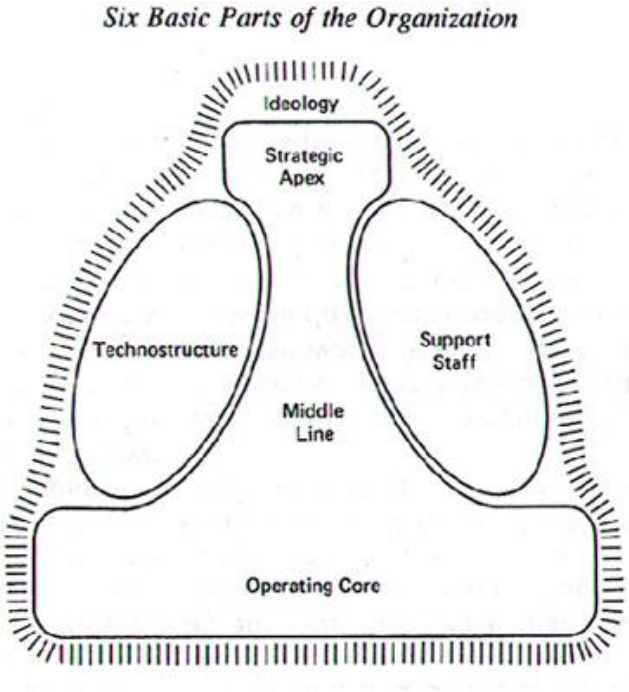

Figure 1. Mintzberg's organizational components.

Figure 1 shows that people whose work is directly related to products and services, named "operating core", are at the base of the organization. In the upper part we can find the "strategic apex", responsible for overviewing the entire organization, ensuring its mission is met and owners' needs are satisfied. Between the "strategic apex" and "operating core" sits the "middle line", a chain of managers with formal authority in productive processes. There are two additional components outside the line of authority. The "technostructure",

focused on the design and performance of process standardization, and the "support staff", providing specialized support in administrative or financial aspects, amongst others.

It is important to mention that Mintzberg introduces a sixth element known as 'ideology', which provides coherence and uniformity to all other organizational components. Ideology, an element considered by Mintzberg as somewhat equivalent to the concept of culture, would include organizational aspects such as traditions and beliefs, thus adding uniqueness to the organization compared to others. Other ideology-derived aspects are "the personal relationship between the individual and the organization or the collective nature of responsibility and choice" [45] (p. 233). It is important to emphasize that according to Mintzberg, ideology is clearly associated to the organization as a whole, without apparent differences amongst organizational components. Thus, his concept of ideology could be considered equivalent to an organizational unitary culture.

In addition to defining the parts structuring organizations, Mintzberg develops a theoretical model with seven typical organizational configurations (entrepreneurial, machine, professional, diversified, innovative, missionary and political). His analysis of organizational structure and typology has influenced the analysis of high-risk organizations. Haber et al. [46] pointed out that nuclear power plants can be described under the machine bureaucracy model, with some structural differences within the operating core. Mintzberg would also support this approach to nuclear organizations. According to him, "an important condition that drives this organization to a machine bureaucracy is its special need for safety" [47] (p. 332). This would mean that procedures are formalized extensively to ensure that they are carried out and result in safe operation.

1.5. Theoretical Foundation of Our Approach

As a summary, the three main theoretical aspects taken as reference framework for the development of this study, are presented below.

Firstly, organizational culture is conceived as a factor determining human behavior within organizations. Furthermore, as revealed in the analysis of catastrophic events in high-risk industries, it is necessary to consider that organizational culture has an impact on the management of safety.

Secondly, this study takes the differentiation perspective of Martin as reference framework, thus considering that the working environment is comprised of groups with differentiated subcultures, in line with the views of Guldenmund [48] (p. 26):

> "Cultures are neither homogeneous not fully integrated. On the one hand, because disagreement and even conflict will always arise. On the other hand, because people within a culture adopt its core with mixed intensity."

At this point, it is important to clarify that we agree with the following definition of organizational subculture [49] (p. 38):

> "A subset of an organization's members who interact regularly with one another, identify themselves as a distinct group within the organization, share a set of problems commonly defined to be the problems of all, and routinely take action on the basis of collective understandings unique to the group."

From this differentiation perspective, we think it is relevant to assess the complementarity of organizational subcultures to prevent the existence of "blind safety spots" [40].

Thirdly and last, this study embraces the approach of Mintzberg [45] on the relevance of organizational structure and its organizational components, which in our opinion, could be contributors to the creation of subcultures.

Based on these theoretical perspectives, our research is focused on the following:

1. Describing the organizational culture of the Spanish nuclear industry.
2. Identifying features of different subcultures within the Spanish nuclear industry. To do so, the influence of some demographic variables on organizational culture is analyzed. The following variables have been studied:
    - Sector (working at nuclear power plants or at nuclear public companies);
    - Location (working at the facility or at the headquarters);
    - Contractual relationships (own staff or contractors);
    - Organizational components identified by Mintzberg [45] (strategic apex, middle line, operating core, technostructure and support staff).

2. Materials and Method

Within the context of the Spanish nuclear industry, the relationship between nuclear facility safety and organizational aspects has been prioritized within the field of research. In 1999, a collaboration agreement was signed between the Spanish nuclear regulator (CSN), Spain's Public Research Agency for Energy, Technology and Environment (CIEMAT) and the Spanish Association of Utilities (UNESA). Such agreement led to the development of a research program and to the establishment of independent safety culture evaluations carried out in nuclear organizations. It was agreed to use the evaluation methodology applied in the Canadian nuclear industry [50]. Such methodology has been used continuously in all Spanish nuclear facilities since the year 2000.

2.1. Sample Characteristics

This study takes as object of analysis the quantitative data obtained via external organizational culture evaluation surveys collected between the years 2007 and 2019. The sample consists of 5825 workers from all Spanish nuclear power plants (including Garoña NPP, now under decommissioning) and the public nuclear industry companies: management of radwaste and dismantling processes (ENRESA), manufacture of nuclear fuel (ENUSA) and manufacture of nuclear equipment components (ENSA). The study sample is composed of data from the latest safety culture assessment conducted in each organization. Data from more than one culture assessment per organization is not included. The different size of the facilities (one or two reactors) implies that some are represented by more subjects. As shown in Table 1, a total of seven organizations are analyzed, four of them are nuclear power plants (4618 individuals) and three are public companies within the nuclear industry (1207 individuals). A total of 31 individuals were removed from the sample population as they did not respond to some scales. This led to a final sample comprised of 5794 workers. The sample includes workers from all organizational components as identified by

Mintzberg. Due to confidentiality reasons, the names of these companies are not disclosed, and they will be referred to as nuclear power plant (NPP) # or nuclear public company (NPC) #.

Table 1. Study sample and descriptives.

Variable		Sample N (%)	Total N (%)
Organization	Nuclear Power Plant (NPP) 1	292 (5.01%)	4618 (79.28%)
	Nuclear Power Plant 2	533 (9.15%)	
	Nuclear Power Plant 3	1975 (33.91%)	
	Nuclear Power Plant 4	1818 (31.21%)	
	Nuclear Public (NPC) Company 1	444 (7.62%)	1207 (20.72%)
	Nuclear Public Company 2	437 (7.50%)	
	Nuclear Public Company 3	326 (5.60%)	
	Total Sample		5825 (100%)
Location	Facility	4530 (84.53%)	5359 (100%)
	Headquarters	829 (15.47%)	
Contract	Own Staff	3031 (55.86%)	5426 (100%)
	Contractors	2395 (44.14%)	
Mintzberg (NPP1)	Strategic Apex	23 (3.54%)	650 (100%)
	Middle Line	66(10.15%)	
	Operating Core	219 (33.69%)	
	Technostructure	126 (19.38%)	
	Support Staff	216 (33.23%)	

2.1. Measurement Instrument

The survey known as OCI (Organizational Culture Inventory®, copyrighted by the company Human Synergistics) [51] was used in all external evaluations and administered by members of the independent evaluating team.

The OCI is an instrument with high internal scale consistency, as well as discriminant and convergent validity [52]. The OCI's validity and reliability have been widely proven [53–55]. It is also one of the most cited and used surveys in a large variety of fields [56].

The OCI includes 120 items assessed on a Likert scale from 1 to 5. Items are structured in 12 styles or behavioral norms, which are in turn grouped in three types of culture [57,58]. Low scores point to norms with a lower expectation

within the organization. The three types of culture established by the OCI are as follows:

- Constructive Culture: Workers are encouraged to cooperate, reaching high levels of motivation, satisfaction, teamwork and service quality.
- Passive/Defensive Culture: Organization members are expected to please individuals in positions of authority, and they wait for others to act first.
- Aggressive/Defensive Culture: Organization members are expected to oppose new ideas, to compete amongst them and to seem competent and independent.

Table 2 includes the OCI styles description (reproduced by permission of Human Synergistics).

Table 2. Descriptions of the twelve styles measured by the Organizational Culture Inventory® (OCI®) (and sample items) *.

Constructive Norms [Cultural Styles Promoting Satisfaction Behaviors]
Achievement: An Achievement culture characterizes organizations that do things well and value members who set and accomplish their own goals. Members are expected to set challenging but realistic goals, establish plans to reach these goals, and pursue them with enthusiasm. (Pursue a standard of excellence; Openly show enthusiasm)
Self-Actualizing: A Self-Actualizing culture characterizes organizations that value creativity, quality over quantity, and both task accomplishment and individual growth. Members are encouraged to gain enjoyment from their work, develop themselves, and take on new and interesting activities. (Think in unique and independent ways; Do even simple tasks well)
Humanistic/Encouraging: A Humanistic-Encouraging culture characterizes organizations that are managed in a participative and person-centered way. Members are expected to be supportive, constructive, and open to influence in their dealings with one another. (Help others to grow and develop; Take time with people)
Affiliative: An Affiliative culture characterizes organizations that place a high priority on constructive interpersonal relationships. Members are expected to be friendly, open, and sensitive to the satisfaction of their work group. (Deal with others in a friendly, pleasant way; share feelings and thoughts)
Passive/Defensive Norms [Cultural Styles Promoting People/Security Behaviors]
Approval: An Approval culture describes organizations in which conflicts are avoided and interpersonal relationships are pleasant--at least superficially. Members feel that they should agree with, gain the approval of, and be liked by others. ("Go along" with others; Be liked by everyone)
Conventional: A Conventional culture is descriptive of organizations that are conservative, traditional, and bureaucratically controlled. Members are expected to conform, follow the rules, and make a good impression. (Always follow policies and practices; Fit into the "mold")
Dependent: A Dependent culture is descriptive of organizations that are hierarchically controlled and do not empower their members. Centralized decision making in such organizations leads members to do only what they are told and to clear all decisions with superiors. (Please those in positions of authority; Do what is expected)
Avoidance: An Avoidance culture characterizes organizations that fail to reward success but nevertheless punish mistakes. This negative reward system leads members to shift responsibilities to others and avoid any possibility of being blamed for a mistake. (Wait for others to act first; Take few chances)
Aggressive/Defensive Norms [Cultural Styles Promoting Task/Security Behaviors]
Oppositional: An Oppositional culture describes organizations in which confrontation and negativism are rewarded. Members gain status and influence by being critical and thus are reinforced to oppose the ideas of others. (Point out flaws; Be hard to impress)
Power: A Power culture is descriptive of nonparticipative organizations structured on the basis of the authority inherent in members' positions. Members believe they will be rewarded for taking charge, controlling subordinates and, at the same time, being responsive to the demands of superiors. (Build up one's power base; Demand loyalty)
Competitive: A Competitive culture is one in which winning is valued and members are rewarded for outperforming one another. Members operate in a "win-lose" framework and believe they must work against (rather than with) their peers to be noticed. (Turn the job into a contest; Never appear to lose)
Perfectionistic: A Perfectionistic culture characterizes organizations in which perfectionism, persistence, and hard work are valued. Members feel they must avoid any mistakes, keep track of everything, and work long hours to attain narrowly defined objectives. (Do things perfectly; Keep on top of everything)

*Note: Research and development b: Robert A. Cooke, Ph.D. Style names, descriptions and items are copyrighted © and used with permission. From Organizational Culture Inventory by [51] Robert A. Cooke and J. Clayton Lafferty, 1987, Plymouth, MI: Human Synergistics International. Copyright © 1987, 2020 by Human Synergistics, Inc. Reproduced with permission. The OCI style descriptions and items may not be reproduced without the expressed and written permission from Human Synergistics.

2.3. Data Analysis

All data analyses were conducted using IBM SPSS Statistics v22.0 [59]. The distributions of scores, skewness and kurtosis suggested data were normally distributed. Cronbach's alpha (α) internal consistency reliability [60] was calculated for the twelve styles of the OCI, considering acceptable values of α ranging from 0.7 [61]. Construct validity was examined using principal component factor analysis with varimax rotation [62]. The overall reliability of the factor solution was also tested using Cronbach's alpha.

Comparative analyses between groups (Table 3) were carried out by calculating the mean differences obtained by groups in the three organizational cultures, and on the twelve OCI styles, effect sizes were computed as Cohen's δ, considering effect sizes as small ($\delta \geq 0.2$), medium ($\delta \geq 0.5$) or large ($\delta \geq 0.8$) [63] (Cohen, 1988).

Finally, a repeated-measures mixed model analysis of variance (ANOVA) was adjusted to analyze the organizational culture according to the Mintzberg organizational classification. The between-group variable was Mintzberg's level (with five groups), and the within-group variable was organizational culture (with three measures). Bonferroni-corrected p-values were calculated for between-group post hoc comparisons. Tests were considered significant at $p < 0.05$.

Table 3. Variables used in the comparative analyses.

Studied Variables		
	Definition	**Variables**
Sector	Type of nuclear sector organization	Nuclear Power Plants/Nuclear Public Companies (companies specializing in radwaste and dismantling processes, fuel manufacturing and nuclear component manufacturing)
Location	Personal workplace.	Facility/Headquarters
Contractual relationship	Contractual situation of workforce	Own personnel/Contractor
Mintzberg Component	Organizational component in which personnel are integrated according to Mintzberg's classification (1989)	Strategic Apex/Middle Line/Operating Core/Technostructure/Support Staff

3. Results

3.1. Reliabilities, Factorial Components and Global Descriptives of the OCI

The reliability analysis provides internal consistency values that are high or very high in most scales and in the three OCI cultures. The "Dependent" (α = 0.64) and "Oppositional" (α = 0.48) styles provide the lowest Cronbach's α results.

A three-factor solution resulted from exploratory factor analysis of the OCI data. All three factors are comparable to those found in previous research [11,64], except for the styles "Avoidance" and "Perfectionistic", with factorial loading values within the "Aggressive/Defensive" and "Passive/Defensive" cultures, respectively. To ensure a more accurate comparison between our results and those of previous studies and considering the high internal consistency in the three culture types, analyses within our study maintain the definitions for the three styles proposed by OCI authors, complementing them with comparative analyses and profiles of each individual style.

Table 4 shows results obtained from the reliability analysis, factorial analysis, as well as from descriptive OCI information.

Table 4. Reliability, principal factor component analysis and descriptive statistics of the OCI styles.

OCI Styles	Component						
	Constructive	Passive /Defensive	Aggressive /Defensive	Cronbach's α	M	SD	N
Humanistic-Encouraging	0.91	−0.03	−0.13	0.93	3.55	0.87	5782
Affiliative	0.90	0.06	−0.20	0.94	3.62	0.90	5790
Achievement	0.87	0.12	0.10	0.76	3.37	0.63	5781
Self-Actualizing	0.90	−0.03	−0.02	0.83	3.35	0.72	5779
Approval	0.07	0.61	0.42	0.76	2.82	0.63	5782
Conventional	−0.17	0.88	0.06	0.78	3.30	0.66	5779
Dependent	0.05	0.85	0.14	0.64	3.26	0.56	5784
Avoidance	−0.53	0.29	0.61	0.83	2.30	0.75	5779
Oppositional	0.26	0.08	0.81	0.48	2.77	0.46	5781
Power	−0.21	0.40	0.69	0.91	2.62	0.65	5790
Competitive	−0.35	0.24	0.78	0.91	2.15	0.87	5782
Perfectionistic	0.12	0.69	0.25	0.73	3.11	0.61	5790
Cronbach's α	0.96	0.89	0.89				
M*	3.47	2.92	2.66				
SD	0.71	0.50	0.50				
N	5794	5794	5794				

*Note: Mean=M; Standard Deviation=SD; Sample=N. Constructive mean (Humanistic-Encouraging, Affiliative, Achievement, Self-Actualizing); Passive/Defensive mean (Approval, Conventional, Dependent, Avoidance) and Aggressive/Defensive mean (Oppositional, Power, Competitive, Perfectionistic).

Analyses show that the "Constructive" cluster is the one that best defines the organizational culture of the Spanish nuclear industry, with an average score of 3.47, followed by the "Passive/Defensive" cluster with a 2.92 average. The cluster with the lowest score is "Aggressive/Defensive", with an average score of 2.66 (Figure 2). In terms of styles (Figure 3), the highest survey score was reached in the "Affiliative" (3.62) style of the "Constructive" cluster, whereas the lowest score was in the" Competitive" (2.15) style of the "Aggressive/Defensive" cluster.

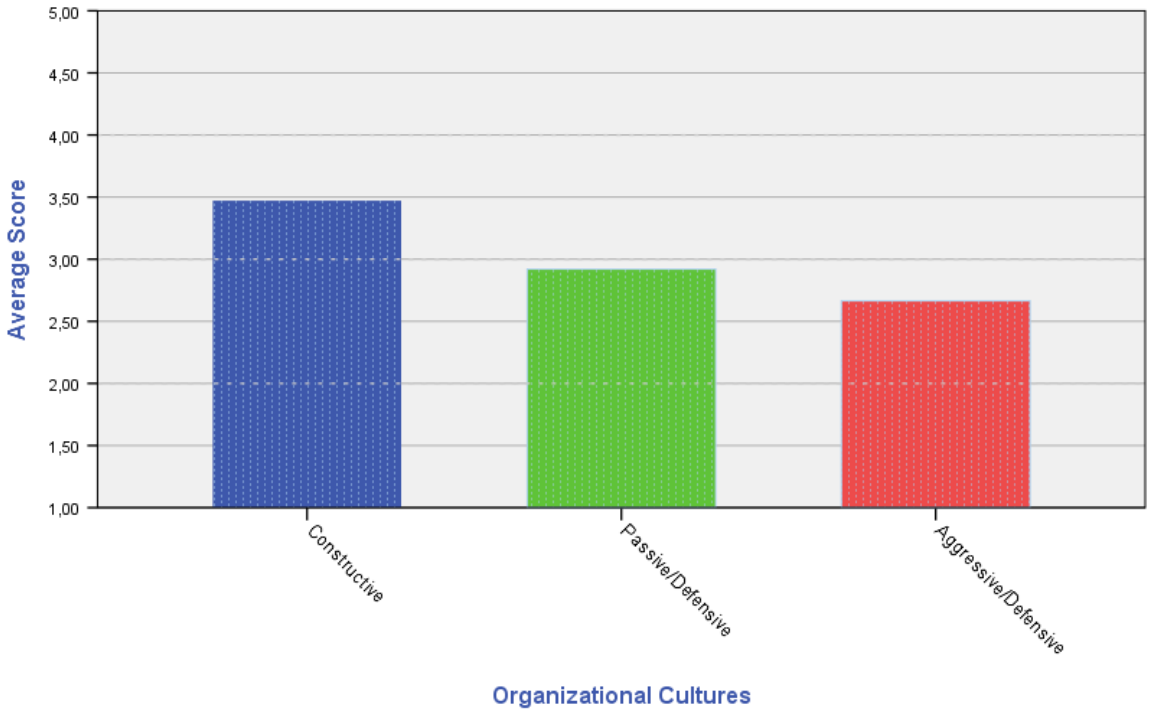

Figure 2. OCI Organizational culture averages.

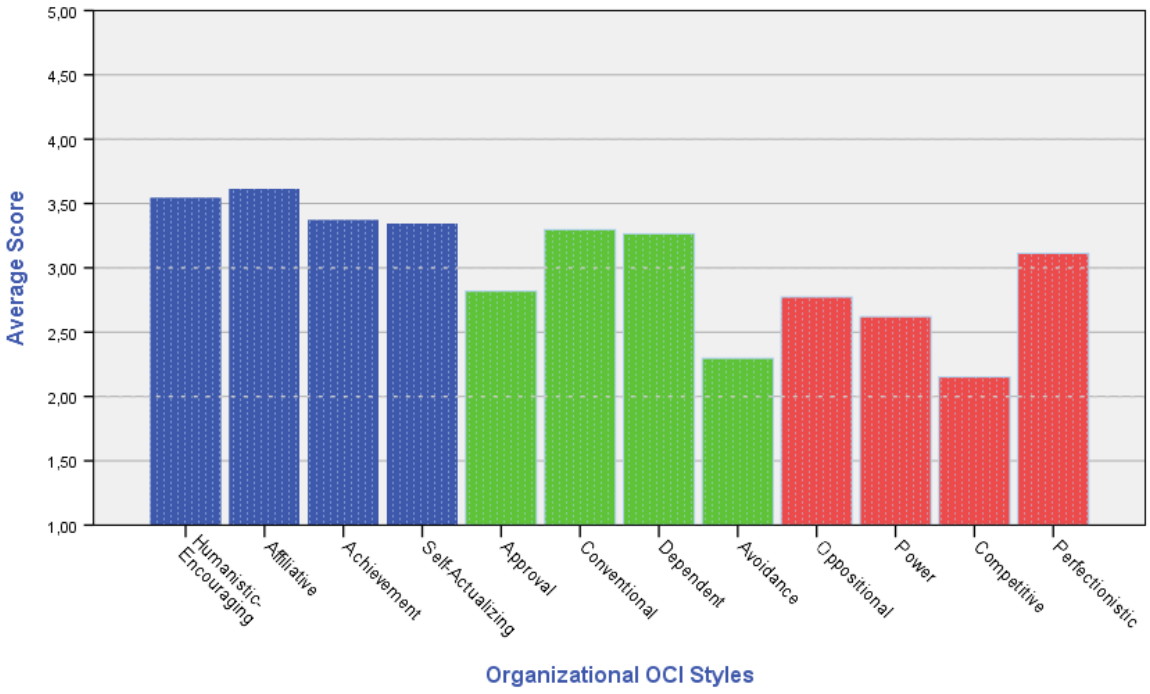

Figure 3. OCI Styles averages.

3.2. Cultural Differences by Demographic Variables

3.2.1. Differences by Type of Organization

The comparative analysis by type of organization shows relevant differences between nuclear power plants (NPP) and nuclear public companies (NPC) (Table 5; Figure 4). NPP have higher average scores (M) in the" Constructive" cluster (NPP M = 3.55; NPC M = 3.18; δ = 0.54) whereas NPC scores higher in the "Passive/Defensive cluster" (NPP M = 2.89; NPC M = 3.04; δ = −0.30).

Within the "Constructive" cluster, it is worth mentioning the differences in the "Humanistic-Encouraging" (NPP M = 3.65; NPC M = 3.16; δ = 0.57) and "Affiliative" (NPP M = 3.71; NPC M = 3.26; δ = 0.52) styles. In both "Defensive" styles, NPP score lower than NPC in "Conventional" (NPP M = 3.27; NPC M = 3.41; δ = −0.22), "Avoidance" (NPP M = 2.25; NPC M = 2.48; δ = −0.32), "Oppositional" (NPP M = 2.79; NPC M = 2.69; δ = 0.22) and "Competitive" (NPP M = 2.10; NPC M = 2.36; δ = −0.31) styles, (Table 5; Figure 5).

Table 5. Descriptive statistics of the OCI organizational cultures and styles for the nuclear industry and differences between nuclear power plants (NPP) and nuclear public companies (NPC).

	Nuclear Industry		**NPP**		**NPC**		**NPP/NPC**
OCI Styles	M	SD	M	SD	M	SD	Cohen's δ
Humanistic-Encouraging	3.55	0.87	3.65	0.85	3.16	0.86	0.57
Affiliative	3.62	0.90	3.71	0.89	3.26	0.84	0.52
Achievement	3.37	0.63	3.43	0.60	3.15	0.67	0.46
Self-Actualizing	3.35	0.72	3.40	0.70	3.14	0.74	0.38
Approval	2.82	0.63	2.80	0.65	2.91	0.57	−0.18
Conventional	3.30	0.66	3.27	0.67	3.41	0.62	−0.22
Dependent	3.26	0.56	3.24	0.56	3.35	0.53	−0.19
Avoidance	2.30	0.75	2.25	0.74	2.48	0.73	−0.32
Oppositional	2.77	0.46	2.79	0.46	2.69	0.46	0.22
Power	2.62	0.65	2.60	0.65	2.70	0.64	−0.15
Competitive	2.15	0.87	2.10	0.89	2.36	0.79	−0.31
Perfectionistic	3.11	0.61	3.11	0.61	3.14	0.60	−0.05
Constructive	3.47	0.71	3.55	0.69	3.18	0.71	0.54
Passive/Defensive	2.92	0.50	2.89	0.51	3.04	0.46	−0.30
Aggressive/Defensive	2.66	0.50	2.65	0.50	2.72	0.47	−0.15

*Note: Mean=M; Standard Deviation =SD.

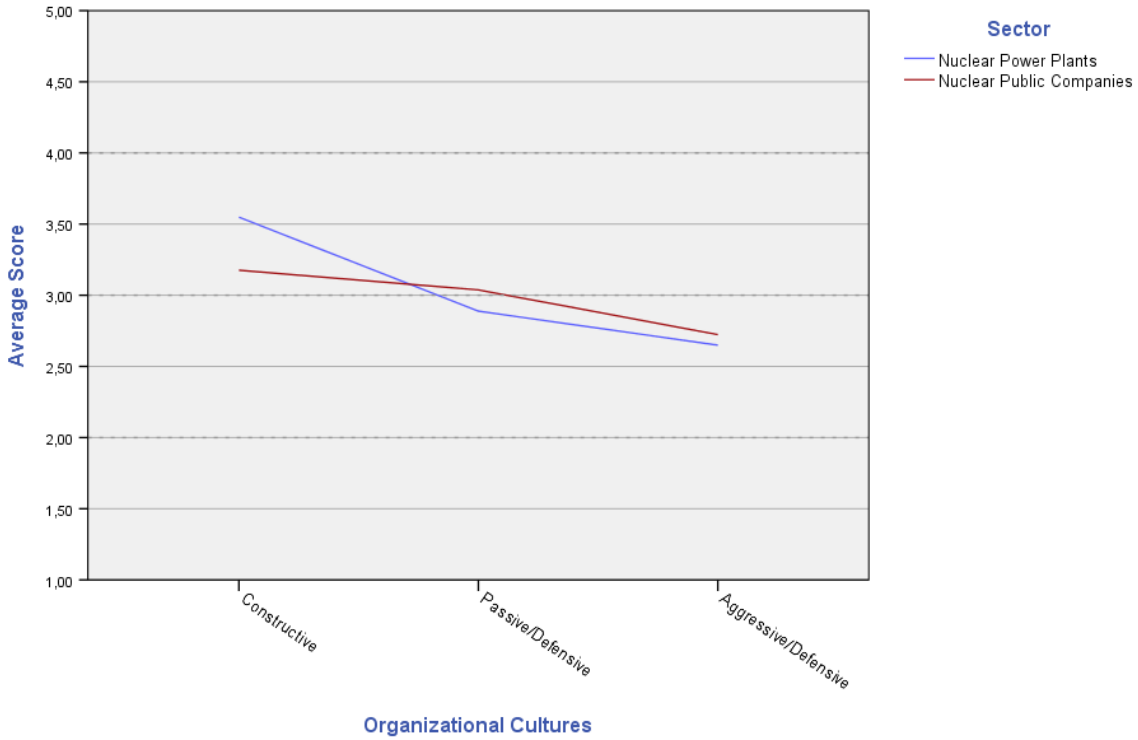

Figure 4. OCI organizational cultures averages by nuclear sector.

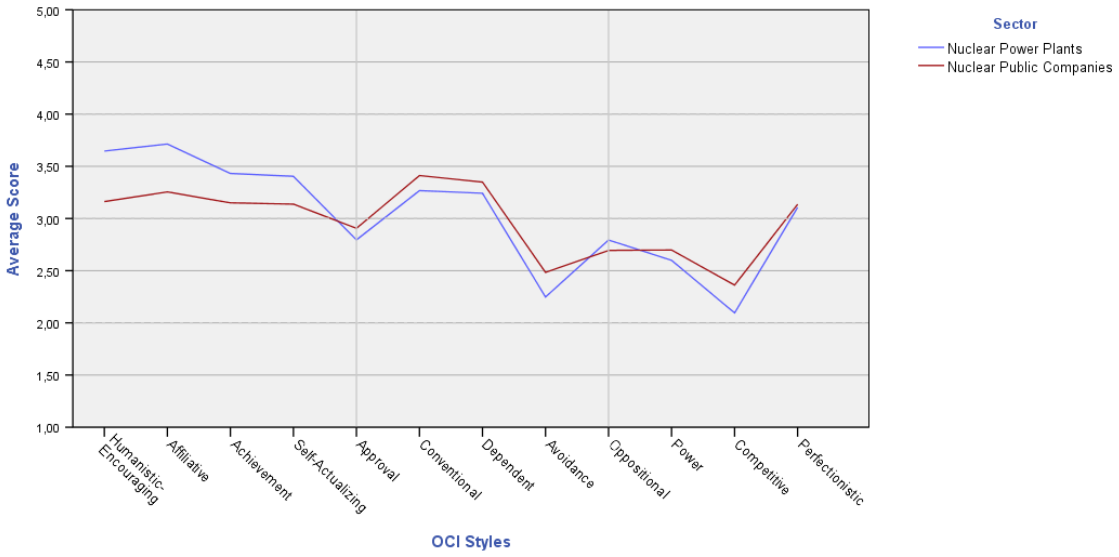

Figure 5. OCI styles averages for Spanish nuclear sector.

If only NPP are considered (Table 6a), the statistical analysis shows very compact results within the "Constructive" organizational culture, with only a single difference of a small effect size (δ = −0.24) between two stations. Within "Defensive" organizational cultures, there are more differences between the stations, although with small effect sizes.

Results also show differences of small or medium effect size between NPC1 and both NPC2 and NPC3 organizations in all three OCI cultures (Table 6b).

Table 6. OCI organizational cultures averages and effect sizes for (a) nuclear power plants **(**NPP) and for (b) nuclear public companies **(**NPC).

(a) NPP

OCI Cultures	NPP1		NPP2		NPP3		NPP4	
	M	SD	M	SD	M	SD	M	SD
Constructive	3.47	0.57	3.61	0.65	3.57	0.68	3.52	0.72
Passive/Defensive	2.84	0.51	2.95	0.48	2.83	0.51	2.95	0.49
Aggressive/Defensive	2.52	0.44	2.72	0.49	2.59	0.50	2.71	0.51
	Cohen's δ							
	NPP1/NPP2		NPP1/NPP3		NPP1/NPP4		NPP2/NPP3	NPP2/NPP4	NPP3/NPP4
Constructive	−0.24		−0.15		−0.08		0.07	0.13	0.07
Passive/Defensive	−0.22		0.02		−0.22		0.24	0.01	0.23
Aggressive/Defensive	−0.42		−0.14		−0.37		0.26	0.03	0.23

(b) (NPC)

OCI Cultures	NPC1		NPC2		NPC3	
	M	SD	M	SD	M	SD
Constructive	3.39	0.69	3.01	0.70	3.11	0.68
Passive/Defensive	2.94	0.46	3.13	0.44	3.05	0.44
Aggressive/Defensive	2.64	0.46	2.73	0.44	2.83	0.51
	Cohen's δ					
	NPC1/NPC2		NPC1/NPC3		NPC2/NPC3	
Constructive	−0.53		−0.40		−0.16	
Passive/Defensive	0.41		0.23		0.18	
Aggressive/Defensive	0.20		0.39		-0.20	

*Note: Mean=M; Standard Deviation=SD.

3.2.2. Differences by Work Location (Facility vs. Headquarters)

Considering NPP and NPC together, facility personnel score higher than headquarters personnel in the "Constructive" cluster (facility M = 3.52; headquarters M = 3.34; δ = 0.26) (Table 7; Figure 6).

Within the "Defensive" clusters, there are no relevant work location-based differences, except in the "Oppositional" style (facility M = 2.79; headquarters M = 2.67; δ = 0.26) (Table 7; Figure 7).

If only NPP are considered, there are no differences by work location in the "Constructive" organizational culture, but facility personnel score higher in" Defensive" cultures (Table 7).

On the contrary, in NPC there are differences in work location in the "Constructive" organizational culture (Table 7). Personnel working onsite perceive a more "Constructive" culture (facility M = 3.28; headquarters M = 3.03; δ = 0.36). There are also differences in the "Aggressive/Defensive", "Oppositional" (facility M = 2.74; headquarters M = 2.56; δ = 0.40) and "Perfectionistic" styles (facility M = 3.13; headquarters M = 3.01; δ = 0.21), with facility personnel scoring higher. There are no work location-based differences in the "Passive/Defensive" styles.

Table 7. Descriptive statistics of the OCI organizational cultures and styles by work location.

	Spanish Nuclear Industry					NPP					NPC				
	Facility		Headq.			Facility		Headq.			Facility		Headq.		
OCI Styles	M	SD	M	SD	Cohen's δ	M	SD	M	SD	Cohen's δ	M	SD	M	SD	Cohen's δ
Humanistic-Encouraging	3.61	0.85	3.38	0.92	0.27	3.65	0.85	3.61	.82	0.05	3.30	0.82	2.98	0.93	0.38
Affiliative	3.69	0.89	3.43	0.90	0.29	3.73	0.90	3.62	0.85	0.13	3.38	0.80	3.11	0.89	0.32
Achievement	3.40	0.61	3.30	0.71	0.16	3.43	0.60	3.46	0.63	−0.04	3.20	0.64	3.04	0.77	0.24
Self-Actualizing	3.39	0.70	3.25	0.78	0.20	3.41	0.70	3.40	0.72	0.01	3.25	0.71	2.98	0.80	0.35
Approval	2.83	0.64	2.70	0.63	0.21	2.82	0.65	2.60	0.61	0.34	2.91	0.54	2.86	0.63	0.09
Conventional	3.30	0.65	3.26	0.69	0.05	3.28	0.66	3.16	0.68	0.18	3.40	0.59	3.44	0.68	−0.06
Dependent	3.26	0.56	3.24	0.57	0.04	3.25	0.56	3.16	0.57	0.16	3.34	0.52	3.38	0.56	−0.07
Avoidance	2.28	0.74	2.26	0.74	0.03	2.26	0.75	2.11	0.67	0.21	2.42	0.69	2.51	0.78	−0.13
Oppositional	2.79	0.46	2.67	0.43	0.26	2.80	0.47	2.74	0.41	0.14	2.74	0.45	2.56	0.45	0.40
Power	2.62	0.64	2.56	0.65	0.08	2.61	0.65	2.49	0.64	0.19	2.66	0.59	2.69	0.66	−0.05
Competitive	2.13	0.87	2.03	0.84	0.12	2.12	0.89	1.91	0.84	0.24	2.28	0.71	2.25	0.79	0.03
Perfectionistic	3.11	0.61	3.06	0.61	0.09	3.11	0.61	3.09	0.62	0.04	3.13	0.57	3.01	0.60	0.21
Constructive	3.52	0.69	3.34	0.77	0.26	3.55	0.69	3.52	0.69	0.05	3.28	0.67	3.03	0.79	0.36
Passive/Defensive	2.92	0.49	2.86	0.53	0.11	2.90	0.50	2.76	0.51	0.29	3.02	0.42	3.05	0.54	−0.06
Aggressive/Defensive	2.67	0.49	2.58	0.48	0.17	2.66	0.50	2.56	0.49	0.21	2.70	0.43	2.63	0.47	0.16

*Note: Mean=M; Standard Deviation=SD; Sample=N.

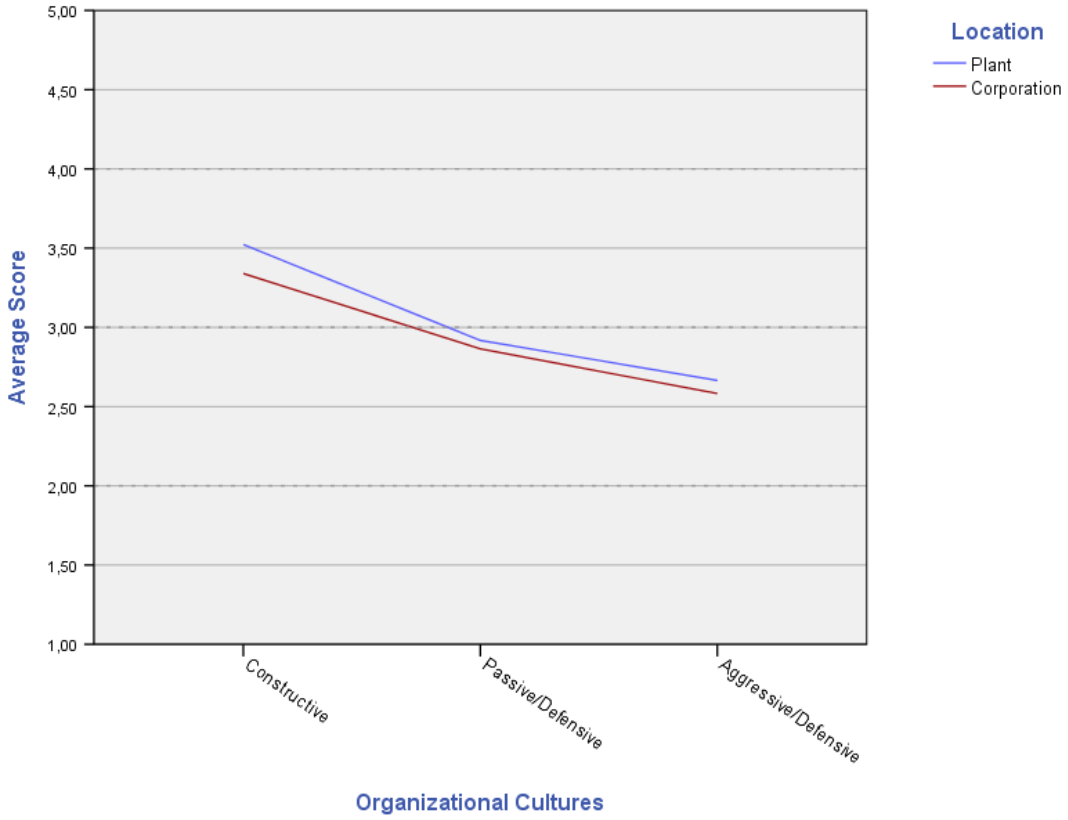

Figure 6. OCI organizational cultures averages by work location.

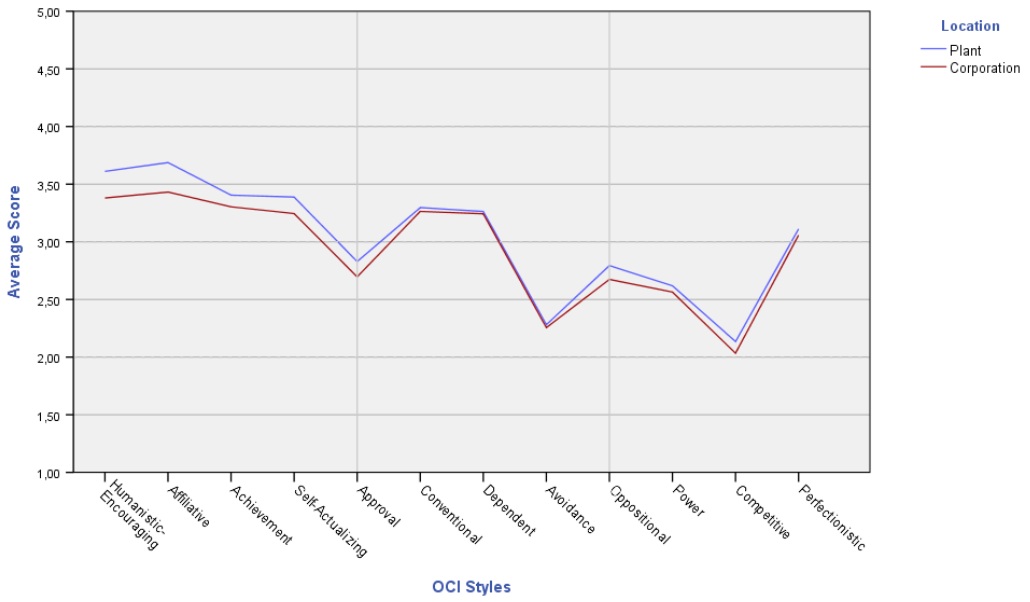

Figure 7. OCI styles averages by work location.

3.2.3. Differences by Contractual Relationship (Own Staff vs. Contractor)

Considering NPP and NPC together, results show homogeneity of scores in all three OCI types of culture between own staff and contractors (Table 8; Figure 8). There is only a small difference in the "Affiliative" style of the "Constructive" cluster (own staff M = 3.54; contractor M = 3.73; δ = −0.21) (Table 8; Figure 9).

There are no differences in any of the three OCI organizational cultures by contractual relationship in NPP, with the only exception of a small one in the "Competitive" style in which contractor personnel score higher than own staff (own staff M = 1.98; contractor M = 2.16; δ = −0.21), (NPP; Table 8).

In NPC, contractor personnel score higher than own staff in the "Constructive" organizational culture (own staff M = 3.13; contractor M = 3.53; δ = −0.57). The norms with the highest differences are "Humanistic-Encouraging" (δ = 0.62), "Affiliative" (δ = 0.54) and" Self-Actualizing" (δ = 0.53). Similarly, contractor personnel scores lower in the "Passive/Defensive" organizational culture (own staff M = 3.05; contractor M = 2.92; δ = 0.28). Regarding "Defensive" styles, there are small size differences in the "Conventional", "Avoidance",

"Oppositional", "Competitive" and "Perfectionistic" styles, with contractors scoring lower in all of them, except in the "Oppositional" style. It is worth mentioning that in this case, the analysis was only carried out in one organization (NPC; Table 8).

Table 8. Descriptive statistics of the OCI organizational cultures and styles by contractual relationship.

	Spanish Nuclear Industry					**NPP**					**NPC**				
	Own Staff		**Contractor**			**Own Staff**		**Contractor**			**Own Staff**		**Contractor**		
OCI Styles	M	SD	M	SD	Cohen's δ	M	SD	M	SD	Cohen's δ	M	SD	M	SD	Cohen's δ
Humanistic-Encouraging	3.50	0.88	3.63	0.85	−0.15	3.70	0.81	3.63	0.86	0.09	3.10	0.86	3.63	0.74	−0.62
Affiliative	3.54	0.88	3.73	0.91	−0.21	3.72	0.85	3.73	0.91	−0.02	3.20	0.85	3.66	0.76	−0.54
Achievement	3.36	0.63	3.39	0.61	−0.05	3.49	0.58	3.39	0.61	0.16	3.12	0.67	3.35	0.60	−0.35
Self-Actualizing	3.34	0.72	3.38	0.70	−0.06	3.46	0.68	3.37	0.70	0.13	3.09	0.73	3.48	0.70	−0.53
Approval	2.78	0.62	2.84	0.64	−0.09	2.73	0.64	2.84	0.64	−0.17	2.90	0.57	2.89	0.56	0.02
Conventional	3.29	0.66	3.29	0.66	0.00	3.23	0.66	3.29	0.66	−0.10	3.43	0.63	3.30	0.57	0.21
Dependent	3.27	0.54	3.24	0.57	0.05	3.23	0.54	3.24	0.57	−0.02	3.36	0.53	3.27	0.54	0.16
Avoidance	2.29	0.72	2.28	0.77	0.01	2.17	0.69	2.28	0.77	−0.15	2.51	0.73	2.23	0.64	0.39
Oppositional	2.75	0.44	2.80	0.49	−0.11	2.80	0.42	2.80	0.49	−0.02	2.67	0.45	2.83	0.44	−0.36
Power	2.60	0.64	2.62	0.65	−0.04	2.55	0.63	2.62	0.65	−0.12	2.71	0.64	2.58	0.57	0.20
Competitive	2.12	0.84	2.16	0.91	−0.05	1.98	0.82	2.16	0.92	−0.21	2.38	0.80	2.14	0.65	0.30
Perfectionistic	3.15	0.59	3.07	0.63	0.13	3.14	0.58	3.07	0.63	0.12	3.15	0.61	3.03	0.55	0.20
Constructive	3.44	0.71	3.53	0.69	−0.14	3.59	0.66	3.53	0.69	0.09	3.13	0.71	3.53	0.62	−0.57
Passive/Defensive	2.91	0.50	2.91	0.49	−0.01	2.84	0.50	2.91	0.50	−0.15	3.05	0.46	2.92	0.40	0.28
Aggressive/Defensive	2.65	0.48	2.66	0.52	−0.02	2.61	0.47	2.66	0.52	−0.10	2.73	0.48	2.65	0.42	0.18

*Note: Mean=M; Standard Deviation=SD.

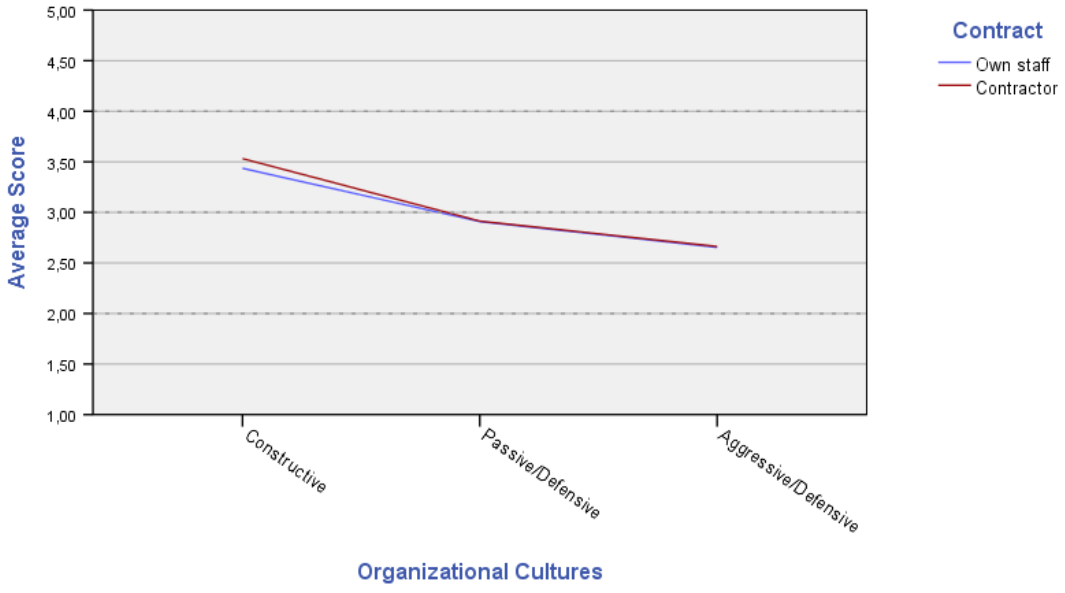

Figure 8. OCI organizational cultures averages by contractual relationship.

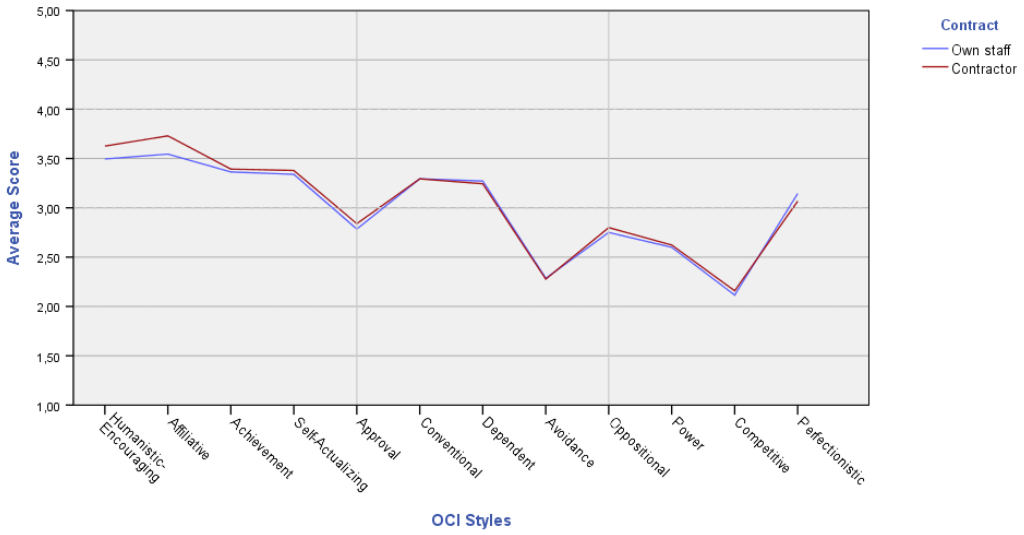

Figure 9. OCI styles averages by contractual relationship.

Key study findings by demographic variables are summarized in Table 9.

Table 9. Main findings.

	Spanish Nuclear Industry	Nuclear Power Plants	Nuclear Public Companies
Sector	The dominant cultural style is "Constructive" (3.47), followed by "Passive/Defensive" (2.91) and "Aggressive/Defensive" (2.66). The main differences in this survey are found in the "Humanistic–Encouraging" and "Affiliative" styles.	Homogeneity between plants in the "Constructive" culture. Differences between plants in the "Defensive" cultures.	Differences between organizations in the "Constructive" style (medium effect size $\delta = 0.53$). Multiple differences in terms of styles.
Location	Facility personnel score higher in the "Constructive" culture than headquarters personnel.	Facility personnel have higher scores in the "Defensive" style than headquarters personnel.	Headquarters personnel have higher scores in the "Constructive" culture than facility personnel.
Contractual relationship	No differences in terms of contractual relationship.	No differences in terms of contractual relationship.	Results obtained from one single organization. Contractors score higher in the "Constructive" culture. The largest size magnitude in the survey is in the "Humanistic–Encouraging" (δ = 0.62) style.

3.2.4. Differences by Mintzberg's Organizational Components

Table 10 shows statistical data for the analysis of cultural styles according to Mintzberg's model.

Table 10. Descriptive statistics by Mintzberg's components of the (a) OCI organizational cultures; (b) OCI "Constructive" styles; (c) OCI "Passive/Defensive" styles and (d) OCI "Aggressive/Defensive" styles *.

Table 10a

	(a) Organizational cultures									
	Constructive				Passive/Defensive			Aggressive/Defensive		
Mintzberg Component	N	M	SD	Sig	M	SD	Sig	M	SD	Sig
a Strategic Apex	14	3.59	0.54		2.57	0.33		2.38	0.29	
b Middle Line	27	3.45	0.51		2.77	0.52		2.46	0.37	
c Operating Core	133	3.44	0.53		2.92	0.50	d	2.61	0.43	d
d Technostructure	36	3.43	0.75		2.61	0.46	c	2.38	0.41	c
e Support Staff	72	3.58	0.56		2.88	0.47		2.47	0.50	
Total	282	3.48	0.57		2.84	0.49		2.52	0.44	

Table 10b

	(b) Constructive Styles												
	Humanistic Encouraging				Affiliative			Achievement			Self-Actualizing		
Mintzberg Component	N	M	SD	Sig	M	SD	Sig	M	SD	Sig	M	SD	Sig
a Strategic Apex	14	3.81	0.65		3.52	0.58		3.54	0.52		3.47	0.60	
b Middle Line	27	3.57	0.71		3.53	0.63		3.38	0.37		3.33	0.56	
c Operating Core	133	3.47	0.67		3.52	0.67		3.35	0.47		3.41	0.59	
d Technostructure	36	3.52	0.84		3.50	0.94		3.32	0.65		3.39	0.79	
e Support Staff	72	3.64	0.69		3.76	0.66		3.43	0.54		3.50	0.64	
Total	282	3.55	0.70		3.58	0.70		3.38	0.51		3.42	0.63	

Table 10c

	(c) Passive/Defensive Styles												
	Approval				Conventional			Dependent			Avoidance		
Mintzberg Component	N	M	SD	Sig	M	SD	Sig	M	SD	Sig	M	SD	Sig
a Strategic Apex	14	2.43	0.57		2.92	0.47		3.08	0.48		1.84	0.35	
b Middle Line	27	2.64	0.68		3.15	0.65		3.14	0.56		2.14	0.67	
c Operating Core	133	2.82	0.63	d	3.31	0.63		3.27	0.55		2.26	0.63	d
d Technostructure	36	2.47	0.59	c/e	3.00	0.55		3.12	0.51		1.84	0.60	c
e Support Staff	72	2.87	0.63	d	3.25	0.60		3.28	0.54		2.09	0.59	
Total	282	2.75	0.64		3.22	0.62		3.23	0.54		2.13	0.62	

Table 10d

	(d) Aggressive/Defensive Styles												
		Oppositional			Power			Competitive			Perfectionistic		
Mintzberg Component	N	M	SD	Sig	M	SD	Sig	M	SD	Sig	M	SD	Sig
a Strategic Apex	14	2.71	0.34		2.29	0.41		1.63	0.61		2.88	0.44	
b Middle Line	27	2.73	0.39		2.36	0.53		1.81	0.64		2.94	0.44	
c Operating Core	133	2.79	0.41		2.46	0.59		2.02	0.68		3.18	0.53	d
d Technostructure	36	2.60	0.33		2.24	0.59		1.77	0.60		2.89	0.53	c
e Support Staff	72	2.69	0.46		2.28	0.65		1.94	0.73		2.97	0.53	
Total	282	2.73	0.41		2.37	0.60		1.93	0.68		3.05	0.53	

*Note: Mean=M; Standard Deviation=SD; Sample=N; Significance=Sig. "Sig" columns contain the codes of the Mintzberg's organizational components with statistically significant differences (Bonferroni−corrected $p < 0.05$).

The "Constructive" cluster score is homogeneous in all five organizational components (Figure 10). Although strategic apex and support staff in the "Constructive" cluster have a higher score than middle line, operating core and technostructure, differences are not statistically significant. Such homogeneity does not exist in the "Defensive" styles, where technostructure and strategic apex personnel have similar scores in both "Defensive" clusters and support staff and middle line in the "Aggressive/Defensive" cluster, although with statistically significant differences between technostructure and operating core. Operating core personnel have higher scores than technostructure personnel in the "Passive/Defensive" cluster ($t(167) = 3.46$; $p = 0.007$; $d = 0.31$; 95% CI: 0.06, 0.57) and "Aggressive/Defensive" cluster ($t(167) = 2.93$; $p = 0.039$; $d = 0.24$; 95% CI: 0.01, 0.47).

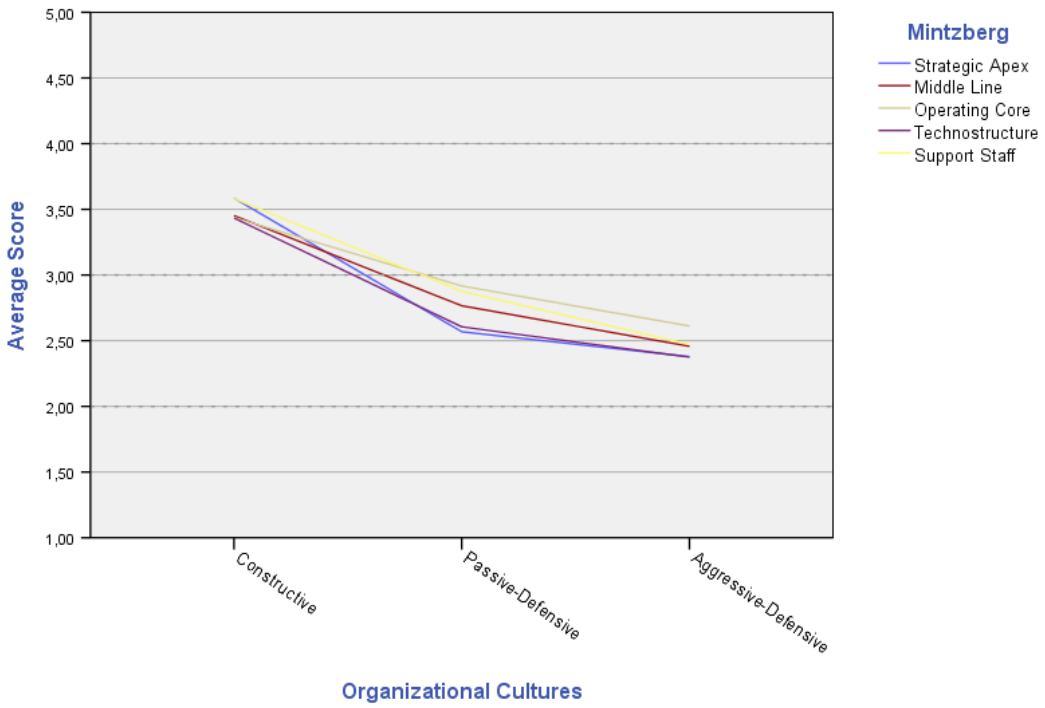

Figure 10. OCI organizational cultures averages by Mintzberg's organizational components.

When comparing component results for the twelve OCI styles (Tables 10b, 10c and 10d), statistically significant differences are observed in the "Defensive" styles for "Approval", "Avoidance" and "Perfectionistic" (Figure 11). Operating core personnel have a higher score than technostructure personnel in the styles "Approval" ($t(167) = 3.00$; $p = 0.027$; $d = 0.36$; 95% CI = 0.02, 0.69), "Avoidance" ($t(167) = 3.82$; $p = 0.003$; $d = 0.42$; 95% CI=0.10, 0.74) and "Perfectionistic" ($t(167) = 2.9$; $p = 0.031$; $d = 0.29$; 95% CI = 0.02, 0.56). Similarly, support personnel perceive a more "Approval"–based culture than technostructure personnel ($t(106) = 3.15$; $p = 0.016$; $d = 0.41$; 95% CI = 0.05, 0.77).

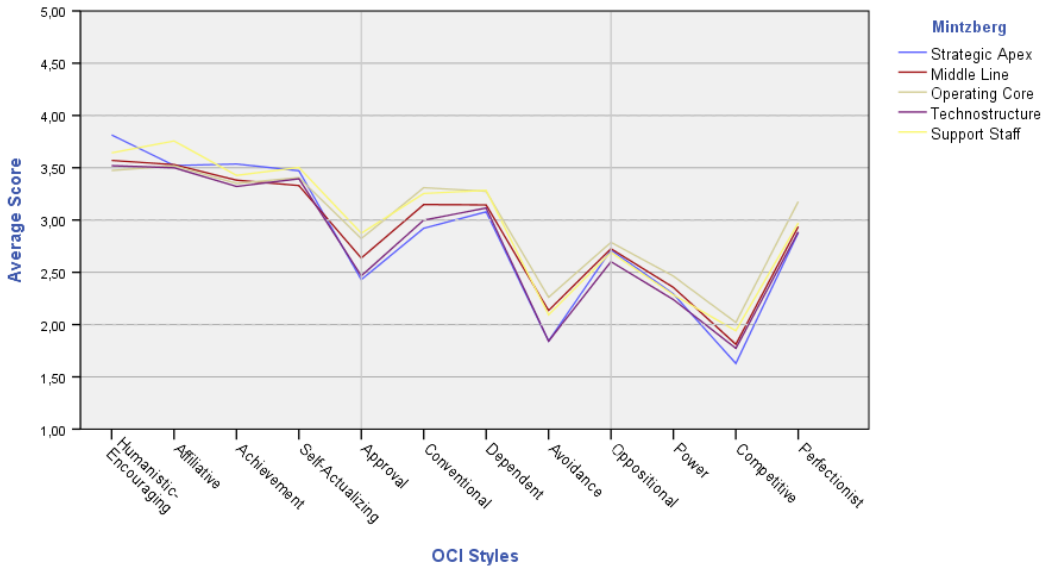

Figure 11. OCI styles averages by Mintzberg's organizational components.

4. Discussion

This paper describes the organizational culture of the Spanish nuclear industry based on OCI survey responses from independent safety culture evaluations carried out over the last decade in companies within the nuclear sector. Such evaluations also allow exploring the existence (or lack thereof) of organizational subcultures depending on the type of organization (nuclear power plant or other types of nuclear companies), workplace (facility or headquarters), contractual relationship (own staff or contractor) and organizational components according to Mintzberg's theory.

4.1. Organizational Culture of the Spanish Nuclear Industry

According to Schein [20], organizational culture is defined as shared basic assumptions influencing the way in which organization members feel and act. It is also an essential element for the safety of high-risk organizations. Investigations carried out after severe nuclear accidents have shown the relevance of culture and organizational factors on safety [16–18]. Similarly, organizational culture is not necessarily a single construct, as it can comprise a number of subcultures [8,9,20–22,24,25].

The first relevant result of this study is the identification of two main traits defining the organizational culture of Spanish nuclear organizations. In OCI terms, the first trait of the sector's organizational culture is mainly "Constructive". It is a type of organizational culture aimed at ensuring excellence and achieving results in a manner compatible with the well–being and professional development of personnel. High scores in the "Affiliative" style also reflect a special focus on the promotion of interpersonal collaborative relationships, thus favoring satisfaction within the work group.

The second trait defining the organizational culture of the Spanish nuclear industry is determined by high scores in some "Defensive" styles within the OCI. More specifically, it is a culture fostering behaviors of a "Conventional", "Dependent" and "Perfectionistic" nature, and therefore encouraging workers to seek the rules and obey them; seek to be guided; and wait for orders instead of having initiatives. It is worth noting the relevance of this second feature of the global culture of the nuclear industry considering that the OCI model is strongly normative, in a way socially accepted behaviors are mainly concentrated within the "Constructive" culture.

These results are interpreted according to previous research efforts pointing to greater desirability of the "Constructive" cluster over the "Defensive" clusters within the organizational culture. Balthazard et al. [11] consider that "Constructive" behaviors should produce desirable outcomes and minimize unwanted results. Within the nuclear industry, "Constructive" styles are linked to effective problem-solving [65]. Previous studies have also highlighted the strong link between "Constructive" culture and safety-relevant aspects, such as a blame-free environment [66], job satisfaction and motivation and satisfaction [67], as well as trust in supervisors and organizations [68]. Other research projects reveal that "Constructive" cultural styles are the most influential to obtain an adequate safety culture [19]. On the contrary, "Defensive" styles seem to be related to detrimental organizational aspects, such as social loafing, stress, low

motivation and low job satisfaction [69]. Some "Defensive" behavioral norms (e.g., "Avoidance") are also negatively associated to safety culture [70].

In the light of these findings, one has to wonder to which extent this cultural duality of the "Constructive" and "Defensive" styles is caused by the technological specificity of the nuclear industry. In other words, could the stringent requirements and needs of the nuclear technology be conditioning the coexistence of "Defensive" behaviors and "Constructive" behaviors? Similarly, safety implications should also be considered: to which extent does the safety of nuclear organizations depend on these "Defensive" traits—which clearly foster compliance with the organizational status quo—interweaving within the set of prevailing "Constructive" style norms? Is it possible to enhance safety culture by minimizing "Defensive" behaviors?

To address all these questions, specific investigations should be carried out to determine the impact of some "Defensive" styles on safety, especially in terms of the "Conventional", "Dependent" and "Perfectionistic" norms.

In addition, we consider that it would also be of interest in future research to study how some aspects of the context, such as catastrophic events (e.g., Fukushima), impact on organizational culture. This study, due to its scope and the nature of its data (different companies whose evaluations have been carried out in different time periods), has not allowed this analysis.

4.2. Existence of Organizational Subcultures within the Spanish Nuclear Industry

As for the organizational type, results show that there are two clearly differentiated organizational cultures within the Spanish nuclear industry. On the one hand, a group of private companies in charge of commercial nuclear power plants and, on the other hand, auxiliary public organizations which support the nuclear industry by conducting activities such as radwaste management and decommissioning, as well as nuclear component and fuel manufacture. This means that compared to auxiliary organizations, nuclear

power plants have a more distinct "Constructive" style and put less emphasis on "Passive/Defensive" norms. Furthermore, within the group of nuclear power plants, there are very few differences in the "Constructive" styles and small differentiating nuances in the "Defensive" styles, whereas the group comprised of public nuclear companies perceive culture more heterogeneous, especially in the "Constructive" styles.

It is important to point out that two potentially determining factors of this cultural differentiation could be the type of organizational ownership (private vs. public) and a potentially different concept of risk (power stations focus more on nuclear safety and public companies on conventional risks). Previous studies have proven the differing nature of challenges faced by these two types of organizations within Spain's energy framework [71].

The workplace-based analysis also reveals some differences between individuals working in the facilities versus those in headquarters. Facilities score higher than headquarters in the "Constructive" cluster within the Spanish nuclear industry. Furthermore, facility personnel also score higher in the OCI scales defining the "Defensive" culture. In this regard, it is possible to speak about a facility personnel subculture and a headquarters personnel subculture, both perhaps linked to the level of proximity to technological aspects. In this sense, previous studies highlighted how proximity to technological risks influences the perceptions of individuals [72].

In terms of contractual relationship, analyses suggest there is strong cultural uniformity between own staff and contractors, with both groups of individuals perceiving the organization's cultural norms under the same order of magnitude. Despite being two clearly differentiated groups in the everyday working life (e.g., wages, labor conditions, organizational ownership, etc.), these results may show the strong inclusive nature of plant culture. In other words, the organizational culture has an inclusive property capable of homogenizing all employees, both own staff and contractors, and making them have a similar perception of cultural

norms. Culture assessments have included long term-contractors, so the time variable could also be a determining factor in this homogeneous vision. Future studies considering seniority in the organization could analyze this aspect more in depth.

As for Mintzberg's organizational components [47], it seems that labor division and task coordination, which are considered elements structuring organizations, could also be determining factors of the organizational culture (or ideology, as presented by Mintzberg). Thus, results show that the technostructure and operating core have different "Defensive" styles—operating core personnel, who carry out tasks relating to the distinctive activity of the organization (safe and reliable operation and maintenance of the facilities), perceive a more "Passive" and "Aggressive" culture than technostructure personnel, who are more specialized and carry out tasks of less hierarchical nature and involving a larger intellectual challenge. In behavioral terms, operating core personnel seem to perceive organizational norms that promote agreements, encourage a blame-free environment and prevent conflicts, as well as a high level of attention to detail, whereas the technostructure seems to require cultural styles that are more humanistic, with less avoidance and competition among its members. In other words, aspects circumscribed to compliance with standardized activities seem to be more relevant in the operating core than in the technostructure. That would fit the adequacy of the machine bureaucracy model for nuclear power plants, as identified by Mintzberg [47] (p. 315).

In short, the results show that the organizational culture of the Spanish nuclear sector is homogeneous. However, it is also observed that some demographic variables such as organizational type, location and organizational components are associated with differentiated cultural features (subcultures). It is worth asking to what extent this is clear cultural differentiation or, whether it is simply cultural nuances within the framework of a shared general culture. In other words, integration, or differentiation? [23]. Coinciding with the point of

view of Trice and Beyer [21], results seem to indicate that the Spanish nuclear sector has a common organizational culture that coexists with some subcultures with which it shares characteristics.

The potential existence of subcultures within the nuclear industry could have safety implications. These subcultures, as explained in the introductory theoretical framework, are not necessarily a negative factor and could actually increase the organization's adaptive capacity [40–42]. Thus, it is paramount to consider the implications of this cultural differentiation in terms of safety. That would entail, for example, the need to determine how different professional groups address the importance of safety [30]; how these differences are addressed by managers and; to which degree cultural differences can exist without affecting organizational cohesion. These questions highlight the importance of carrying out additional investigations to understand how interactions between culturally differentiated components and groups determine the safety level of high-risk organizations.

4.3. Limitations

The lack of information on organizational seniority as well as on the workers department is a limitation for this study, especially since it is a factor that potentially influences the organizational culture [30,33]. Another limitation is the fact that we only had information on the organizational components proposed by Mintzberg for one nuclear company. In this regard, the small sample size of some organizational components (e.g., strategic apex) could have limited the statistical significance and power of the analyses. That means results should be interpreted as a reflection of differences between groups with the most extreme scores.

Additionally, it would have been desirable to have responses to open−ended questions to analyze from a qualitative perspective how subcultural differences influence interpretations and employees' courses of action.

5. Conclusions

The results of the present study show that the organizational culture of the Spanish nuclear industry is, in terms of Organizational Culture Inventory® (OCI), mainly "Constructive", with some key "Defensive" traits. It is a culture in which a main driving cultural force promoting "Constructive" and collaborative behaviors coexists with other key normative patterns fostering "Defensive" behaviors of the "Conventional", "Dependent" and "Perfectionistic" styles.

Results also show that there are indications of different organizational subcultures. Three factors seem to contribute to its establishment: a) the type of organization (nuclear power plant or auxiliary companies specializing in radwaste management, fuel manufacturing, as well as production of large nuclear components); b) the common workplace (facility or headquarters) and c) aspects deriving from the organizational structure (Mintzberg's organizational components). In terms of type, nuclear power plants are more homogeneous, more "Constructive" and less "Passive/Defensive" than auxiliary nuclear companies. As for the workplace, organizational culture at the facilities seems to be more "Constructive" than at the headquarters. Lastly, if Mintzberg's organizational components are considered, the operating core perceives the organizational culture in more "Defensive" terms than the technostructure. It is worth noting that results show a lack of subcultures associated to contractual relationship types, with homogeneous results between own staff and contractors.

Future research should be conducted to learn more about the complementarity of organizational subcultures as a tool to prevent the existence of "blind safety spots" [40]. Cultural differences should be considered key factors of safe evolutions in nuclear facilities, meaning research should also focus on how safety is built as a result of cultural interactions [42].

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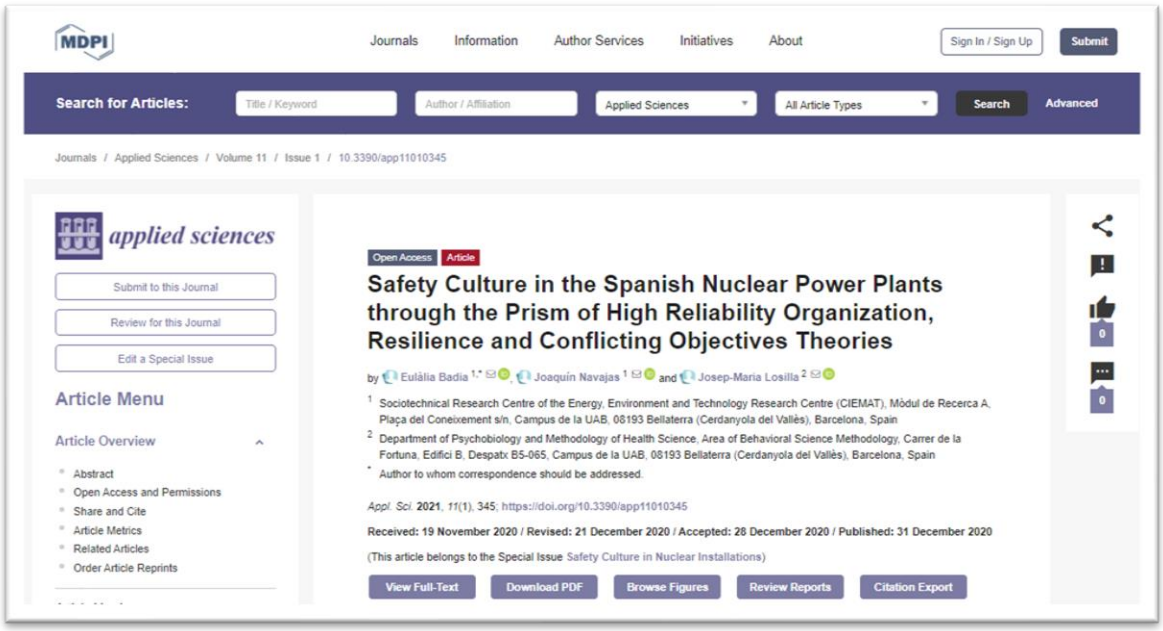
4.2. Study 2: Safety Culture in the Spanish Nuclear Power Plants through the Prism of High Reliability Organization, Resilience and Conflicting Objectives Theories



(Badia, Navajas & Losilla, 2021).

Safety Culture in the Spanish Nuclear Power Plants through the Prism of High Reliability Organization, Resilience and Conflicting Objectives Theories

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Featured Application: The description of safety culture traits within the Spanish nuclear power plants, both globally and at the particular level, can benefit the safe performance of facilities.

Abstract: Safety culture is the result of values, attitudes, and perceptions of the members of an organization that prioritize safety over competing goals. Previous research has shown the impact that organizational aspects can have in safety performance. Under the prism of the theoretical approaches from the high reliability organizations theory (HROT), resilience engineering (RE), and conflicting objectives perspective, this study was aimed at describing the overall main safety culture traits of the Spanish nuclear power plants, as well as identifying particularities associated with subcultures. For this purpose, a statistical analysis of safety culture surveys and behavioral anchored rating scales (BARS), handed over to all the operating Spanish nuclear power plants, was carried out. Results reveal that safety is a recognized value that prevails over production, there is a high degree of standardization, power plants are better

prepared to organize plans and strategies than to adapt and cope with the needs of a crisis, and there is a critical and fragmented perception about the processes of resources allocation. Findings also identify that sociodemographic aspects, such as work location and contractual relationship, seem to be shaping differentiated visions. Several safety implications linked to the results are discussed.

Keywords: safety culture; organizational culture; organizational subcultures; nuclear industry; high reliability organizations; resilience engineering; conflicting objective perspective

1. Introduction

The Spanish nuclear industry faces gradual, definitive decommissioning within as part of a new energy model change. Over the next 15 years, all operating plants will have to shut down. Within this end-of-cycle stage, the framework of safety culture is an essential aspect to guarantee safe operation until plants permanently shutdown.

This paper aims to describe the organizational culture for the safety of Spanish nuclear power plants, taking three relevant theoretical approaches within the scope of high reliability organizations as a reference. To do that, quantitative data obtained from safety culture surveys were analyzed. These were administered to all workers at currently operating nuclear power plants, together with a behavioral anchored rating scale (BARS) distributed to a representative sample of workers.

Outlined below are the theoretical foundations of this research: (a) What is considered organizational culture? (b) What is considered safety culture (or organizational culture for safety)? (c) Based on the theory of high reliability organizations, resilience engineering, and conflicting objectives perspective, what are the theoretical approaches used to describe the safety culture of Spanish nuclear power plants?

1.1. Organizational Culture

Studies on culture have an interdisciplinary nature and are widely diverse in their purpose and scope. Cooper [1] points out that when researchers address culture, some focus on the way people think, while others focus on behavioral aspects.

Within the scope of the theory of organizations, Schein [2] considers that organizational culture comprises the experience gained by individuals within an organization, with the aim to adapt to their environment and solve problems.

Although some authors such as Edwards et al. [3] (p. 71) define organization culture as "culture held by members of a given organization", this culture is not necessarily uniform or homogeneous amongst all members [4–6]. Different groups may have different points of view concerning their environment [7]. This lack of consensus and the existence of subcultures could be the result of multiple external or internal factors, including power, leadership, layout, experience, or knowledge, among others [8].

On the other hand, investigations resulting from catastrophic industrial accidents have contributed to acknowledging that safety is influenced by the cultural context of work practices [9]. From an organizational perspective, safety can be conceived as "the ability of individuals or organizations to deal with risks and hazards so as to avoid damage or losses and yet still achieve their goals" [10] (p. 5). In that sense, studies on organizational culture can contribute to identifying aspects that should be considered in order to further prioritize safety [11]. Over the last 40 years, the emphasis on various system aspects relating to safety has evolved from a purely technological perspective to a more inclusive vision. Simultaneously, new catastrophic accidents have been taken as reference. At the first stage, Hale and Hovden [12] pointed out that after the Seveso accident in 1976, it was considered that technology could explain the cause of accidents. After the Three Mile Island event (1979), more emphasis was placed on the unsafe acts of individuals carrying out tasks. In a third stage, linked to the accidents affecting Bhopal (1984), Chernobyl (1986), and the Challenger (1986), the importance of safety management was highlighted. After the events of Tokaimura (1999), Davis–Besse (2002), and Columbia (2003), the focus of attention shifted towards organizational aspects. Finally, the Fukushima accident (2011) also revealed the impact of organizational aspects on safety, as well as the importance of an organization's resilience in the face of an unexpected situation [13].

Therefore, it can be said that the evolution of safety paradigms has tended to a more inclusive vision with the aim to understand the complex relationship between technology, humans, and organizations [14]. The last two stages link safety to adaption, meaning that an organization's capacity to adapt to changing circumstances [15] and to adequately manage uncertainties [16] is considered paramount to safety.

1.2. Safety Culture

The term 'safety culture' was coined after the Chernobyl nuclear accident in 1986. As abovementioned, the investigation report of this event revealed the role of cultural and organizational aspects as contributors to this accident. Ever since, many developments, definitions, and models on the term 'safety culture' have been carried out by nuclear industry agencies referenced and reported in scientific literature.

Originally, the International Atomic Energy Agency (IAEA) defined safety culture as "the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance." [17] (p. 4). The IAEA's vision of safety culture has broadened in time towards convergence with the concept of organizational culture [18]. As for the Institute of Nuclear Power Operations (INPO) and the U.S. Nuclear Regulatory Commission (NRC), they describe the term as "the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment" [19,20] (p. iv; p. 34773).

From an academic sphere, there has been some discussion around the link between safety culture and organizational culture. Hopkins [11] points out that according to some authors, each organization has a specific safety culture, whereas for others this only exists if there is an overriding commitment to safety.

Other researchers consider that safety culture is just a part, an aspect, or an effect resulting from the organizational culture [9,11,21,22]. According to Clarke, [23] safety culture is a subset of the organizational culture comprising beliefs and values specifically related to health and safety. Richter and Koch [5] (p. 705) define safety culture as "the shared and learned meanings, experiences and interpretations of work and safety…which guide peoples' actions towards risks, accidents, and prevention."

Despite this disparity of perspectives, there seems to be a basic agreement in that (a) safety culture takes place in organizations which highly prioritize beliefs, values, and attitudes related to safety [1,21], and (b) it is a multidimensional concept which includes numerous elements of an organizational nature [24]. Some authors claim the need to deviate the attention from the concept of 'safety culture' to the concept of 'organizational culture' in order to avoid potential ambiguities [11,21,25] . It is assumed that organizational culture influences safety by providing reference frameworks through which risks and hazards are detected, assessed, or dismissed, as well as by determining conventions for behavior, interaction, and communication between individuals within the organization [9].

1.3. Theories of Organizational Safety

Taken as a reference for this study, the main features of the three safety theories for complex organizations are described in the following subsections.

1.3.1. Theory of High Reliability Organizations

The theory of "high reliability organizations" (HRO) was developed with the aim to understand which factors determine that complex, high-risk organizations, such as those in the aeronautics sector and the nuclear industry, are able to maintain high safety levels [26]. HRO are seen as organizations capable of maintaining an error-free performance for long periods of time [27].

In this way, even if they are organizations operating in complex, high-risk environments, they are mostly accident-free [28].

A central element shared by the authors of this approach is the principle that accidents are avoidable. The theory of HRO stands, in practice, as an academic counter-proposal to the "normal accident theory" (NAT) formulated by Perrow [29]. The NAT assumes a certain fatalism on the unavoidability of accidents in complex organizations. An unavoidability caused by high-coupling between technology and organization and the unpredictability of the system, in which a failed part could affect all others and the system as a whole.

On the contrary, the theory of HRO proclaims that technologically complex organizations have a set of processes that effectively prevent and detect catastrophic failure [27,30]. The consistency and stability required for failure-free operation would be achieved through a set of technical and organizational features, such as (a) management commitment to ensure safety is an overriding priority at all levels, (b) existence of redundancy systems, (c) decentralization of the decision-making process, (d) ongoing technical training of personnel, (e) organizational learning based on operational events, (f) promotion of communication, and (g) reward for individuals who report problems [31,32].

It is worth noting that the approach of the HRO theory ended by converging with some aspects of resilience engineering, integrating an approach both preventive and adaptive within safety management. Prevention requires the identification of events that should not occur and precursor events which might lead to them, as well as the creation of procedures to prevent undesirable events [33]. In addition to prevention, organizational reliability requires resilience [34] to handle organizational variations while maintaining stable systems [33,35].

In this sense, Weick and Sutcliffe [36] point to five key aspects to maintaining high safety standards: (1) a preoccupation with failure, (2) a reluctance to simplify, (3) a sensitivity to operations, (4) a commitment to resilience, and (5)

deference to expertise. The first three address the capacity of an organization to anticipate unexpected problems, whereas the last two refer to the capacity of the organization to contain unexpected problems once they have occurred. In other words, high reliability organizations are able to detect and manage unexpected events while sustaining reliable performance.

1.3.2. Resilience Engineering Perspective

According to Grabowsk et al. [37], complex high-risk systems need to have two characteristics to ensure safety: reliability during routine activities and capacity to adapt to inherent system variability. From the theory of organizations, the term resilience is used to define the organizational capacity to prepare for, respond to, and recover from unexpected emergencies and crises [38,39].

Hollnagel [40] describes two different modes through which safety can be attained. The first approach, 'Safety-I', or centralized control, is associated with a concern to understand things that go wrong. The second approach, 'Safety-II', or guided adaptability, includes the knowledge of how and why things go well, and is defined as the capacity to be successful under changing conditions. The term 'Safety II' is also used to refer to resilience engineering (hereinafter, RE).

Hollnagel et al. [41] (p. xxxvi) define resilience as "the intrinsic ability of a system to adjust its operation before, during, or after changes or disturbances, so as to ensure the operations required, under expected or unexpected conditions." It implies variability in the performance and capacity of individuals and organizations to adapt continuously to situational changes in their daily work with the aim to ensure a good outcome [40] (p. 137). According to Hollnagel, engineering resilience has four main pillars: (1) capacity to respond, (2) to monitor, (3) to anticipate, and (4) to learn to adapt or recover from accidental events [41].

In some organizations, adaptation could be a prerequisite of safe performance, whereas in others it might lead to significant damages [42]. Thus, performance adjustments are seen as a precursor to both success and failure. It is considered that the more tightly coupled (interdependence between parts of the system) and intractable (complex systems subject to change) performance is, such as in the case of nuclear power plants, the more necessary it is to have an adaptive response because the risk of adverse results is high [43].

1.3.3. Conflicting Objectives Perspective

The "conflicting objectives perspective" (COP) by Rasmussen [44] is supported by the basic idea that human activities are characterized by an ongoing search for balance against pressures resulting from partially conflictive goals. According to Rasmussen, high-risk technological systems are subject to multiple pressures: activities have to be profitable, safe, and imply a reasonable workload for personnel. It is a dynamic, complex sociotechnical system in which safety and quality could be gradually relegated in favor of other goals such as production and time pressure. This conflict between goals often generates a dilemma due to the inability to balance them correctly. It is precisely that lack of balance, caused by antagonism between goals, which can lead to accidents.

It is worth noting that, at every organizational level, people respond to pressure by taking compensatory measures without knowing how such actions will integrate with decisions made by others [45]. When individuals and organizations constantly make compensatory decisions to deal with the pressure resulting from differing goals, activities tend to move towards potentially unacceptable limits.

In the case of complex systems, these decisions and adaptions to balance all types of pressure are made locally, without central coordination or understanding their impact on safety [46]. These uncoordinated adaption

attempts could accumulate in time, taking the system away from its design parameters [44]. According to Dekker [46], some organizations seem to head for failure even if they appear to operate well and have success, whereas others seem to avoid significant organizational accidents even if they have faced similar risk situations with potential catastrophic consequences many times before.

Based on the "conflicting objectives perspective", Rasmussen develops the "drift to danger" model, which he defines as a "systemic migration of organizational behavior toward accident under the influence of pressure toward cost-effectiveness in an aggressive, competing environment." [44] (p. 189). This model seeks to effectively manage conflicting goals, making unacceptable risk limits both explicit and known.

In short, it is important to mention that for the COP, accidents are the result of a normal organizational behavior that is altered by environmental pressures, complex technology, and social system processes. From this approach, the resolution of some organizational dilemmas eventually leads to decisions which, from an accumulative sense, could negatively impact the safety of an organization.

1.4. Objectives and Theoretical Framework of This Study

The objective of this study is to describe the main safety culture characteristics of Spanish nuclear power plants, taking as an analysis framework the traits of the three theoretical approaches on the safety of high-risk organizations: theory of HRO, resilience engineering, and the conflicting objectives perspective. This study is conducted with secondary data obtained from independent safety culture evaluations in all Spanish nuclear power plants using the same methodology, hence providing a source of information that is reliable and consistent with the purpose of the study. The nature of the data favors the assessment of key aspects of each theoretical perspective. It is

important to emphasize that this study is not aimed at engaging in theoretical discussions or comparing theoretical approaches, but to describe safety culture using available instruments and data. We adopt an eclectic theoretical perspective based on the complementarity of theoretical approaches resulting from the multidimensional nature of safety. That implies, as pointed out by Le Coze [47], the need to consider that concepts may overlap or complement each other, as explained in different theories. All three theories highlight how important aspects such as reliability, resilience, and decision-making are for the safety of complex organizations. There are also specific elements to each of these approaches that grant greater amplitude to the description of the subject matter. In short, our study takes note of the following statements to describe safety culture:

- Theory of HRO: (a) the central value of safety as an aspect conditioning values and behaviors within the organization, (b) the necessary awareness of risk inherent to work activities and processes, and (c) a constructive work environment enabling discrepancies without fear of retaliation;
- Resilience engineering perspective: (a) the capacity to anticipate crisis situations and (b) the capacity to respond to unexpected events;
- Conflicting objectives perspective considers three dilemmatic organizational aspects whose resolution does impact safety: (a) safety vs. production, (b) resources vs. shortage, and (c) formalization vs. informalization.

Lastly, our research is also based on a concept of safety culture as an inseparable part of organizational culture [9]. Although the term 'safety culture' is used, it actually serves as a conceptually useful label that links the organization's culture to its safety focus.

2. Method

2.1. Sample Characteristics

The collaboration agreement from 1999 between the Spanish Nuclear Regulator (CSN), the Public Research Agency for Energy, Technology and Environment (CIEMAT), and the Electrical Industry (UNESA), favored the development of a research program and the establishment of independent safety culture evaluations of Spanish nuclear facilities. Within the framework of this agreement, the evaluation methodology of Nuclear Organization and Management Analysis Concept (NOMAC), used by the Canadian nuclear industry [48], was adopted. This methodology has been used in all Spanish nuclear facilities ever since.

The aim of this study was to analyze quantitative data obtained during external independent safety culture evaluations in all Spanish nuclear power plants currently in operation (seven reactors). As shown in Table 1, the survey sample includes a total of 4326 workers. The name of the three nuclear organizations is not disclosed due to confidentiality obligations. Thus, they will be referred to as nuclear power plant (NPP) NPP1, NPP2, and NPP3.

Table 1. Study survey sample and descriptives.

Variable		Survey Sample N (%)	Total N (%)
Organization	Nuclear Power Plant 1	533 (12.32%)	
	Nuclear Power Plant 2	1975 (45.70%)	
	Nuclear Power Plant 3	1818 (42.03%)	4326 (100%)
Personal workplace (Location)	Facility	3767 (88.84%)	
	Headquarters	473 (11.16%)	4240 (100%)
Contractual situation of workforce (Contract)	Own staff	1715 (42.85%)	
	Contractors	2287 (57.15%)	4002 (100%)

The analysis was performed for the entire sample and according to some demographic variables with the aim to identify potential differences (subcultures) between groups, as shown in previous studies [49–52]. Analyzed variables were as follows:

- Organization (three different nuclear organizations with a total of five reactors);
- Location (working at the facility or at the headquarters);
- Contractual relationship (own staff or contractors).

The variability of these three variables in relation to the entire sample (organization, location, and contract) is due to the fact that some individuals did not provide all the sociodemographic data when taking the survey (this option was allowed if they believed it necessary to ensure anonymity).

2.2. Data and Measurement Instrument

This study was conducted with secondary data obtained from independent safety culture evaluations. Analysis data were obtained by administering the following measurement instruments: (1) a survey including four standardized scales given to all nuclear power plant members and (2) three behavioral anchored rating scales given to a representative sample of each nuclear power plant. Both BARS and surveys were administered physically on paper (years 2015, 2018, and 2019).

The survey comprised four scales, all of them with Likert-type responses with seven fixed-choice options: safety [53], risk perception [53], safety conscious work environment (SCWE) [54] and organizational resilience. The authors of this last scale also suggested that it could be approached as two subscales: planning capacity and adaptive capacity [55,56]. The upper part of Table 2 shows a content summary of these scales together with theoretical elements identified to describe safety culture.

In addition to surveys, the NOMAC methodology uses BARS as a measurement instrument. BARS are an evaluation instrument used to establish behavioral norms within a continuous scale [57]. They are scales providing specific examples of behavioral norms to which a numerical value is assigned. In other words, they are an evaluation tool linking a set of specific narrative examples of behavior to a numerical scale [58], meaning each example is associated with a score (1 through 5) for favorable, moderate or unfavorable behaviors (high > 3, medium = 3, low < 3) related to a specific attribute. The design of BARS includes the definition of an attribute followed by five graded behavioral examples, from which individuals are asked to choose the one which best describes the organizational scenario in that specific attribute [59,60]. As explained by Jacobs et al. [61] (p. 606), "BARS methodology results in explicit statements regarding requisite job behaviors and their perceived value."

As opposed to surveys that were distributed to all nuclear power plant members, BARS were administered only to personnel participating in individual interviews and focus groups (some 10–15% of personnel in the organization).

This study analyzes the following three BARS: attention to safety, formalization, and resource allocation [62]. The lower part of Table 2 shows the aspects measured by each of the BARS.

Table 2. Measurement scales.

Safety Theories	Measurement Instrument	Scale Definition *(Sample Items)*
		Survey Scales:
Theory of high reliability organizations	"Safety" [53]	Safety (40 items): measures individual perception of the importance of safety in relation to the success or achievement of the organization. Safety is defined as the act of operating while ensuring that the likelihood of error is low because the consequences of making a mistake are considerable *(To which extent does error reporting help you to do your job well while complying with expectations?).*
Theory of high reliability organizations	"Hazard" [53]	Hazard (4 items): It measures people's perception of how dangerous their job is *(What is the level of hazard in your job?).*
Theory of high reliability organizations	"Safety conscious work environment" (SCWE) [54] (Elaborated following Nuclear Energy Institute [63] and Nuclear Regulatory Commission [64] guidelines on SCWEs).	SCWE (7 items): It measures the perception of respondents with regards to the freedom to make questions or express concerns relating to nuclear safety without fear of retaliation or discrimination *(Can I openly question the decisions of my managers?).*
Resilience engineering perspective	"Organizational resilience" [55,56]	Global Resilience global (13 items): It measures the organization's capacity to plan, respond to, and recover from emergencies and crises (composed of 2 factors). Factor 1, Planning (5 items): It refers to the development of plans and strategies to effectively manage crises *(Are we aware of how a crisis could impact us?).* Factor 2, Adaptive Capacity (7 items): It refers to the act of facing organizational needs before they become critical *(Is our organization capable of making difficult decisions quickly?).*
		Behavioral anchored rating scales (BARS) [62]:
Conflicting objectives perspective (safety priority vs. production priority)	"Attention to Safety"	Attention to safety: Safety refers to the characteristics of the work environment, such as the norms, rules, and common understandings that influence facility personnel's perceptions of the importance that the organization places on safety. It includes the degree to which a critical, questioning attitude exists that is directed toward facility improvement *(Individuals in the facility believe safety is the number one priority and that perspective is reinforced by senior (high-level) management and clearly disseminated to all individuals in the facility).*
Conflicting objectives perspective (precise objectives and sufficient resources vs. vague objectives and resource shortage)	"Resources allocation"	Resources allocation: Refers to the manner in which the facility distributes its resources including personnel, equipment, time, and budget *(Most employees are aware of the goals of the organization but are not sure how the goals affect their own job. Personnel do not always have the support or resources necessary to correct).*
Conflicting objectives perspective (formalization vs. informalization)	"Formalization"	Formalization refers to the extent to which there are well-identified rules, procedures, and/or standardized methods for routine activities as well as unusual occurrences *(No system of updating is apparent, and many procedures are outdated. Procedural adherence is lacking in day-to-day operations).*

2.3. Data Analyses

All data analyses were conducted using IBM SPSS Statistics v22.0 [65]. The distributions of scores, skewness, and kurtosis suggested that quantitative data were normally distributed. Cronbach's alpha (α) internal consistency reliability [66] was calculated for the six scales, considering acceptable values of α ranging from 0.7 [67].

Paired samples t-test was carried out to assess within-subject differences in the scores obtained in the six scales and in the three BARS. The t-test and one-way ANOVA were carried out to compare responses by organization, by location, and by contractual relationship. Effect sizes were calculated using Cohen's δ, considering effect sizes as small ($\delta \geq 0.2$), medium ($\delta \geq 0.5$), or large ($\delta \geq 0.8$) [68].

In contrast to the analyses of the six scales (Hazard, Perception, Safety, SCWE, Planning, Adaptive capacity, and Overall resilience) applied to the entire population of Spanish nuclear power plant workers, responses to BARS (Attention to safety, Formalization, and Resources allocation) were only available from a representative sample of these workers. Thus, in addition to effect-size measures to assess the magnitude of differences, t-test and one-way ANOVA, with corrected degrees of freedom if Levene's test for equality of variances is statistically significant, were adjusted to carry out comparative analyses between groups for the three BARS administered to a representative sample in each nuclear power plant.

Bonferroni-corrected p-values were calculated for between-groups post hoc comparisons. Tests were considered significant at $p < 0.05$. The five possible BARS scores were also grouped in three categories (scores higher than 3 were considered "high", equal to 3 were "medium", and lower than 3 were "low") to represent results by means of stacked graph bars.

3. Results

3.1. Reliabilities, Factorial Components, and Global Descriptives of the Scales

The reliability analysis of all six survey scales provides good internal consistency values (Cronbach's α over 0.80).

Table 3 shows results obtained from scale reliability analyses, percentages of categorized BARS, and descriptive information from all.

A two-factor solution resulted from factor analysis of the organizational resilience scale. The two factors are comparable to those found in previous research [55,56], except for the item 5, with factorial loading values within adaptive capacity instead of planning. To ensure a more accurate comparison between our results and those of previous studies, and considering the high internal consistency in both indicators, analyses within our study maintained the definitions for the two factors within the organizational resilience scale as proposed by the authors. Table 4 includes the results of factorial analyses of the organizational resilience scale.

Table 3. Reliability and descriptive statistics of scales for the Spanish nuclear power plants.

	Spanish Nuclear Power Plants (4326)						
Scales	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**Cronbach's α**
Hazard perception	4317	4.24	1.66				0.85
Safety	4319	5.89	0.77				0.96
SCWE	4317	4.69	1.42				0.89
Planning	3777	5.40	1.08				0.81
Adaptive capacity	3777	4.51	1.31				0.91
Overall resilience	3778	4.95	1.10				0.92
Attention to safety	479	4.40	0.72	87.89	11.06	1.04	
Formalization	144	4.10	0.76	87.50	7.64	4.86	
Resources allocation	183	3.39	1.08	53.30	20.33	26.37	

Table 4. Principal factor component analysis of the organizational resilience scale.

		Factors	
	Resilience Items [55]	Planning	Adaptive capacity
1	We are mindful of how a crisis could affect us	0.70	
2	We believe emergency plans must be practiced and tested to be effective	0.75	
3	We are able to shift rapidly from business-as-usual to respond to crises	0.73	0.31
4	We build relationships with organizations we might have to work with in a crisis	0.59	0.50
5	Our priorities for recovery would provide direction for staff in a crisis	0.52	0.63
6	There is a sense of teamwork and camaraderie in our organization		0.76
7	Our organization maintains sufficient resources to absorb some unexpected change	0.40	0.67
8	People in our organization ''own'' a problem until it is resolved	0.35	0.74
9	Staff have the information and knowledge they need to respond to unexpected problems	0.42	0.68
10	Managers in our organization lead by example		0.83
11	Staff are rewarded for ''thinking outside the box''		0.75
12	Our organization can make tough decisions quickly	0.31	0.67
13	Managers actively listen for problems		0.83

Analyses for nuclear power plants show that the average for the six scales is above the midpoint. The highest scores are obtained in the safety scale, with an average of 5.89. As for the risk perception scale, it has the lowest scores with an average of 4.24.

Within-subjects comparisons between the six scales (upper part of Table 5) show magnitude differences of $\delta > 0.20$ in all cases except between the hazard perception and adaptive capacity scales ($\delta = -0.13$) and the SCWE and adaptive capacity ($\delta = 0.19$) scales. It is worth mentioning the significant differences between the hazard perception and safety scales ($\delta = -0.95$) and the planning and adaptive capacity scales of resilience ($\delta = 0.92$). Comparisons by pairs for the BARS (lower part of Table 5) show magnitudes of large effect ($\delta > 0.80$).

Table 5. Within-subjects comparisons for scales and BARS.

						95% CI Cohen's δ	
	SCALES	**N**	**M**	**SD**	**Cohen's δ**	**Inferior**	**Superior**
Pair 1	Hazard—Safety	4317	−1.65	1.73	−0.96	−0.99	−0.93
Pair 2	Hazard—SCWE	4315	−0.46	2.13	−0.21	−0.24	−0.18
Pair 3	Hazard—Planning	3776	−1.16	1.93	−0.60	−0.63	−0.57
Pair 4	Hazard—Adaptive capacity	3776	−0.27	2.11	−0.13	−0.16	−0.10
Pair 5	Hazard—Overall resilience	3777	−0.72	1.96	−0.36	−0.40	−0.33
Pair 6	Safety—SCWE	4317	1.20	1.26	0.95	0.92	0.98
Pair 7	Safety—Planning	3777	0.49	0.95	0.52	0.49	0.55
Pair 8	Safety—Adaptive capacity	3777	1.38	1.18	1.17	1.14	1.20
Pair 9	Safety—Overall resilience	3778	0.93	0.95	0.98	0.95	1.01
Pair 10	SCWE—Planning	3777	−0.69	1.22	−0.57	−0.60	−0.54
Pair 11	SCWE—Adaptive capacity	3777	0.20	1.02	0.19	0.16	0.23
Pair 12	SCWE—Overall resilience	3778	−0.25	1.01	−0.25	−0.28	−0.21
Pair 13	Planning—Adaptive capacity	3776	0.89	0.96	0.92	0.89	0.96
Pair 14	Planning—Overall resilience	3777	0.45	0.48	0.92	0.89	0.96
Pair 15	Adaptive capacity—Overall resilience	3777	−0.45	0.48	−0.92	−0.96	−0.89
	BARS						
Pair 1	Attention to safety—Formalization	145	0.31	0.87	0.35*	0.19	0.52
Pair 2	Attention to safety—Resource allocation	182	1.16	1.09	1.06*	0.91	1.21
Pair 3	Formalization—Resource allocation	24	0.74	1.03	0.72*	0.29	1.14

Note: * statistically significant differences (Bonferroni-corrected $p < 0.017$).

Furthermore, it is worth highlighting that in terms of organizational resilience, personnel assign a higher score to the organization's development of plans and strategies for effective crisis management (planning M = 5.40) than to the capacity to address organizational needs before they become critical (adaptive capacity M = 4.51) (Table 3 and Figure 1).

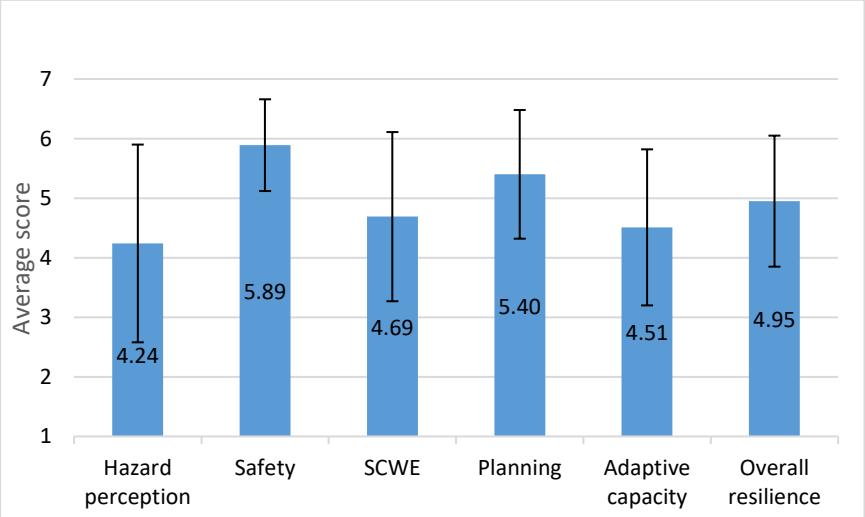

Figure 1. Scale averages with error bars (SD).

On the other hand, BARS results for all Spanish nuclear power plants show that the highest score is recorded in the attention to safety scale, with an average of 4.40 (Figure 2). Nearly 88% of workers consider that the organization highly prioritizes safety in favor of production (BARS attention to safety), and that norms are well defined, with normalized methods and procedures (BARS formalization). On the contrary, it is also important to mention that 11.06% of workers consider that the balance between plant safety and operation is compromised, and 1.04% of them believe production is prioritized over safety (BARS attention to safety) (Figure 3).

The BARS with the lowest score is resources allocation (BARS resources allocation) with a 3.39 average (Table 3, Figure 2). The result of this scale shows that perception of organizational resources allocation (both in terms of personnel, equipment, time, and economic budget) is positively valued by 53% of workers. On the contrary, 26.37% of them have a negative opinion (Figure 3). This is the study scale with the lowest scores (in both surveys and BARS).

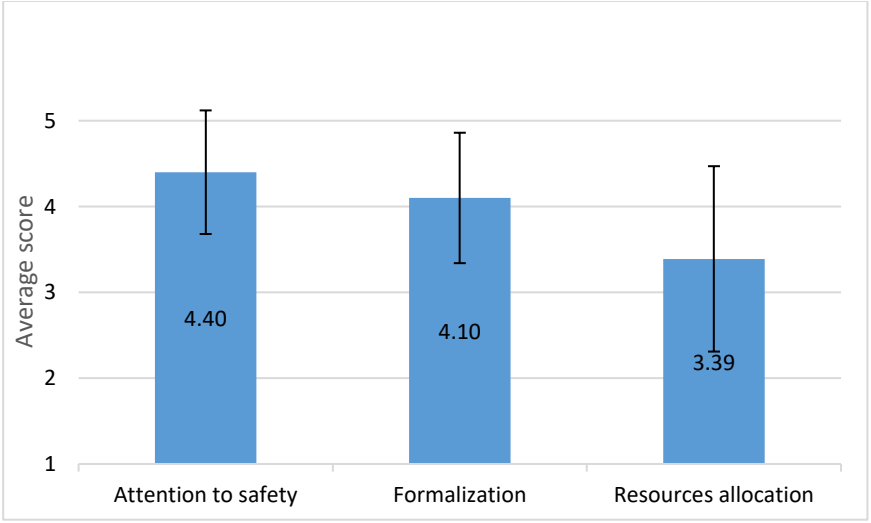

Figure 2. BARS averages with error bars (SD).

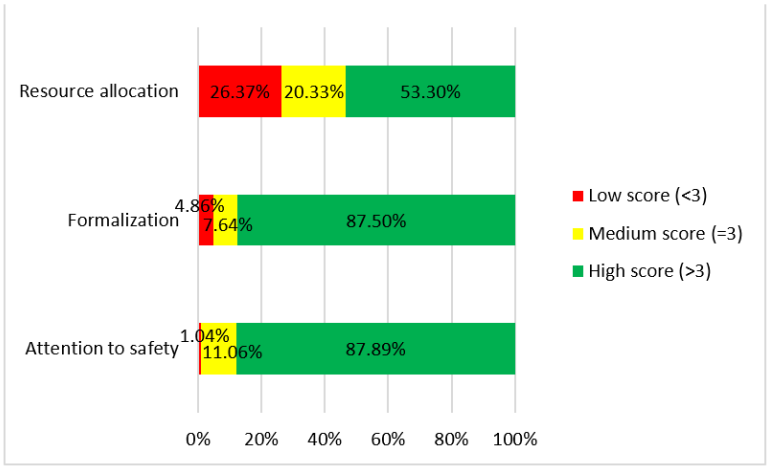

Figure 3. Global percentages of categorized BARS.

3.2. Cultural Differences by Demographic Variables

3.2.1. Differences by Company

The comparative analysis of the six survey scales by the demographic variable "company" shows that, generally speaking, there is a high level of homogeneity between nuclear power plants ($\delta < 0.20$) (Table 6, Figure 4). The only difference is found in the risk perception scale, which has a lower score in NPP2 than in NPP3, even if this difference is very small (NPP2 M = 4.07; NPP3 M = 4.41; $\delta = -0.20$).

The comparison between BARS attention to safety in the nuclear power plants provides quite a compact vision, as shown by Cohen δ values ($F(2476) = 0.835$, $p = 0.434$; $\delta < 0.20$) (Table 7, Figure 5). However, it is worth noting that although the three nuclear organizations have a favorable vision of how the organization prioritizes safety, over 12% of personnel in NPP1 and NPP2 think there is a fragile balance between plant safety and production. The most negative visions on this topic (1.71%) are found in NPP 2 (Figure 6).

The analysis of BARS formalization shows heterogeneity between the stations. Some differences are statistically significant ($F(2141) = 4.399$; $p = 0.014$) and have magnitudes with a moderate effect between NPP1/NPP3 (NPP1 M = 4.07; NPP3 M = 4.36; $\delta = -0.47$) and NPP2/NPP3 (NPP2 M = 3.92; NPP3 M = 4.36; $\delta = -0.57$) (Table 7, Figure 7). The larger number of employees with a critical score in terms of norm definition and procedure and method normalization is found in NPP2 (11.11%) (Figure 7).

On the contrary, BARS resources allocation only shows a small and statistically insignificant difference ($F(2180) = 0.921$; $p = 0.400$) between NPP1 and the other two nuclear plants (NPP2 and NPP3)—with NPP1 more critical in terms of resources allocation. Results also reveal that opinions about resources

allocation within the organization are quite polarized. Over 25% of personnel in NPP1 and NPP3 have a critical vision on this issue (Figure 8).

Table 6. Descriptive statistics of the scales by company.

	NPP1 (N = 533)			NPP2 (N = 1975)			NPP3 (N = 1818)		
Scales	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**
Hazard perception	532	4.25	1.60	1973	4.07	1.66	1812	4.41	1.65
Safety	533	5.94	0.72	1974	5.91	0.70	1812	5.86	0.85
SCWE	532	4.61	1.49	1974	4.81	1.40	1811	4.58	1.42
Planning				1972	5.32	1.08	1805	5.48	1.07
Adaptive capacity				1972	4.45	1.25	1805	4.57	1.36
Overall resilience				1972	4.89	1.07	1806	5.02	1.13
	Cohen's δ								
	NPP1-NPP2			**NPP1-NPP3**			**NPP2-NPP3**		
Hazard perception	0.11			−0.10			−0.20		
Safety	0.05			0.10			0.06		
SCWE	−0.14			0.02			0.16		
Planning							−0.15		
Adaptive capacity							−0.09		
Overall resilience							−0.13		

Table 7. Descriptive statistics of the BARS by company.

	NPP1 (N = 126)						NPP2 (N = 175)						NPP3 (N = 180)					
Scales	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**
Attention to safety	125	4.33	0.70	87.20	12.00	0.80	174	4.40	0.73	90.86	7.43	1.71	180	4.44	0.73	85.56	13.89	0.56
Formalization	45	4.07	0.65	86.67	13.33	0.00	54	3.92	0.92	81.48	7.41	11.11	45	4.36	0.56	95.56	2.22	2.22
Resources allocation	42	3.19	1.13	42.86	19.05	38.10	59	3.47	0.97	63.33	18.33	18.33	82	3.41	1.12	52.44	21.95	25.61
	Cohen's δ (CI95%)																	
	NPP1-NPP2						**NPP1-NPP3**						**NPP2-NPP3**					
Attention to safety	−0.10 (−0.24. 0.09)						−0.15 (−0.27. 0.06)						−0.05 (−0.19. 0.12)					
Formalization	0.19 (−0.17. 0.47)						−0.47 (−0.54. −0.03) *						−0.57 (−0.75. −0.13) *					
Resources allocation	−0.27(−0.70 0.13)						−0.20 (−0.65. 0.20)						0.06 (−0.30. 0.42)					

Note: *statistically significant differences by company (Bonferroni-corrected $p < 0.017$).

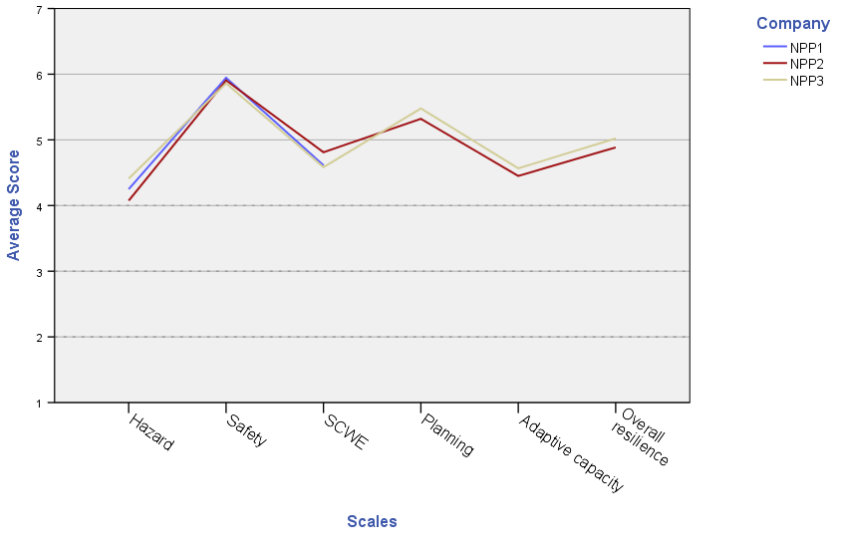

Figure 4. Scale averages by company.

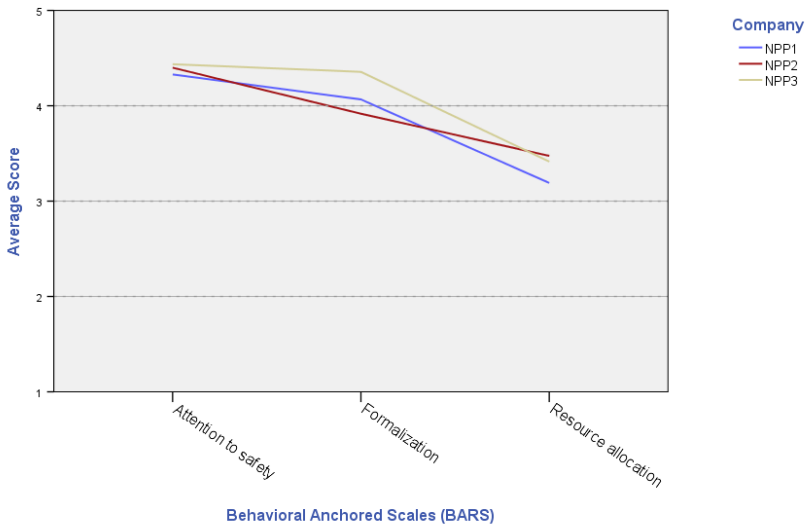

Figure 5. BARS averages by company.

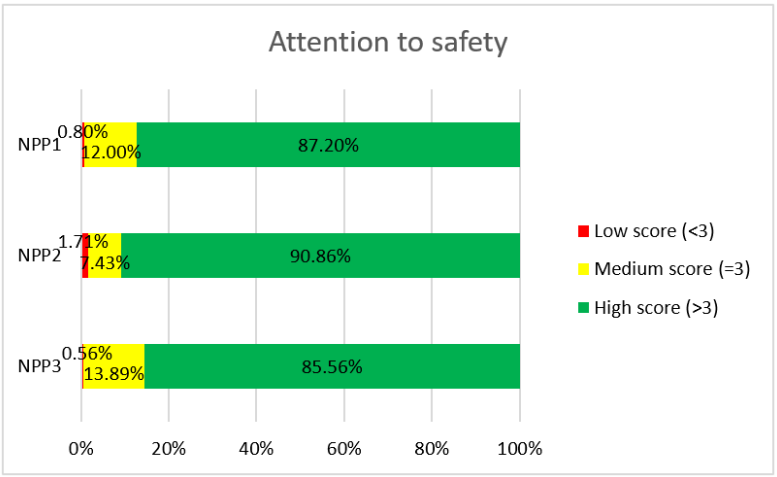

Figure 6. Categorized BARS percentages for attention to safety, by company.

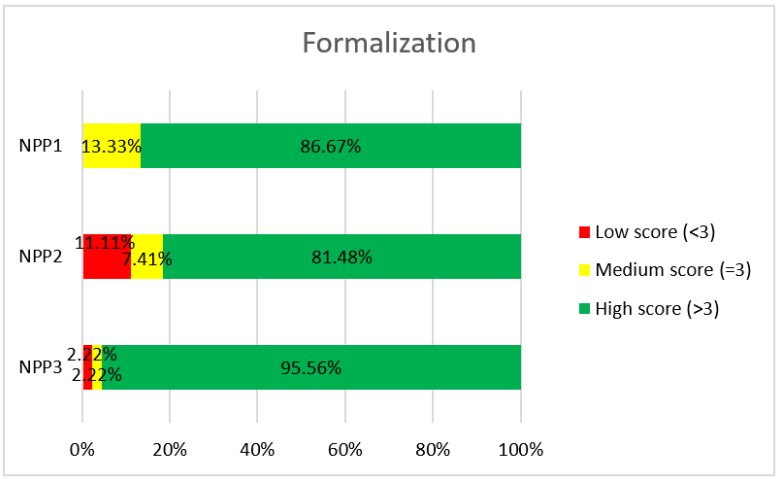

Figure 7. Categorized BARS percentages for formalization, by company.

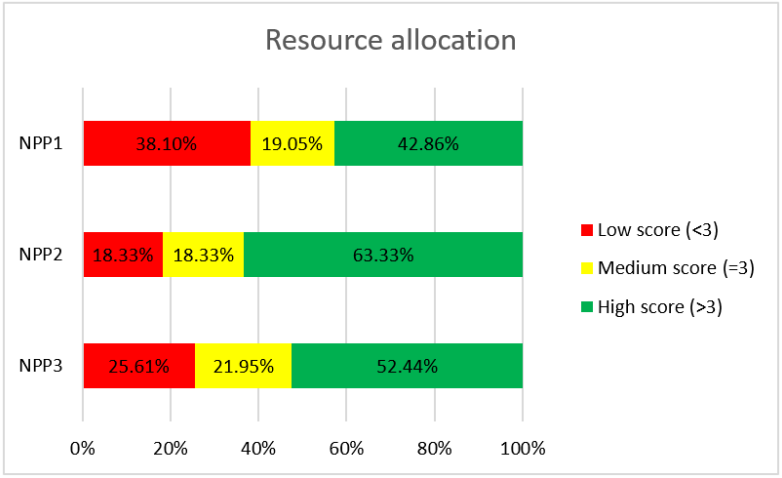

Figure 8. Categorized BARS percentages for resource allocation by company.

3.2.2. Differences by Work Location (Facility/Headquarters)

Generally speaking, the analysis of survey scales by workplace shows homogeneous results between headquarters personnel and facility personnel ($\delta < 0.20$). The only relevant difference is found in the hazard perception scale (facility M = 4.38; headquarters M = 3.16; $\delta = 0.76$) (Table 8, Figure 9). Within this scale, personnel working at the facility have a higher average score than headquarters personnel.

However, this workplace-based homogeneity in scores is not present in the three BARS within this study, all of which show differences that are statistically significant and have magnitudes of medium effect (attention to safety: facility M = 4.33; headquarters M = 4.74; $t(75.05) = -4.99$; $p = 0.000$; $\delta = -0.58$), (formalization: facility M = 3.93; headquarters M = 4.46; $t(17.55) = -2.67$; $p = 0.002$; $\delta = -0.67$), (resources allocation: facility M = 3.25; headquarters M = 3.84; $t(83.48) = -3.85$; $p = 0.000$; $\delta = -0.60$) (Table 9, Figure 10). Headquarters personnel score higher than facility personnel in terms of emphasis on safety (97.92% vs. 86.77%) (Figure 11), formalization level (100% vs. 86.36%) (Figure 12), and resources allocation (82.86% vs. 46.62%) (Figure 13). It is interesting to mention the BARS for resource distribution in the case of facility personnel is interesting, as only 46.62% of them give it a positive score.

Table 8. Descriptive statistics of the scales by work location.

	Facility (N = 3767)			**Headquarters (N = 473)**			
Scales	**N**	**M**	**SD**	**N**	**M**	**SD**	**Cohen's δ**
Hazard perception	3759	4.38	1.62	473	3.16	1.54	0.76
Safety	3761	5.89	0.78	473	5.89	0.68	0.00
SCWE	3759	4.66	1.42	473	4.92	1.44	−0.18
Planning	3318	5.38	1.08	432	5.53	1.04	−0.14
Adaptive capacity	3318	4.48	1.31	432	4.68	1.28	−0.16
Overall resilience	3319	4.93	1.10	432	5.11	1.08	−0.16

Table 9. Descriptive statistics of the BARS by work location.

	Facility (N = 274)						Headquarters (N = 48)						
Scales	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**Cohen's δ (CI95%)**
Attention to safety	272	4.33	0.72	86.77	12.06	1.16	48	4.74	0.47	97.92	2.08	0.00	−0.58 (−0.89. −0.28) *
Formalization	91	3.93	0.81	86.36	8.33	5.30	12	4.46	0.45	100.00	0.00	0.00	−0.67 (−1.28. −0.06) *
Resources allocation	82	3.25	1.09	46.62	22.30	31.08	35	3.84	0.68	82.86	11.43	5.71	−0.60 (−1.00. −0.20) *

Note: *statistically significant differences (Bonferroni-corrected $p < 0.025$).

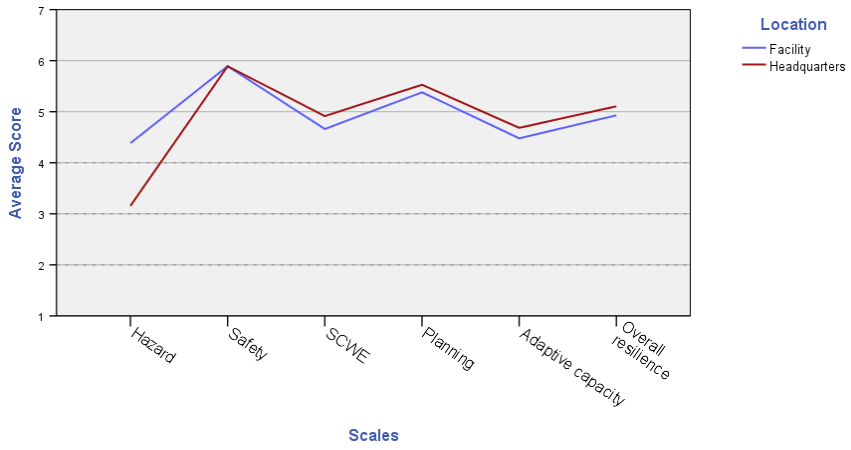

Figure 9. Scales averages by location.

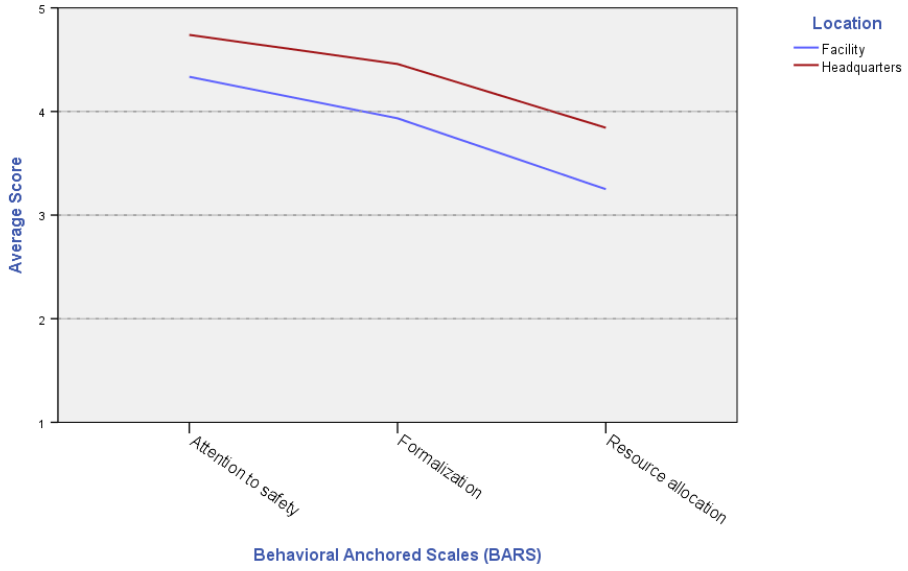

Figure 10. BARS averages by location.

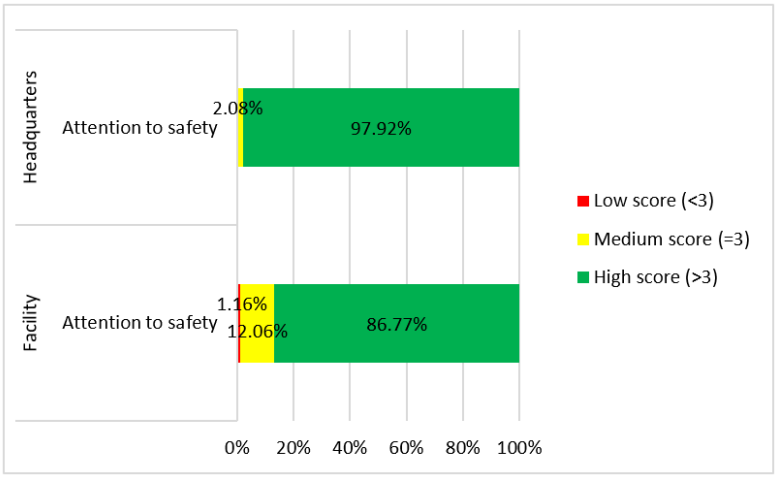

Figure 11. Categorized BARS percentages for attention to safety, by location.

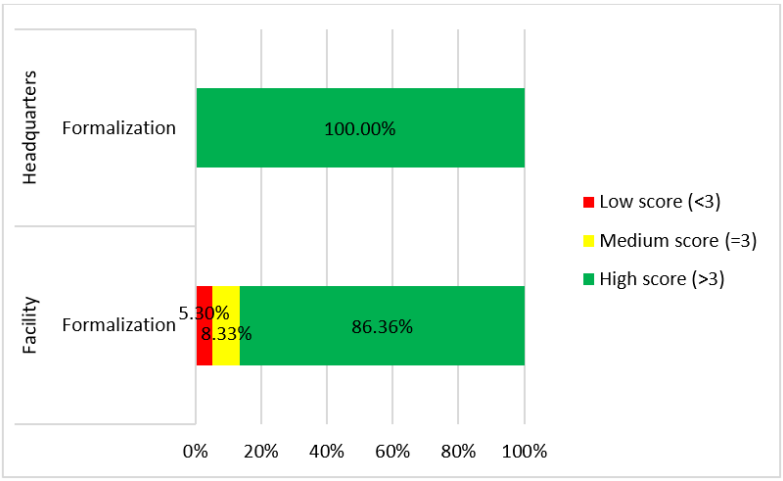

Figure 12. Categorized BARS percentages for formalization, by location.

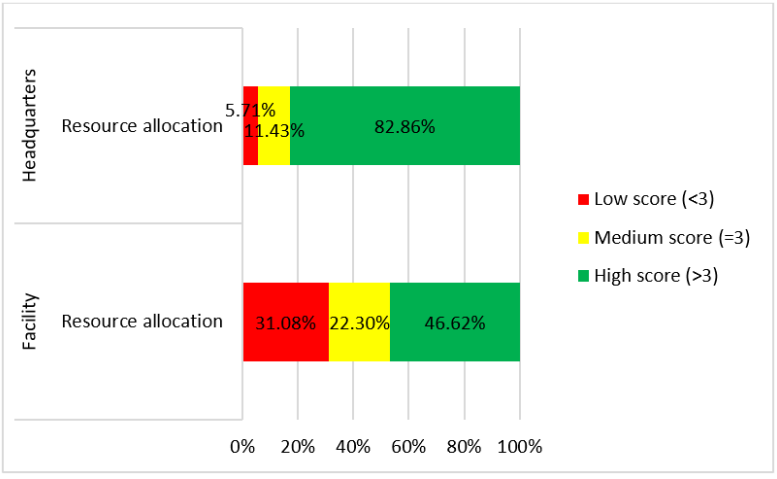

Figure 13. Categorized BARS percentages for resources allocation, by location.

3.2.3. Differences by Contractual Relationship (Own Staff/Contractor)

Personnel in nuclear power plants score homogeneously in the safety and hazard perception scales, but show differences in the remaining survey scales. Own staff score higher than contractors in SCWE scales (own M = 5.07; contractor M = 4.47; δ = 0.43), planning (own M = 5.69; contractor M = 5.24; δ = 0.44), adaptive capacity (own M = 4.77; contractor M = 4.38; δ = 0.31), and overall resilience (own M = 5.23; contractor M = 4.81; δ = 0.40). That is, contractor personnel have a lower perception of blame-free environment and lower organizational resilience (Table 10, Figure 14).

Table 10. Descriptive statistics of the scales by contractual relationship.

	Own staff (N = 1715)			Contractor (N = 2287)			
Scales	**N**	**M**	**SD**	**N**	**M**	**SD**	**Cohen's δ**
Hazard perception	1714	4.39	1.65	2286	4.10	1.66	0.18
Safety	1715	5.99	0.70	2287	5.85	0.78	0.19
SCWE	1715	5.07	1.42	2286	4.47	1.35	0.43
Planning	1376	5.69	0.95	2114	5.24	1.10	0.44
Adaptive capacity	1377	4.77	1.24	2113	4.38	1.30	0.31
Overall resilience	1377	5.23	1.02	2114	4.81	1.09	0.40

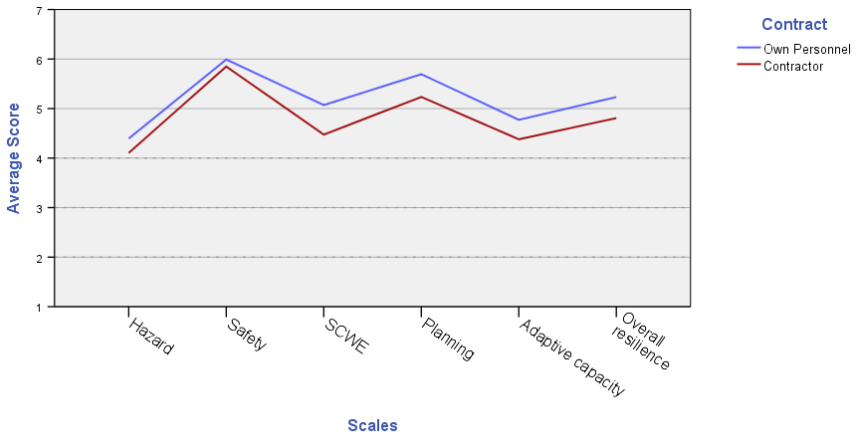

Figure 14. Scales averages by contract.

BARS results are not homogeneous when it comes to contractual. On the one hand, some differences are statistically significant and have magnitudes with a small effect in terms of safety and norm and procedure quality (attention to safety: own M = 4.46; contractor M = 4.20; t (96.62) = 2.66; p = 0.009; δ = −0.38),

(formalization: own M = 4.17; contractor M = 3.80; t (33.30) = 1.80; p = 0.081; δ = −0.48). On the other hand, no significant differences are observed, although their magnitudes have a small average effect in resource distribution scores (resources allocation: own M = 3.49; contractor M = 3.06; t (167) = 1.49; p = 0.138; δ = 0.39) (Table 11, Figure 15).

Own staff score higher in emphasis on safety (Figure 16), formalization (Figure 17), and resources allocation (Figure 18) than contractor personnel. The score obtained by contractors in the BARS for resource distribution is interesting, because 43.75% (low) of them have a negative impression, as opposed to 22.22% in the case of own staff.

Table 11. Descriptive statistics of the BARS by contractual relationship.

	Own staff (N = 367)						Contractors (N = 76)						
Scales	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**N**	**M**	**SD**	**% High**	**% Med**	**% Low**	**Cohen's δ (CI95%)**
Attention to safety	365	4.46	0.66	91.51	7.67	0.82	76	4.20	0.81	77.63	21.05	1.32	0.38 (0.14. 0.63) *
Formalization	111	4.17	0.68	90.99	5.41	3.60	28	3.80	1.01	71.43	17.86	10.71	0.48 (0.06. 0.90) *
Resources allocation	153	3.49	1.04	58.82	18.95	22.22	16	3.06	1.34	31.25	25.00	43.75	0.39 (−0.13. 0.91)

Note: *statistically significant differences (Bonferroni-corrected $p < 0.025$).

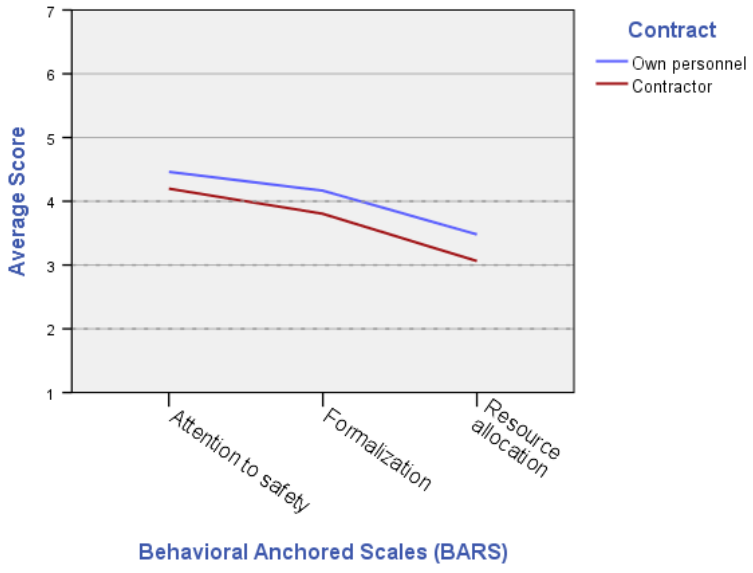

Figure 15. BARS averages by contractual relationship.

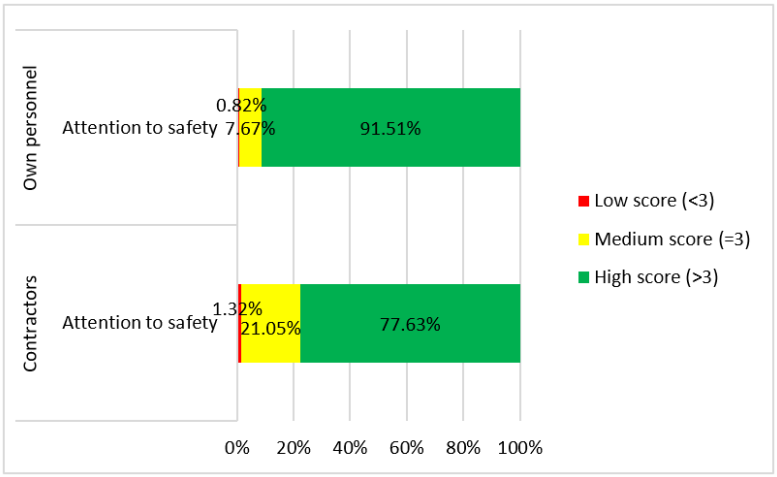

Figure 16. Categorized BARS percentages for attention to safety, by contractual relationship.

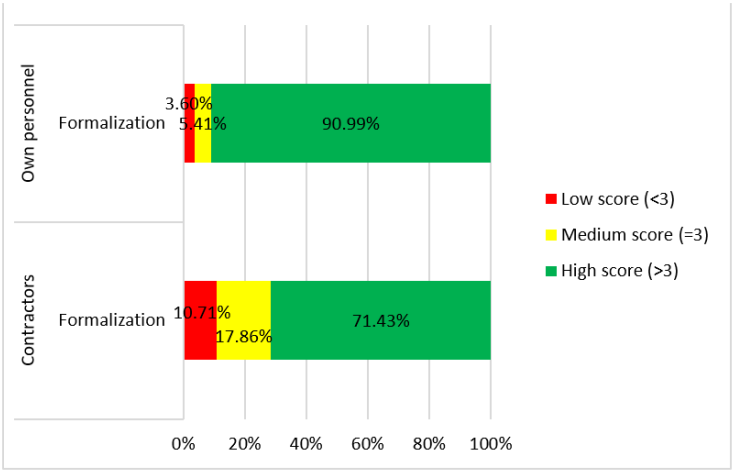

Figure 17. Categorized BARS percentages for formalization, by contractual relationship.

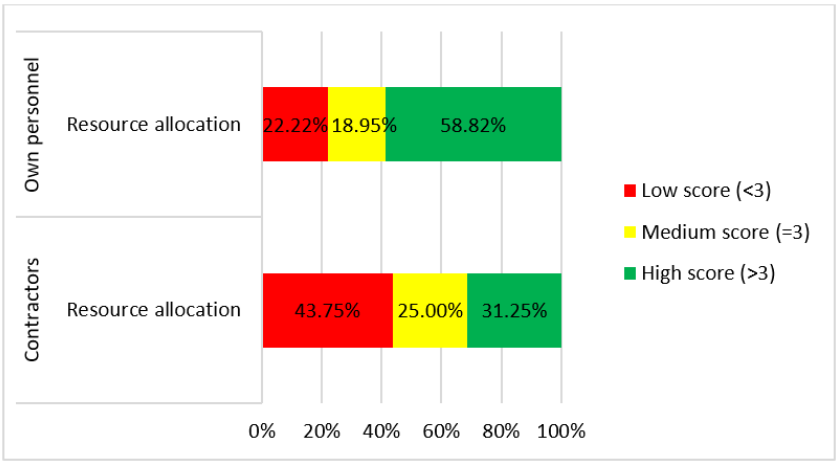

Figure 18. Categorized BARS percentages for resources allocation, by contractual relationship.

4. Discussion

The results of this study contribute to characterizing the safety culture traits of Spanish nuclear power plants (SNPPs) in accordance with some of the main theoretical approaches of the high-risk industry. As abovementioned, it is important to clarify that this study is not focused on contrasting or revising theories from a theoretical point of view, but on describing some safety culture traits within the Spanish nuclear industry. This is therefore a descriptive study that uses secondary data obtained from all nuclear power plants. The measurement instruments used in this study have been in use for 20 years in the Spanish nuclear industry as part of the NOMAC methodology, except for the resilience scale, which was added in the last few evaluations. Continued use of the same methodology has favored an overall analysis of the safety culture of the industry, as well as comparative analyses between different groups and organizations.

Therefore, results are interpreted by taking into account the need for high-risk organizations to (a) prioritize safety (HRO theory); (b) manage unexpected events (resilience engineering), and (c) manage existing organizational dilemmas adequately so as to ensure decision-making does not lead to accidents (conflicting objectives perspective).

Analysis of these results revealed both current uniformity and heterogeneity aspects relating to safety culture in SNPPs [49,69,70]; i.e., the results of this study reflect the existence of a global safety culture pattern that goes beyond the actual organization but which, at the same time, facilitates the identification of differentiating traits potentially linked to subcultures.

4.1. General Safety Culture Traits of SNPPs

To ensure error-free operation, the theory of HRO considers that it is absolutely necessary to prioritize and focus on safety at all organizational levels [31,32]. In this regard, high scores obtained in the safety and planning scales and

in the attention to safety and formalization BARS are relevant aspects of our study. These results reveal four key defining characteristics of safety culture in SNPPs: (a) the perception of safety as an essential condition to successfully operate the plant (safety scale); (b) the assessment of solid organizational preparation and proactiveness to address potential problems (scale of resilience planning); (c) the belief that the organization prioritizes safety against production aspects (BARS attention to safety); and (d) the perception of a high level of activity standardization and documentation (BARS formalization). These four attributes are features of high reliability organizations [26].

Our results also show a certain level of ambivalence concerning the capacity to manage organizational variability while maintaining system stability, in line with the postulates of Weick et al. [35] and Schulman [33]. This characteristic is postulated from the theory of HRO and the engineering of resilience as a requirement for safe and reliable plant operation [37]. In this regard, workers in nuclear power plants perceive stations as organizations using robust preparatory practices to effectively and proactively manage future crises (planning scale). On the contrary, the perception of their strength to manage crisis is not as high (adaptive capacity). Thus, considering the paradigm of resilience and uncertainty management [16,71], SNPPs are satisfactorily perceived as organizations that promote planning activities. Having stated that, the perception of their capacity to adapt to uncertainty and the unexpected is not as satisfactory.

One last critical aspect of the SNPPs safety culture identified in our results is the organizational process relating to the establishment of objectives and resources allocation (BARS resources allocation). This is the study's range scale with the lowest average score and the one showing the highest level of polarization, that is, of opposite opinions confronted. Considering the dilemmatic aspect of this scale, it is worth noting that a considerable percentage of respondents perceive a scarcity of resources (including people, equipment,

time, and budget) and deficiencies in the way the organization establishes and communicates its objectives.

4.2. Specific Safety Culture Traits of SNPPs

The comparative analysis based on the three study variables (company, location, and contractual relationship) shows an interesting paradox: the existence of a uniform safety culture amongst the organizations, but also the coexistence of significant differentiating traits relating to location and contractual relationship.

In general terms, these data suggest that there is strong cultural homogeneity amongst the three nuclear organizations included within this study. In all three, the same resulting pattern is obtained, with high scores for safety (scale and BARS), anticipative capacity (subscale of resilience), level of formalization (BARS), and, to a lesser extent, the processes of resources allocation and establishment of objectives (BARS). However, it is important to point out that within the scope of formalization there are significant differences between two out of the three organizations.

Concerning differentiation, the analysis reveals that the variables ”place of work” and ”contractual relationship” may potentially lead to the creation of subcultures and to conform a safety culture with unique traits. This differentiation is present both in terms of the entire sector and within each of the organization’s part of this study.

As for ”location”, results show that personnel working at the facility score higher than personnel at the headquarters in the hazard scale. This is in fact the most statistically significant difference of the entire study. This finding is coherent with previous studies [72], which show that individual perceptions on hazard levels at the workplace in a nuclear organization seem to be associated to proximity to the technological element. That means workers within the group directly linked to plant operations, i.e., facility personnel, score higher in risk

perception. Differentiated grades are also observed in all BARS. Headquarters personnel have a more favorable vision than facility personnel of the importance given by the organization to safety (BARS attention to safety), quality of standards, and procedures (BARS formalization) and allocation of resources (BARS resources allocation). The difference in this last BARS is quite significant, revealing that headquarters personnel have a much more positive view of resources allocation processes (82% vs. 46%). In short, it can be concluded that the safety culture of facility personnel differs from global safety culture mainly in their risk awareness, and also in a less categorical resolution of the safety–production dilemma (less clearly positioned towards safety), and a more critical vision of the processes for resources allocation and establishment of objectives.

The analysis based on "contractual relationship" shows the level of variability in relation to overall safety culture traits. Contractors score lower than personnel in all measurement instruments used to describe the purpose of this study (the safety culture of SNPPs). On the one hand, contractors are less categorical when it comes to the priority of safety, level of formalization, and adequacy of resources allocation. Their score is also more aligned to safety culture at the facility. On the other hand, there are also significant differences in the perception of both a blame-free environment (SCWE scale) and the organization's capacity to respond to crises (resilience subscale). Contractors point to a lower level of freedom to express concerns and seem to be more concerned about the consequences of dissenting. They also assign a lower score to the organization's capacity to plan, respond to, and recover from crisis.

Considering these results and an increasing number of contractors in nuclear power plants (exceeding the number of own staff), it is necessary to consider the impact these cultural differences may have on the overall safety of Spanish nuclear power plants. Although own staff and contractors both perceive organizational culture norms within the same order of magnitude [52], this study reveals that, on the contrary, such uniformity does not exist when it comes to

other determining safety culture aspects, such as blame-free environment, management of variability, assessment of safety priority, level of formalization, and availability of resources. Uneven labor conditions (in terms of contractual stability, wages, or the nature of the job to carry out) may determine this differentiated perception of SNPPs safety culture by contractor personnel.

4.3. Implications of This Study

This study reveals the usefulness of the three theoretical approaches to understand the practical reality of the industry. The aim is, in terms of the Turner and Pidgeon analogy [6], to reduce ”blind spots” affecting the safety of Spanish nuclear power plants during their end-of-cycle stage, within prospects of gradual shutdown over the next few years. The diversity of these theories provides, as if they were watchtowers, a comprehensive, wide, and detailed view of the status of safety culture within the industry. The idea is to apply a pragmatic approach that integrates concepts not necessarily aligned but certainly complementary—a kind of theoretical crossbreeding that makes it possible to understand a concept as polyhedral and complex as organizational culture. The ”real” safety of high reliability organizations is more robust if theoretical diversity is added as an interpretative framework for its ”reading”, rather than with a monolithic view from a single theoretical prism. In this regard, this study shows some valuable safety-related contributions provided by other, less known theoretical approaches, such as the conflicting objectives perspective (COP). Measuring how organizations solve organizational dilemmas provides insights that complement knowledge about the value they place on risk and safety (HRO) and how they manage uncertainty (RE). In short, the analysis of results under the interpretative framework of the three theoretical approaches of reference in our study favors practical reflections on safety culture at SNPPs.

According to the theory of HRO, organizational culture should be focused on safety and to prevent catastrophic failures, and to promote a constructive

work environment that tolerates discrepancies [27,30]. Based on the results of our study, one could wonder to what extent the existence of workers who perceive that safety is not always the priority could be considered as a warning. Perhaps one could also consider that the resolution of the safety–production dilemma is sensitive towards safety once the local context or executing activity (facility, contractor) is the actual focus. Similarly, it is necessary to wonder about the impact of differentiated perceptions when it comes to the possibility to dissent without fear of retaliation (contractors).

The theory of resilience includes the stages before, during, and after disruptions [73]. Nuclear power plants are complex organizations that operate under variable conditions and comprise highly interdependent parts. Thus, their adaptive capacity is paramount to prevent disastrous consequences [43]. In fact, the essence of organizational resilience is the capacity to recover the system's dynamic stability following critical disturbances [74]. Considering this approach, results show that SNPPs are perceived as solid organizations in their development of anticipative activities, but less solid and robust in their coping capacity. Accordingly, it is necessary to consider the impact of this differentiated perception as a question to be addressed in order to make SNPPs more resilient.

Lastly, within the COP framework [44] it is necessary to ask if SNPPs take into consideration the importance of correctly managing conflicting objectives. In other words, to which extent is the resolution of the dichotomy "precise objectives and sufficient resources" versus "vague objectives and resource shortage" coherent with the emphasis on safety? Similarly, from a perspective that is both dynamic and changing over time, to what extent could safety and quality be gradually displaced in favor of an increased sensitivity towards economic costs and time pressures? In this respect, it is necessary that top management address objectives that are partially conflicting, making unacceptable risk-related limits both visible and known, as proposed by Rasmussen [44] (p. 189).

4.4. Limitations

The use of secondary data allowed us to adopt a descriptive approach to safety culture, without being able to analyze theoretical questions in depth. In this sense, aspects such as the lack of demographic information on organizational seniority or professional groups, which could be potential moderating factors of the organizational culture, are a limitation for the current study.

Lastly, having a qualitative approach in the data collection strategy probably would have provided additional insights to deepen the understanding of some group differences and results observed.

5. Conclusions

There have always been multiple definitions and developments of safety culture [17]. Scientific literature conceives safety culture as a diverse, multidimensional construct of organizational culture [21], which is created in organizations that prioritize beliefs, values, and attitudes relating to safety [1,9]). This multidimensional characteristic of safety makes it possible to study culture from different theoretical approaches in which concepts may overlap or complement each other [47].

Based on this concept, our study's reference framework is based on core items of the theories HRO [27,30], RE [37,43,72], and COP [44], with the aim to describe the main traits of safety culture in Spanish nuclear power plants. To do that, quantitative secondary data obtained from surveys and behavioral anchored rating scales in all Spanish nuclear power plants was taken as an object of analysis. Both the industry as a whole and the specificities of each possible subculture were considered by the statistical analysis [75].

Results show the following defining characteristics of safety culture: (a) high perception of the importance of safety, (b) clear resolution of the safety–production dilemma, (c) positive vision of the organization's capacity to prepare for crisis scenarios, and (d) high level of process and activity formalization. On

the other hand, results show the existence of a critical, polarized vision amongst the workforce concerning the organization's distribution of personnel, equipment, time, and budget. In short, there is an organizational culture in which a shared view of the importance of safety, anticipative capacity, and level of formalization coexists with a more critical, fragmented perception of resources allocation and target establishment processes.

Regarding possible subcultures, the study reveals an interesting paradox, the existence of a uniform culture within Spanish nuclear power plants that coexists with differences linked to work location and contractual relationship. Facility personnel have higher risk awareness, as well as a more critical vision of the resolution of the safety–production dilemma and of processes for resources allocation and establishment of objectives. As for contractors, the analysis shows this group is clearly different from own staff in all study scales, with considerable differences in blame-free environment and the organization's adaptive capacity in case of crisis.

Future research should further analyze how safe plant performance is impacted by a fragmented perception of the resolution given to the resource availability dilemma (sufficient vs. insufficient) or clearly differentiated perceptions between own staff and contractors.

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Institutional Review Board Statement: This study is based on secondary data from independent safety culture assessments. The confidentiality and anonymity of the participants was guaranteed at all times.

Informed Consent Statement: All subjects involved in the study participated in the organizational culture and safety surveys on a voluntary basis.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to confidentiality restrictions.

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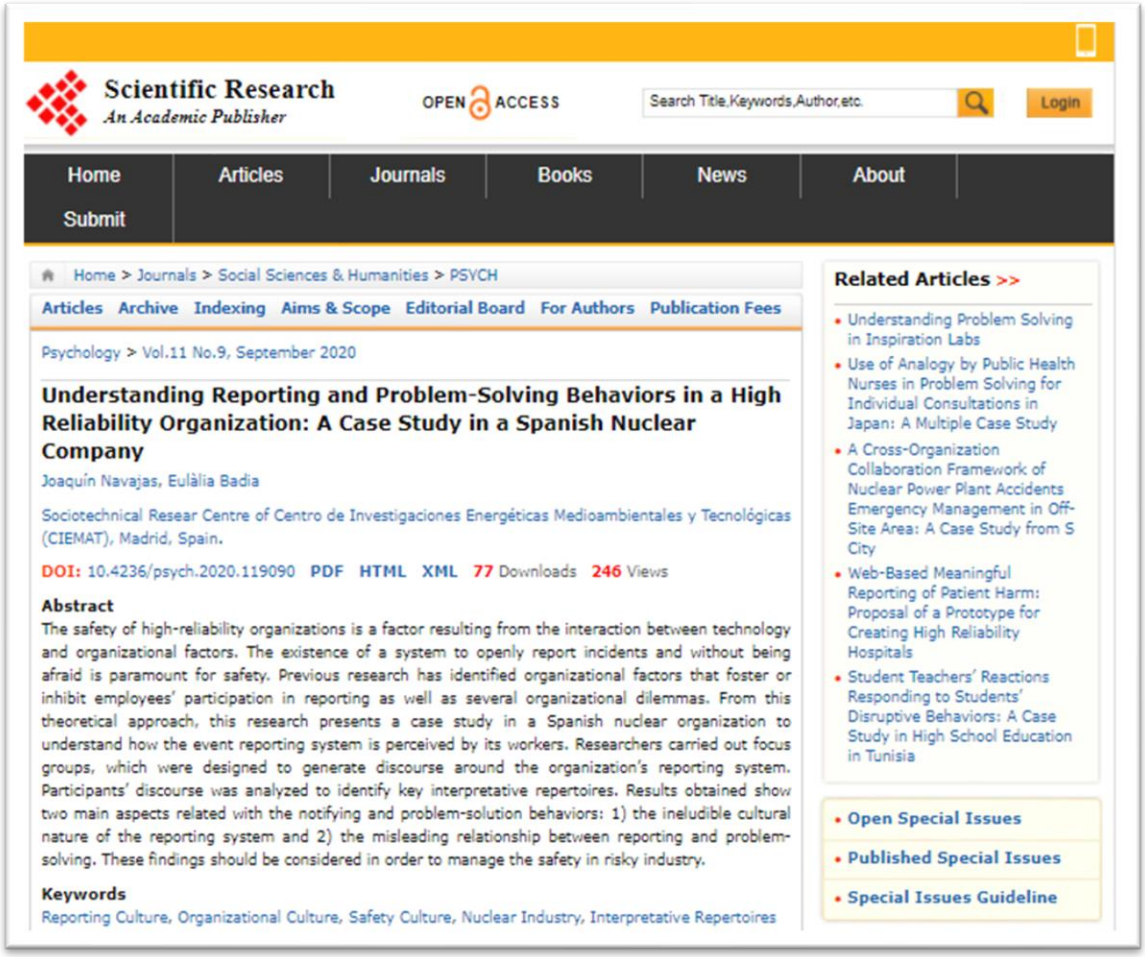
4.3. Study 3. Understanding Reporting and Problem-Solving Behaviors in a High Reliability Organization: A Case Study in a Spanish Nuclear Company



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Understanding Reporting and Problem-Solving Behaviors in a High Reliability Organization: A Case Study in a Spanish Nuclear Company

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Abstract

The safety of high-reliability organizations is a factor resulting from the interaction between technology and organizational factors. The existence of a system to openly report incidents and without being afraid is paramount for safety. Previous research has identified organizational factors that foster or inhibit employees' participation in reporting as well as several organizational dilemmas. From this theoretical approach, this research presents a case study in a Spanish nuclear organization to understand how the event reporting system is perceived by its workers. Researchers carried out focus groups, which were designed to generate discourse around the organization's reporting system. Participants' discourse was analyzed to identify key interpretative repertoires. Results obtained show two main aspects related with the notifying and problem-solution behaviors: 1) the ineludible cultural nature of the reporting system and 2) the misleading relationship between reporting and problem-solving. These findings should be considered in order to manage the safety in risky industry.

Keywords

Reporting Culture, Organizational Culture, Safety Culture, Nuclear Industry, Interpretative Repertoires

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Understanding reporting and problem-solving behaviors in a high reliability organization. A case study in a Spanish nuclear company

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Keywords: Reporting culture, organizational culture; safety culture; nuclear industry; interpretative repertoires

1. Introduction

This paper aims to understand how the event reporting system is perceived in a Spanish nuclear industry organization and intends to enhance knowledge on factors related to reporting system perception and problem resolution approaches. The purpose is to identify factors determining participation in the organization's reporting system. To do that, the 'interpretative repertoires' (Potter & Wetherell, 1987) of focus group participants regarding the performance of their organizational reporting system were analyzed from a qualitative approach.

Prior to sharing study results, the significance of reporting systems in high reliability organizations and their inherent relationship to safety is discussed. The approach taken by the nuclear industry and on recent scientific literature data, will be assessed in detail. The common ground of all approaches is the assumption that having a participative reporting system opened to all employees contributes to increased organizational safety.

1.1. Reporting system in high reliability organizations

The safety of high reliability organizations (hereinafter, HRO), such as nuclear power plants, chemical processing facilities, or health systems, is conceived as a factor resulting from the interaction of technology and organizational components, especially considering technical and human subsystems are tightly interrelated (Perrow, 1984; Rasmussen, 1997).

From a sociotechnical approach, the analysis of risk and safety prevents simplistic assumptions based on a merely technological concept of safety (Hopkins, 2006; Le Coze, 2008; Le Coze, 2019). Thus, organizational culture became a relevant factor to better understand safety in high reliability organizations (Vaughan, 1996). Therefore, aspects related to the promotion of employee commitment or their participation in safety programs, become important.

From this point of view, the existence of a system to report incidents is paramount for safety. The safest organizations have implemented efficient strategies to report, identify and manage the consequences of error (Reason, 1997; K. Weick & Sutcliffe, 2007). It is highly recommended to establish an open reporting system for near misses and accidents without fear of punishment (Health and Safety Executive, 2013). From an error management approach, it is considered that "Errors are ubiquitous. Errors cannot be completely prevented" (Frese & Keith, 2015:7). Thus, it is necessary to have systems allowing all organization members to communicate safety concerns.

According to (Reason, 1997; Reason, 1990) the reporting culture is a key aspect determining the safety of complex systems. Reason considers that the reporting culture should involve "voluntary" employee participation in safety information systems. It is important to emphasize the idea of participative willfulness, which is directly linked to how the organization manages guilt and penalizes error. It is worth mentioning that according to Reason "a no-blame culture is neither feasible nor desirable" (Reason, 1997:195). Instead, establishing an environment of trust compatible with clear accountability, marking a clear line between acceptable and unacceptable behavior is really important (Reason, 1997).

1.2. Reporting systems within the nuclear industry

Within the scope of the nuclear industry (IAEA, 2002a) , the following problem reporting aspects are considered: a) employees should have an attitude driving them to participate actively in incident reporting; b) the lack of reporting would be a sign of weak safety culture and; c) fostering the participation of employees entails ensuring those who report are not penalized by the organization.

With regards to active participation by all employees, a favorable attitude is shown by workforce's usage of "mechanisms for reporting on safety

shortcomings and suggesting improvements“ (IAEA, 1991:28). To do that, the organization should foster an organizational culture favoring problem identification and resolution through participation of all employees.

Lack of reporting or personnel participation is, according to the International Atomic Energy Agency (IAEA), a symptom of “weak” safety culture. It would also reveal a lack of organizational awareness on the valuable knowledge that can be obtained from problematic events (IAEA, 2002a). To strengthen safety culture, it would be necessary to develop a reporting culture in which “all employees need to be encouraged to report even minor concerns” (IAEA 2002a:8).

Reporting failures and near-misses provide lessons that could prevent more severe events. In that sense, ensuring individuals are not afraid of reporting problems is quite important. The organizational culture should ensure that problem reporting is not retaliated. In other words, “(the employees) must believe that these reports are valued and that they and their colleagues will not be penalized or disciplined as a result of coming forward to make them.” (IAEA, 2002:8).

Similarly, the Nuclear Regulatory Commission (NRC, 2004) links problem identification to an organizational culture in which employees do not fear retaliation in case they err. This idea is explicitly defined in the concept of Safety Conscious Work Environment (hereinafter, SCWE). SCWE is defined as an environment in which employees feel free to raise safety concerns, both to the management and to the NRC without fear of retaliation. The SCWE is a specific safety culture attribute that allows individuals to look for deficiencies and to ensure concerns are addressed. It is essential for the organization to ensure retaliation is not tolerated. In that sense, “an adverse action is deemed retaliatory if it is taken, in whole or in part, because the individual was engaged in a protected activity” (NRC, 2004:5).

According to the Institute of Nuclear Power Operations (INPO), a SCWE is a healthy safety culture "component" that should include the implementation of a corrective action program accessible to all employees. The need for a culture allowing people to report openly and without being afraid is highlighted, so that "individuals feel free to raise nuclear safety concerns without fear of retribution, with confidence that their concerns will be addressed"(INPO, 2013:27).

1.3. Reporting culture determinants

Recent research on reporting culture and their determinants, cover a large variety of high reliability industries, including the nuclear, petrochemical and health sectors. An important number of studies focus on quantifying the relationship between problem reporting and operational performance, the latter measured by quantitative and safety indicators (Hutchinson et al., 2009; Morrow et al., 2014). Generally speaking, there seems to be a clear consensus that the level of reporting is a key indicator of "health" in a high reliability organization (K. Weick & Sutcliffe, 2007). Similarly, a lack of reporting would anticipate future operational problems. In this regard, a study reviewing twelve significant events into depth shows that organizational unreported precursors existed for many of such events (R. Taylor et al., 2017). The extent to which these reporting systems are used seems to indicate the level of organizational attention to safety. According to Hutchinson et al., (2009) there is a clear correlation between reporting culture and safety indicators within the hospital environment. Simons et al., (2015) consider that the reporting culture not only should be measured positively according to the global number of entries, because the implementation of many improvement programs could lead to decreased reporting even if safety culture improved.

Many studies identify leadership as a determining factor when it comes to organizational reporting. Visible commitment by management and leaders seems to be necessary conditions to ensuring employees make use of notifying

systems. A leadership style based on management commitment and on a culture not penalizing error, has a clear influence on work processes (Hsu et al., 2010). Managers who in addition to their managerial skills, are perceived as approachable, seem to determine the frequency of reporting (Oltedal & McArthur, 2011). Similarly, error feedback perception seems to be an organizational factor which significantly predicts the level of reporting (Richter et al., 2014). This feedback should be dynamic and understandable (J. Reason, 1997). A study with senior managers shows that safety culture refers mainly to the terms 'just culture' and 'reporting culture'(Fruhen et al., 2014).

Other studies also concluded that there are many hampering factors inhibiting reporting, aspects such as "extra work, skepticism, perhaps a natural desire to forget that the incident happened, (..) lack of trust and, the fear of reprisals" (Reason, 1997:196) are highlighted. Within the healthcare context, Gifford & Anderson (2010) consider that the lack of support from leaders and insufficient clarity of report results are some organizational barriers that hamper reporting.. A critical element is how employees perceive report undesirability by managers, which would entail "apparent concerns from staff that their reports would not be part of a just response, that bad news would not be welcome at more senior levels" (Taylor et al., 2017:9). Håvold (2005) breaks down the reporting culture in aspects relating to the will to report (near misses or accidents) and the belief that reporting is important to safety.

Leadership perceived as unwillingness to accept responsibility or employees that are blamed, are two aspects with a negative impact (Behari, 2019; Halperin & Bronshtein, 2019). The perception that reports will be censored before they reach system managers appears as a potential inhibiting barrier(Oswald et al., 2018).

According to (Gifford & Anderson, 2010), the main individual factors that would hamper reporting are temporary pressure, lack of feedback and individual fear of retaliation as a result of reporting. (Nordlöf et al., 2015) point out that the

main causes for omission are the time needed to write and describe an event and the shame of admitting an error or reckless act.

Accepting the importance of reporting problems does not necessarily imply that employees actually report (Mjadu & Jarvis, 2018) Yang et al., 2020). A comparative study of sea transport organizations in Norway and Greece revealed that labor conditions and safety culture are the two main predictors of non-reporting within the industry(Nævestad et al., 2018).

A discretionary or volunteer aspect of reporting seems to be an underlying, relevant element that supports such reporting. In a qualitative study by Lekka & Sugden (2011) which combined in-depth interviews with focus groups, it became evident that even if the reporting system was consistently used to report safety incidents, it was not always used for "minor" events. When it came to minor issues, personnel granted themselves the power to decide if reporting was necessary or not, so "staff would exercise their own judgment on whether such incidents should be reported" (Lekka & Sugden, 2011:448).

Some studies mention the difficulty of the actual act of reporting, that is, the challenge of writing down organizational aspects, some of which are complex. In this sense, Anderson et al., (2013) refer to the difficulty of laying out organizationally complex processes onto the report. The approach to problem resolution is also perceived as antagonist to the act of reporting (Sandberg & Albrechtsen, 2018).

1.4. Reporting and organizational dilemmas

The reporting process has a socially-built dimension that closely ties reporting to its social context (van der Westhuizen & Stanz, 2017). From this angle, it is important to consider the concept of 'organizational dilemma' as a useful term to determine the meaning of reporting within organizations.

Organizational dilemmas are a dichotomy by which selecting an alternative seems to imply neglecting another. According to (Steiner, 1998), there is an

organizational dilemma in situations when people are confronted with the need to make a decision (and to act) without having an alternative that seems clearly better than the rest. This type of situations tends to lead to organizational inefficiency when individuals are forced to act or, on the contrary, not to act when the action is needed. Furthermore, organizational dilemmas require some type of organizational learning (Steiner, 1998).

Some crucial dilemmas that may occur in organizations are 1) the dilemma of productivity (Abernathy, 1979) which considers that "short-term efficiency and long-term adaptability are inherently incompatible" (Adler et al., 2009:99) or 2) the innovator's dilemma(Christensen, 1997) which states that organizations tend to avoid radical innovations in order to satisfy its existing clientele. Multiple studies advocate the existence of different dilemmas within organizations from a variety of methodological and qualitative perspectives. In this way, Jonsson & Zakrisson (2005) highlight the dilemmas that face leaders of non-governmental organizations.

Studies on reporting show there are a number of dilemmas associated to the problem reporting act. According to Hor et al. (2010), the justification for the act of informing will depend on the meaning given to the act of reporting within a particular local context. After an ethnographic research, they pointed out that the reporting system and incident management system are highly linked to the local perception of accountability. Henriqson et al., (2014) refer to the "fear of vilification, social reprimand and work conflicts" as an organizational dilemma when it is understood that reporting is necessary (in the name of organization safety) but, on the other hand, it might be conflicting if it affects other colleagues.

1.5. Subject of Study

This research takes on a discursive, qualitative perspective to the study of organizations (Weick et al., 2005). From this standpoint, the aim of the study is to understand the nuclear sector workers' perception about reporting system and

its link to problem-solving. To do that, the "interpretative repertoires" (Potter & Wetherell, 1987) generated by focus group participants were qualitatively analyzed in order to understand the reasons why participants use (or did not use) the reporting system. And also to identify which factors, according to the organization's workers, would contribute to enhancing reporting system performance.

2. Methodology

2.1. Case study organization and context

This research initiative is developed within the framework of the Consortium Agreement CIEMAT – IAEA (2016-19), Coordinated research Project on Organizational Cultural Basis for Successful Performance in NPPs IAEA-I22004 which is focused on analyzing reporting culture foundations in nuclear organizations.

The research is a case study of a Spanish nuclear industry. The organization, a public utility, of with 345 members, authorized this case study. Part of their staff is based at the headquarters and the other is distributed between two nuclear sites. To ensure the organization remains anonymous, in this paper it is referred to as NPC (Nuclear Public Company).

To provide context of the study, this organization underwent a safety culture self-assessment in 2017, with a special focus on strengthening its Reporting and Improvement System (hereinafter RIS), which had been designed and implemented by the quality department without full acceptance or usage by the workforce. The organization allowed researchers to carry out 6 focus groups (2 per site) as part of the Coordinated Research Project (CIEMAT – IAEA), with the aim of collecting accurate information on their reporting system.

2.2. Method and sample

The qualitative measurement method used for this study was focus group. Groups were designed and led by the authors of this study for the purpose of learning more about RIS perception by organization employees. Two thematic areas guided focus group moderation:

a) Assessment of reporting system usage by the organization (both individually and organizationally).
b) Changes needed for RIS improvement as a problem-solving tool.

A total of 8 people participated in each group, all with a similar hierarchical position.

The employee sample was comprised of 48 workers selected by the organization.

Study sample selection considered Mintzberg's components (Mintzberg, 1979) different sites and the alignment of job categories. As a result, focus groups were formed as follows:

- Headquarters: 2 focus group with 4 individuals from the Technostructure and 4 individuals from Support.
- Nuclear facilities: 4 focus groups comprised of 4 individuals from Operational Core, 2 from Technostructure and 2 from Support.

Participants in every focus group had a similar job category (level C and level D employees) to ensure no hierarchical differences between them. Although the sample included all functional units, it excluded the participation of managers, executive positions, and contractor personnel.

All group participants were asked for permission to record, transcribe and analyze the sessions. The anonymity and confidentiality of participants was ensured.

2.3. Qualitative analysis

This study takes the analytical perspective of the Grounded Theory (Glaser & Strauss, 1967), as well as a social constructionist concept by which language is considered a reality-building social practice (Garay et al., 2005). It is important to mention that the Grounded Theory pays special attention to the socially-built nature of reality (Edwards & Potter, 2017; Gergen, 1985), with the aim of producing interpretations of study subjects (Annells, 1996; Glaser & Strauss, 1967).

Within the scope of this paper, discourses were analyzed so as to identify key interpretive repertoires (Potter, J. & Wetherell, 1987). The social reality was approached inductively, meaning textual data immersion favored the understanding of cultural and social order aspects (Íñiguez, 2006). The qualitative analysis of interpretative repertoires provides recurrent patterns of specific, accurate meaning formulations around the NPC reporting system, showing how employees "build" the RIS within their daily activities.

The analysis process followed the guidelines mentioned by (Taylor & Bogdan, 2000), referred to as "analysis in progress": data discovery, coding and relativization. It is important to know that both paper researchers participated in the coding phase, first assigning a code individually and then negotiating such code with the aim to establish end categories. Final interpretation of analysis-collected findings was also negotiated. It software MAXQDA (version 12) was used as a support tool to assign the codes (Rädiker & Kuckartz, 2020).

3. Results

The results of the analysis give information about the two areas used to design the participative process (Assessment of RIS and proposed changes).

3.1. Perception of the reporting system

The qualitative analysis reveals that there are three aspects determining employees' perception of the reporting system.

a) Unawareness of the system and its processes

Most participants acknowledge they have never used the RIS. The reason why individuals do not use this application is supported by two main ideas:

- Lack of accurate information on the application and its use by the organization (what are incidences? what are corrective actions? which is the process followed after reporting?).

- As an IT application, RIS has inherent technological limitations, mainly that is a "cold system", "difficult to use" and "not fostering participation"). It also reveals the need for personnel to have a computer in their workstation, which is not always the case.

Participants repeatedly refer to the lack of knowledge to justify insufficient usage by the organization. The analysis shows there are differences between the sites. For example, whereas personnel at the headquarters referred to a generic lack of project implementation, station workers talked about aspects relating to management hierarchy. The main findings that justify the lack of use are shown in table 1.

Table 1. Summary of main arguments used to explain the scarse organizational use of RIS.

Unawareness of the system and its processes	
Argumentative Ideas	**Fragments**
Lack of information	*"I have little information on the tool"* *"This thing is a bit confusing (….) because I did not attend the course"*
IT application	*"I have never used it. I have no computer and they won't let me have one"* *"An IT system (…) does not encourage people to report the incidences"*
Lack of project implementation (Headquarters)	*"P1: Nothing has been implemented / P2: Yes, it is not sufficiently implemented"*
Influence of mid-level managers (Facility 1)	*"Sometimes you would like to enter something on RIS but it does not suit your boss' agenda"*
Lack of authorization to record incidences (Facility 2)	*"There is a filter: Not everyone can enter an RIS action"*

b) RIS and problem resolution

Three argumentative ideas structure the perception of RIS as a problem-resolution tool:

Cons:

- Tool not adding much benefit: There is consensus on the fact that the RIS does not contribute to solving problems, thus there is a questioning about its problem-solving capability. This is justified by the nature of recorded incidences ("Some incidences entered do not improve anything") and the IT nature of the reporting system ("Entering something on a PC and not following up actions properly...does not provide the benefits it should")
- There are other organizational reporting mechanisms: Personnel mention other problem-resolution mechanisms considered better than RIS, which is not seen as the natural option to solve organizational

issues. The formality of this application is perceived negatively compared to other informal options (face-to-face communication).

> "It is best to talk amongst us, to discuss the issue, to approach your boss directly and not to lose our shared dialog and understanding. RIS should be the very last option"

Pros:

- Problem institutionalization: The formality of this application is considered by some participants as a strength. In other words, they value positively that the system institutionalizes problems not solved using ordinary means.

> "Formalizing certain aspects (…) to make them public and take a more formal approach, ensuring everyone knows the path to follow, making the acceptance and scheduling of your improvement proposal public, and forcing other stakeholders to respond somehow"

There are also different visions depending on the location. At the headquarters, it is linked to problem resolution but only when the issue is considered solvable ("I only enter it when something happened and I already have the solution"; "We know some things cannot be solved, so we do not enter them on RIS"). On the contrary, station personnel think solutions are not linked to the reporting system ("The RIS is talking the talk rather than walking the walk"; "It is a show to let others know how good we are, not to solve issues").

Main argumentative ideas relating to the RIS and its problem-resolution capabilities are shown in table 2.

Table 2. RIS and its problem-resolution.

RIS and problem resolution	
Argumentative Ideas	**Fragments**
It adds no benefit	*"It is not effective"* *"It is not an operational tool* *"It's more theoretical than practical"*
RIS vs. other organizational mechanisms	*"Most problems can be solved without entering them onto RIS"* *"RIS is used when the issue could not be solved"*
Problem institutionalization	*"It formalizes certain aspects from our perspective (…)"* *"RIS can be linked to a corrective action (…) and that is the appeal of this application"*

c) RIS inhibitors

The analysis shows five types of arguments justifying the system's limiting nature.

- No criterion: Consensus amongst all groups on the lack of a clear criterion determining what incidences or problems should be reported.

  Person 1: "The feeling that non-important things are registered and that important things are not" / Person 2: "That's not a feeling. There is actually no criterion, meaning you enter an action in good faith because you think it is relevant enough, but there is no criterion"

- No relevance: Many participants say the irrelevance of incidences reported on a daily basis justifies why people do not report.

  "It is either too much work or something so specific that it cannot benefit the entire organization"

  It is considered irrelevant to report non-important aspects.

  "If you enter it, you are making it more important than it actually is"

- Repercussions of reporting: It is said that reporting could lead to having personal issues with coworkers or managers. As a participant put it: "Reporting creates problems for you". This type of argument is common across different focus groups.

  "They tell you: why did you enter that? and this? If you report: Water is cold, then Mr. X comes and says: Listen, why did you enter that? Are you aware of the mess you have caused?"

  "People feel it is going to lead to problems, so you prefer to take shortcuts"

  "It is used as a weapon, as something coercive: "I am going to enter an RIS action so you do this!"

- Work Overload: Some plant participants say that in addition to leading to personal drawbacks, it may actually increase the workload.

  "This sometimes turns into more work, into an overload"

  "It leads to a work turmoil which eventually causes obstacles and hampers daily activities"

- Auditable by the Regulator: Groups at the headquarters say that the fact this tool can be audited by the Regulator, is an obstacle. This characteristic seems to limit the type of registered issues.

  "We know the RIS is looked at by external parties. When a Regulator inspection comes, they say: Show me the RIS, and if there are 8 or 9 actions… the Regulator loves to see open actions. I love for them to see those actions because they are not mine, but I need to be empathetic because I don't want them to see 6 actions assigned to someone"

Main argumentative ideas relating to the RIS inhibitors are shown in table 3.

Table 3. RIS inhibitors.

RIS inhibitors	
Argumentative Ideas	**Fragments**
No criterion	*"It is not a tool that clearly defines what is an incidence, a problem or the means to solve them"*
No relevance	*"Sometimes silly things get entered onto RIS, a tool that should only be used for serious stuff"*
Repercussions of reporting	*"It seems to create more problems than it solves"* *"People feel it is going to lead to problems, so they prefer to take shortcuts"*

3.2. Improvements for a more efficient system

The analysis shows that employees perceive the need to improve technical and organizational RIS elements before it can become an optimal reporting system.

a) Technical conditions

Three types of arguments relating to technical tool aspects are mentioned.

- Clarifying the purpose: All groups agree on the need to clearly and accurately define the purpose of the RIS, its benefit and the type of events to be reported:

  "I think it is important to explain what it should be used for (…), not only entering issues and incidences but also solutions"

- Clarifying the link between this tool and safety.

  "It should be more focused on work safety, on overall site improvement"

"RIS should not be an instrument by which you accuse yourself of administrative non-compliance, but rather a development element ensuring safe project implementation, with a more preventive approach, instead of a tool to admit guilt"

Table 4. RIS technical conditions

RIS technical conditions	
Argumentative Ideas	**Fragments**
Clarifying the purpose	"*It is important to explain what it should be used for*"
	"*The RIS should not be used for everything. It is something specific for nuclear aspects*"
Usage procedure and criteria	"*There should be a document containing the criteria*"
	"*RIS? From now on, use it for everything!" And I said "but we have a work order here*"

- Usage procedure and criteria: The need to have a usage procedure is mentioned ("there should be a work procedure for it, which is not the case, so that we know exactly what should be entered"), as well as the need to have specific training on RIS usage.

  It seems evident, especially at the stations, that it is necessary to clarify RIS usage in relation to daily-used processes (such as work orders).

  "Sometimes we enter RIS actions when it should actually be a work order"

Main argumentative ideas relating to the RIS technical conditions are shown in table 4.

b) Organizational conditions

Three types of arguments relating to organizational aspects were mentioned as conditions to make the RIS tool more efficient:

- Senior management commitment: RIS success is linked to visible management commitment to the tool. It is also considered necessary

to engage all organizational areas so that it is not considered only a tool used by the quality department:

"Management is the secret of success"

"If each one of our managers called us at the end of the month and said: some amber traffic lights should be red or green, then we would be more awareness"

- Acceptance by mid-level managers: Similarly, RIS acceptance and commitment by mid-level managers is considered paramount to ensuring tool enhancement.

"I think the best option would be that once you talk to your boss, he or she would right away enter the issue onto the computer. That would be the best option"

- Blame-free environment: To ensure RIS success, it is considered paramount to have an organizational culture which does not penalize reporting, which does not seek to blame and which facilitates fear-free usage of this tool.

"Having the freedom to do it without thinking you might make enemies"

"More effective and not focused on looking for someone to blame"

Main argumentative ideas relating to the RIS organizational conditions are shown in table 5.

Table 5. RIS organizational conditions.

RIS organizational conditions	
Argumentative Ideas	**Fragments**
Engagement of management and the rest of the organization [Headquarters]	*"Management is the secret of success"* *"If this is a tool for improvement, it should be available for everyone"*
RIS and the line of command [Facility 2]	*"If you ask your bosses, whatever they respond may condition you"* *"Managers have no interest"*
RIS and a blame-free environment	*"Having the freedom to do it without thinking you might make enemies"* *"It should be more effective and not focused on looking for someone to blame"*

4. Discussion

The commitment and participation in reporting systems of employees' at all organizational levels are key elements for the safety of HROs (Reason, 1997). From this perspective, the aim of this study is to understand which main factors contribute to the perception and usage of reporting systems by workers in a Spanish nuclear industry organization. Some organizational logics behind reporting processes are revealed when the reasons that drive personnel to report (or not to report, as it happens in the organization of study) are adequately understood.

Results obtained in this study show two key aspects that need further discussion: a) the ineludible cultural nature of the reporting system and b) the misleading relationship between reporting and problem-solving.

a) The ineludible cultural nature of the reporting system.

Safety culture is one of the safety pillars of HROs. Reference agencies within the nuclear industry inevitably link the existence of a strong, healthy safety culture to a solid reporting system (INPO, 2013; NRC, 2004). Participation in reporting systems by all organization employees becomes paramount ((IAEA, 2002a). Scientific literature has identified organizational factors fostering or hampering the level of participation by employees. Numerous studies agree on the fact that leadership, of both executives and managers, is the crucial element determining the system's operational performance success (Reason, 1997). In turn, leadership influences the existence of a 'blame-free' organizational culture that promotes reporting (Behari, 2019; R. Taylor et al., 2017).

In the case of NPC, the reporting system is, a priori, open to all organizational levels. The quality department has designed a system according to common nuclear industry standards and requirements. Despite its design, incidence reporting on the system is limited and far from meeting the expectations of

organizational managers. Is it because the tool is poorly designed? Is it because of inherent IT tool difficulties? This study coincides with others focusing on the relevance of cultural aspects associated to reporting (van der Westhuizen & Stanz, 2017).

Firstly, the need to clarify the act of reporting becomes clear. Results show the need to accurately determine what should be reported. Individuals doubt on "what to report", "what is an incidence" or where RIS stands in relation to other mechanisms. It is worth mentioning that the definition of what should be reported is determined by the organization, applying criteria which does not depend on employees.

Secondly, the analysis shows that the act of reporting does not occur in an aseptic environment, but within a specific organizational context that eventually determines if reporting will take place or not. As shown by the analysis of groups, reporting in NPC takes place when the potential consequences of such reporting have been forecast. That means certain elements such as work overload, possible negative repercussions or how reporting may affect managers, seem to largely determine incidence reporting within the organization. Furthermore, it is revealed that reporting is conditioned by the fact that reported incidences are visible to the regulator.

The case study of NPC also shows that the organizational culture should be considered to understand the reporting behavior. Reporting is the result of the organizational value given by employees to the act of reporting. In other words, efficient system performance does not depend so much on the user-friendliness of the software or forms to complete, but rather on a set of organizational culture logics which determine the perception of what is suitable or not. The analysis of interpretative repertoires of employees reveals that the reporting system is not an objective procedure or aseptic instrument allowing workers to communicate incidences to higher hierarchical levels. Reporting is part of a blueprint of organizational meanings forming the organizational culture.

Eventually, the analysis of organizational reporting programs is inevitably linked to the organizational culture to ensure a more effective operational performance. Thus, understanding the organizational culture helps to understand the very act of reporting (and vice versa).

b) The misleading relationship between reporting and problem-solving.

The reporting behavior is a key aspect determining the safety of complex systems (Reason, 1997). Behaving indifferently to deficiencies is a sign that a weak safety culture exists (Weick & Sutcliffe, 2007)

With regards to this case study, the high level of RIS dissociation from problem-solving processes, points to the artificiality and lack of operational life of the reporting system. The assessment of RIS as in-house marketing or a mere image proves that in certain operational levels within the organization, the system has no strong practical link to safety. In the face of problems, employees tend to talk amongst themselves or to go directly to a member of management. Based on this study it is possible to extrapolate that a reporting system on its own does not contribute positively to safety. To put it more bluntly, the mere organizational existence of reporting channels does not seem to provide sufficient guarantee that they will be used to solve operational problems and, in turn, to improve safety.

It is paradoxical that many NPC employees point to a fake use of the system to report problems for which the solution is known, and also to failure to use the system to address relevant issues for which there is no known solution. How can that deceptive balance be broken? How to boost a practical use of reporting systems? Study results suggest that strengthening the formal nature of the reporting system could be useful. In that regard, analysis results show that the notarized nature and capacity to institutionalize problems of this instrument are considered a strength.

On the other hand, results also reveal the existence of an underlying organizational dilemma (Steiner, 1998) in RIS usage. Such dilemma can be generically described as follows: "Global problems" vs. "Specific or silly problems". In a practical sense, the dilemma confronts ideal, desirable reporting based on "relevant" problems, against non-desirable, empty reporting of superfluous things. In terms of linguistic pragmatism (Levinson, 1989), the dilemma would be used to justify non-use of RIS to deal with daily, frequent issues. This characteristic of labor problems as minor or non-relevant, would justify the exclusion of formal reporting. Practical resolution of this dilemma at NPC implies justifying that it is not necessary to register minor incidences (categorized as "nonsense") so that the generation of false problems can be prevented.

In short, this study shows that even when people report on the system, the organizational value of such reporting should not be considered natural, nor linked to safety or to the identification of the most pressing problems faced by the organization. In fact, this case study reveals the paradox that it is possible to avoid registering complex problems (by simply reporting easily solvable issues), while justifying the need to report "relevant" problems in order to avoid the communication of daily incidences.

5. Practical implications

The results of this study have practical implications on the safety of high reliability organizations. On the one hand, they reveal that the act of reporting depends on a set of normative values. Thus, an increase in reporting levels would inevitably lead to questioning organizational culture aspects related to beliefs and values. On the other hand, it is also necessary to consider that the mere act of communicating events on the reporting system does not ensure the registration of essential organizational issues with the aim to address them. Care should be taken so that the resolution of potential reporting-related

organizational dilemmas is commensurate with the safety significance of reported events.

6. Study limitations

This case study contains findings obtained solely from one organization. It would be interesting to compare these results to those of other organizations within this industry. In terms of design, it would also have been important to hold focus groups with middle managers and executives. This RIS system vision is confined to executing levels within the organization. It is important to emphasize that participants were selected by the organization, excluding executive positions and contractor personnel. This sampling characteristic should be considered since from a critical reflective perspective it is considered that methodological decisions are never neutral (Navajas et al., 2013).

7. Conclusions

The existence of an incident reporting system is a fundamental aspect in high reliability organizations (Reason, 1997; Weick et al., 2005). Such systems must allow the reporting by employees at all organizational levels. Therefore, it is crucial that the organizational culture encourages an attitude that leads to an active participation (IAEA, 2002b). From this theoretical approach, the aim of this study is to contribute to the knowledge of factors impacting on reporting behavior. Thus, a case study has been undertaken in an organization of the Spanish nuclear sector. Through the development of focus groups, the research has attempted to clarify what factors promote and hamper the use of the organization's reporting system. For so, a qualitative analysis of the 'interpretative repertoires' of the focus group participants has been carried out.

The case study reveals that there are two aspects determining employees 'utilization of the reporting system. First, the inescapable influence of organizational culture on the reporting system, which determines what to report

depending on people's forecast of the consequences. The qualitative analysis shows that reporting is the result of the organizational value given by employees to the act of reporting. In fact, the organizational cultural logics determine the perception of what is acceptable to report. Second, there is a paradoxical relationship between the reporting system and problem-solving. In this respect, the existence of reporting channels does not ensure that the main operational problems are recorded and addressed. This study shows the existence of an organizational dilemma that confronts desirable reporting with not valuable reporting. The resolution of this dilemma would be used to justify the lack of use of the reporting system to notify minor incidents or the fake use of the system to report problems for which the solution is already known.

Future research regarding reporting behaviors should include all the organizational levels, such as strategic apex and middle line (Mintzberg, 1979) which, as prior studies have shown (Badia et al., 2020), may be determining diverse organizational subcultures in the Spanish nuclear industry.

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5. Dissertation conclusions

This dissertation aims to provide knowledge on organizational and safety culture in the Spanish nuclear industry. In fact, the main goal of this research paper is to contribute to better understand organizational culture, an intangible ideological asset within the scope of high-risk organizations. Thus, the empirical studies of the thesis describe relevant aspects in the area of safety culture, shedding light on some critical processes which, according to literature, orbit around this construct.

As proven throughout this dissertation, different works have addressed, amongst other things, the type of implicit norms characterizing the Spanish nuclear industry culture, the potential existence of subcultures, the relationship between the organization's structural components and potential subcultures, and the clearly cultural nature of problem reporting mechanisms.

On the other hand, it is worth mentioning that this thesis is born with the motivation to put in value twenty years of external organizational culture evaluations in the Spanish nuclear industry. These were rigorous and independent assessments characterized by a strong critical component that at times made them, to a certain extent, uncomfortable. However, these evaluating practices targeted towards an improvement of safety were promoted by the organizations themselves, under the leadership of the nuclear regulator (CSN). These evaluations are placed within the scope of a questioning tradition (in the nuclear industry) which, without a doubt, was one of the flagships of the Spanish nuclear industry with the aim to ensure safe plant operation. This data was obtained using the same methodology (NOMAC), making it possible to anchor two of the three studies herein.

The main contributions of this dissertation based on its three structural studies, are presented below:

Study 1. Organizational Culture and Subcultures in the Spanish Nuclear Industry

This study provides an overview of the main organizational culture traits of the Spanish nuclear industry. Research shows, from a quantitative perspective, a global representation of culture, with shared regulatory patterns, while simultaneously identifying sectoral peculiarities and differences. Four results within this study are highlighted within the framework of this thesis:

- The existence of a dominant normative pattern, shared by all Spanish nuclear organizations, defined on the literature as "constructive style" (Cooke & Szumal, 1993). This main drive is characterized by compatibility between outcome orientation and result achievement, with an interest to preserve the well-being and professional development of the workforce.
- The coexistence of a secondary normative style fostering conventional, dependent and perfectionist behaviors. This pattern leads to prioritizing defensive behaviors such as adaption, complying with norms, following the guidelines of higher hierarchical levels, and not being involved in errors.
- Identification of distinctive elements in the global culture which could be considered organizational subcultures. Results show that the organizational type, proximity to the technological component or performed tasks seem to be differentiating elements in the perception of culture. In fact, analyses show cultural differences based on the type of company (public nuclear organization vs. private nuclear organization); regular workplace (Facility employees vs. Headquarters employees); and organizational structure (Mintzberg, 1989) (Operating Core personnel vs. Technostructure personnel), thus revealing a potential capacity to generate subcultures.

- Cultural uniformity between staff and long-term contractors. Results show that both groups perceive cultural norms in the organization within the same order of magnitude, highlighting the strong inclusive nature of culture in nuclear organizations. However, both groups of workers, whose daily work in the organization is carried out under quite different scenarios (occupational conditions such as wages or type of contract), have a similar perception of the cultural norms determining their behaviors in the organization.

Study 2. Safety Culture in the Spanish Nuclear Power Plants through the Prism of High Reliability Organization, Resilience and Conflicting Objectives Theories

The second article of this dissertation describes the main characteristics of safety culture in Spanish nuclear power plants. To do that, the study takes as its theoretical framework of reference, three relevant approaches of scientific literature in the area of safety in high-risk organizations. These three approaches highlight the considerable impact on safety of complex aspects such as reliability (HRO), resilience (HRO and RE) and decision-making in dilemmatic contexts (COP). Four contributions of this study are highlighted below:

- Existence of a homogeneous, favorable vision amongst nuclear power plants towards the importance of safety, the organization of plans and strategies to effectively manage crises, and a level of standardization and documentation for their activities.
- A more unfavorable and heterogeneous perception relates to the setting of targets and adequate distribution of resources by the organization (both personnel, as well as equipment, time, and economic budget). This factor emerges as a critical aspect of safety culture in nuclear power plants.
- The proximity of the technological component arises as a factor associated to the creation of subcultures (Facility employees vs. Headquarters employees). This factor does not only seem to condition the norms guiding personnel

behaviors (organizational culture) but also their perceptions in terms of risk awareness, resolution of the safety-production dilemma and processes for allocation of resources and setting up of targets.

- The contract mode (staff vs. contractors) is associated to significant differences in the perception of safety culture. These groups are clearly unequal in terms of professional conditions, despite their similar internalization of organizational culture norms, and have very different perceptions of some safety culture aspects, such as blame-free environment, management of variability, assessment of safety priority, level of formalization and availability of resources.

Study 3. Understanding Reporting and Problem-Solving Behaviors in a High Reliability Organization: A Case Study in a Spanish Nuclear Company

From a qualitative perspective and through an analysis of 'interpretative repertoires' (Potter & Wetherell, 1987) the study favored the understanding of how the reporting system is integrated and becomes a part of the organization's cultural framework. This study shows two relevant findings:

- Behaviors relating to problem notification and, in turn, the use of a critical system for safety by organization members, can be explained by the meaning given to such system within the organizational culture framework. Therefore, the act of reporting derives from a set of normative values within the organization which makes the use of the reporting system desirable or not.
- There is no linear relationship between an increasing notification and a larger capacity to solve problems by the organization. The existence of reporting channels open to the entire organization does not ensure that the main operational problems are recorded or addressed. The case study reveals that the promotion of reporting just of itself can lead to the reporting of trivialities

or easy-to-fix problems, without recording in the system the main aspects in terms of safety.

Based on the results presented, the following aspects should be considered:

- The predominant role in the Spanish nuclear industry of a constructive culture is, according to literature, a positive finding as it relates to cultural norms which benefit aspects such as employee motivation, satisfaction, stress and performance, thus favoring good site performance (Cooke & Szumal, 1993).
- However, the existence of defensive normative patters suggests that the nature of nuclear activities (highly procedural and hierarchical, with errors having a potentially catastrophic nature) can take these organizations to be conventional, dependent and perfectionist. These organizational characteristics need to be managed to ensure they do not hamper important safety aspects of HRO, such as adaptation to variability; innovation; questioning or focus on main actions.
- Understanding the culture traits of some differentiated, identified groups could help to explain the impact of certain behaviors on safety and the overall organizational culture.
- The existence of reporting channels does not necessarily mean they are used to report significant problems or to improve site performance. Organizational culture becomes the framework in which such behaviors make sense and have a meaning. Thus, organizational culture is the context and reference for organization members to eventually determine if reporting behaviors have a practical connection to safety or not.

5.1. Dissertation limits

On the one hand, with regards to the quantitative studies comprising this dissertation, it would have been desirable to include information from additional sociodemographic variables. In that sense, previous studies pointed out that variables such as the professional group or organizational seniority can modify cultural differences (Helmreich & Merritt, 2019; Parker, 2000; Rollenhagen et al., 2013). Similarly, to analyze the findings of these studies in more depth and to make sense of the results presented, it would have been advisable to add to this research qualitative information arising from interviews and focus groups.

On the other hand, it would have been interesting to use quantitative information and data from more than one organization with the aim to complement the analysis carried out within the third study, focusing on determinant factors of reporting system usage. It would have also been interesting to broaden the sample from executing levels to managerial levels, so as to have a global organizational vision.

6. Current and future lines of research

This dissertation is framed within CIEMAT's sociotechnical research tradition which, from a distance, seems to make use of cutting-edge studies when addressing the safety of high-reliability nuclear organizations. Over the last 20 years, CIEMAT has carried out organizational and safety culture assessments in all Spanish nuclear power plants, as well as in the public organizations within the Spanish nuclear industry (ENUSA, ENRESA, ENSA and CIEMAT).

This is also an alive research line which certainly does not end with this work, but that keeps trying to contribute to the changing challenges of safety and the industry from a practical approach. From this preliminary consideration, ongoing research projects, as well as other lines of interest, are included herein.

6.1. Existing lines

The safety culture evaluation of the Spanish Regulator (CSN), responsible for nuclear safety and radiation protection in Spain, is currently in progress.

From a sociotechnical perspective, such evaluation will contribute to complement the research presented on this dissertation. The sociotechnical model (Rasmussen, 1997) conceives the organization as a system in which safety is influenced by various stakeholders. Safety is conditioned by human, technological and organizational factors; their interrelation; and their interaction with the environment (government, regulator, society…). According to this approach, the relationship and adjustment of all these factors contribute largely to system safety. Thus, site reliability is conditioned by the decisions of managers, politicians, regulatory bodies… and not only by the actions of workers in the production line. That means it is desirable to analyze the entire system and not the organization in an isolated manner. The evaluation of the CSN will not only provide a wider perspective of safety culture in the Spanish nuclear industry, but

also facilitate the analysis of relationships and impact of the regulatory culture on the nuclear organizations it regulates and, in turn, on the safety of the nuclear industry.

6.2. Potential lines for the future

6.2.1. Analysis of most relevant events in nuclear power plants

A step that would go beyond the scope of this dissertation is the study of the link between safety culture in nuclear power plants and event occurrence. In that sense, it would be interesting to identify and analyze the underlying organizational components and human behaviors of the most significant events within the sector.

Based on a review of documentation (Licensee Event Reports) submitted by nuclear organizations to the regulatory agency (CSN) following the main events (Annex 13), it could be possible to discuss the implications of organizational and human factors on the safety of nuclear industry organizations.

After analyzing INES events with a category higher than 0 (Annex 3), it would be possible to categorize the organizational and human factors contributing to their occurrence.

Such information would be highly relevant for improvement actions relating to organizational and human factors within the industry.

6.2.2. Studying the impact of the energy transition context on this industry

Another line to pursue would be the analysis of safety risks and challenges being faced by Spanish nuclear organizations within the national context of energy transition. Such a study should have an approach both mixed (quantitative and qualitative) and multidisciplinary (researchers from social

sciences, engineering, chemistry…) so as to engage key stakeholders (nuclear power plants, public sectoral companies, regulatory agency and society).

The phasing out of the Spanish nuclear fleet (last station scheduled to shut down in 2035) and a subsequent increasing number of activities associated to decommissioning and radwaste management processes will set the tone of safety within the country's nuclear industry. The organizations comprising the Spanish nuclear system should adjust to new demands resulting from this external context. Nuclear power plants, the public company in charge of decommissioning nuclear facilities and managing radwaste, the companies which provide support services to the stations, and the regulatory body will be facing a number of technological, organizational, human, regulatory and social challenges. Thus, it is necessary to consider nuclear industry challenges from a global perspective, taking into account how safety is impacted by all these stakeholders and their interactions.

This research could also be framed within the approach of resilience engineering. A resilient organization is capable to anticipate, prepare and handle changing circumstances in an optimal manner and without losing its capacity to achieve its mission (Barnett & Pratt, 2000). In that sense, the results of this study shall contribute to determine the resilience of nuclear organizations in this new changing energy scenario and to address some doubts about this industry: Will it be able to respond to upcoming challenges without compromising organizational well-being? will it adjust positively to new challenging conditions while maintaining safety standards?

The resulting knowledge should contribute to increasing safety levels for both individual players and the nuclear system as a whole. Similarly, it could contribute to making the energy transition process safe, sustainable and competitive in the mid- and long-term.

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8. Annexes

Annex 1. Interview to Dr. Badia

NOTICIERO UNIVERSAL **EVENTOS** Sábado, 19 de junio de 1982

Una vez a la semana

Por Eliseo Bayo

EN POCAS PALABRAS

Catalunya ha quedado aislada en el tratamiento del cáncer

José Badia. (Foto: Francesc Sans)

Guste o no guste, la verdad es ésta. Para el tratamiento de determinados tipos de cáncer, Catalunya se ha quedado aislada por falta de centros y de material adecuado», así se expresa, con cierta desolación el doctor **José Badia.**

En efecto, por desgracia para ellos, centenares y aún millares de enfermos cancerosos que necesitan tratamiento de radioterapia no pueden ser atendidos en Cataluña. Hasta ahora los enfermos más graves, necesitados de tratamiento de urgencia, eran enviados a Madrid y a otros lugares por los médicos catalanes que los atendían. Y aún así, había que vencer una serie de dificultades burocráticas que sobrecargaban de trabajo a los médicos: redactar la carta de historia clínica, notificar a la inspección que tal enfermo debía ser atendido en un centro extraprovincial, pagar el viaje del enfermo y de un acompañante, hacerse el tratamiento y regresar al lugar de origen. Y todo ello sin contar las molestias del enfermo, ni las disparidades de criterio que pudieran surgir sobre el tratamiento por parte de uno y otro médico. Pues aún este tipo de asistencia a salto de mata, problemática y nefasta para todos, pero la única de que se disponía, ha desaparecido. De pronto, fuera de Cataluña han dicho basta. Ya tienen enfermos suficientes en su casa, para cuidar los del vecino. Y Cataluña se ha quedado aislada.

El doctor **José Badia,** encargado del departamento de ginecología oncológica del Hospital de San Pablo, combina a partes iguales una extraordinaria dosis de conocimientos prácticos en el quirófano y de preparación científico-técnica. Es, además, insobornable –lo que no es muy frecuente en estos tiempos– y es capaz de sufrir inconvenientes por defender lo que cree justo y lo es. Menos frecuente aún. Otro en su lugar hubiera arrojado la toalla hace tiempo y se habría sacudido el polvo de este país. Pero se necesitan muchos «bulldozers» burocráticos para derribar una tapia como el **doctor Badia,** a quien, por cierto, adoran sus pacientes:

–Desde hace un año un aparato calibrador de iridio, imprescindible para volver a poner en marcha el tratamiento del cáncer por radiación cavitaria, está retenido en la Aduana de Barcelona por trámites burocráticos. xwjero –en su caso, a Italia– para especializarse en medicina nuclear. Hizo su tesis sobre ella y regresó a España donde volvió a concontrarse con un país dormido, ignorante y zafio. Se han hecho y se hacen aquí asombrosas barbaridades. En los hospitales de las ciudades y en las consultas de los médicos rurales se ha manejado el radium con ignorancia suicida. Ahora empiezan a verse los resultados de lo que se hizo hace unos años. Decenas de médicos con dedos y aún manos amputadas y una población afectada por las radiaciones cuya gravedad, incluso, se desconoce. El gran problema era –y es– que ni siquiera se sabe la cantidad exacta de radium incontrolado que existe en España. Los médicos lo compraban por su cuenta haciendo un viaje a Bélgica y algunos se traían el radium en el bolsillo. En los países adelantados se legisló hace años la prohibición del uso del radium, como elemento nocivo para el personal manipulador, y se sustituyó por otras sustancias que, como el iridio y el cesio, son menos peligrosas que el radium. La Junta de Energía Nuclear quiso poner orden y dictó normas sobre radioprotección que nadie respetó. Algunos centros accedieron a entregar el radium pero otros continúan usándolo. Y enriqueciéndose fabulosamente.

Se ha practicado ua medicina agresiva, producto del desconocimiento general de la actuación de las sustancias, ante el escándalo y la impotencia de los profesionales que predicaban en el desierto. El cáncer, en efecto, está causando estragos y no se ha encontrado todavía el tratamiento definitivo porque se desconoce su etiología. Pero se debería hablar, también, de la gran cantidad de cánceres inducidos por la intervención del personal incompetente. El cáncer que se provca a los enfermos por abuso de métodos radiactivos. Es asombroso que actúen con tanta inconsciencia algunos médicos y no pocos enfermos a los que se ha mentalizado para exigir una medicina cuanto más cara mejor. La indiscriminada toma de radiografías –que tanto satisfacen a médicos y a enfermos– es un peligro bien cierto. Una agresión radiactiva de cuyos peligros no se advierte a la población.

El **doctor Badia** puntualiza:

–Si hubiera una inspección en serio en todos los centros en que se usa material radiactivo, posiblemente habría que clausurarlos casi todos porque debe de haber poquísimos que reúnan condiciones técnicas de radioprotección.

Source: El Noticiero Universal, 19/06/1982

Annex 2. Spanish nuclear industry

SPANISH NUCLEAR INDUSTRY				
Energy production organizations				
Organization	**Location**	**Commercial operation**	**Current situation**	**MWe capacity**
José Cabrera (Zorita) Nuclear Power Plant	Guadalajara	1968-2006	in decomissioning process	160
Santa María de Garoña Nuclear Power Plant	Burgos	1971-2012	in pre-decomissioning	460
Vandellòs I Nuclear Power Plant	Tarragona	1972-1989	in latency stage	480
Almaraz I Nuclear Power Plant (CNAT)	Cáceres	since 1983	in operation	1049
Almaraz II Nuclear Power Plant (CNAT)	Cáceres	since 1984	in operation	1044
Ascó I Nuclear Power Plant (ANAV)	Tarragona	since 1984	in operation	1032
Cofrentes Nuclear Power Plant	Valencia	since 1985	in operation	1092
Ascó II Nuclear Power Plant (ANAV)	Tarragona	since 1986	in operation	1027
Vandellòs II Nuclear Power Plant (ANAV)	Tarragona	since 1988	in operation	1087
Trillo Nuclear Power Plant (CNAT)	Guadalajara	since 1988	in operation	1066
Auxiliary companies of the nuclear industry				
Organization	**Location**	**Creation**	**Current situation**	
ENUSA (Spain's National Uranium Company)	Madrid	1972	working	
ENUSA's fuel assembly plant - Juzbado	Salamanca	1985	working	
ENSA (Nuclear components manufacturer)	Cantabria	1973	working	
ENRESA (National Radwaste Company)	Madrid	1984	working	
ENRESA's low-mid activity storage center - El Cabril	Córdoba	1992	working	

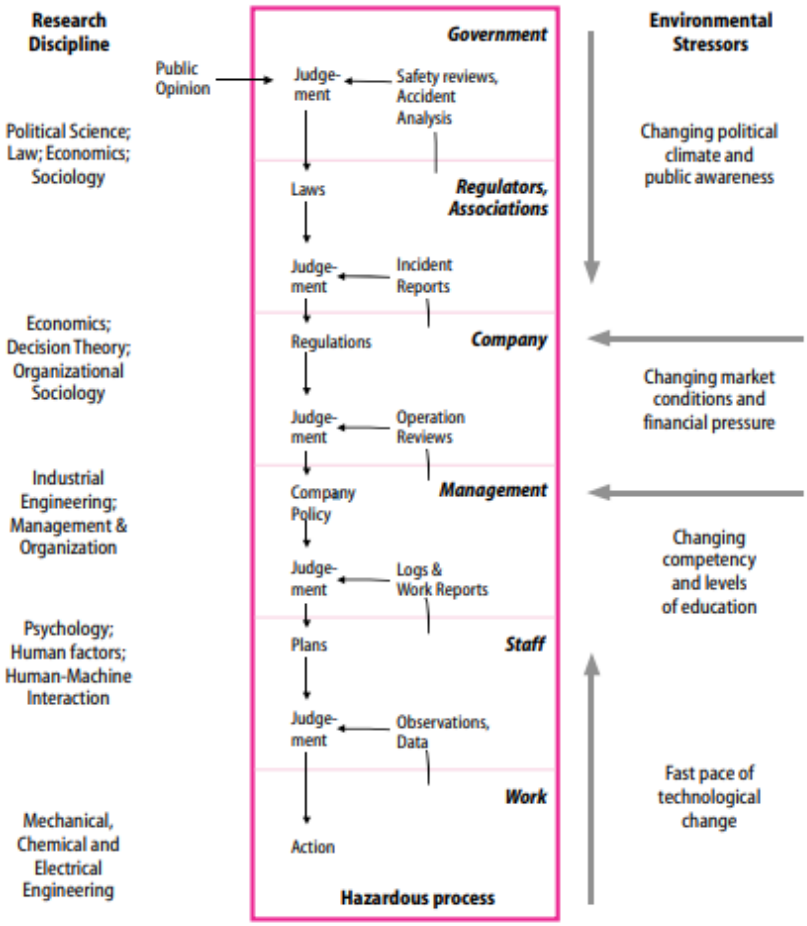
Source: Own elaboration

Annex 3. The International Nuclear and Radiological Event Scale

Description and INES Level	People and the environment	Radiological barriers and controls at facilities	Defence in depth
Major accident Level 7	- Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Serious accident Level 6	- Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with wider consequences Level 5	- Limited release of radioactive material likely to require implementation of some planned countermeasures. - Several deaths from radiation.	- Severe damage to reactor core. - Release of large quantities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire.	
Accident with local consequences Level 4	- Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. - At least one death from radiation.	- Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. - Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious incident Level 3	- Exposure in excess of ten times the statutory annual limit for workers. - Non-lethal deterministic health effect (e.g. burns) from radiation.	- Exposure rates of more than 1 Sv/hr in an operating area. - Severe contamination in an area not expected by design, with a low probability of significant public exposure.	- Near accident at a nuclear power plant with no safety provisions remaining. - Lost or stolen highly radioactive sealed source. - Misdelivered highly radioactive sealed source without adequate radiation procedures in place to handle it.
Incident Level 2	- Exposure of a member of the public in excess of 10mSv. - Exposure of a worker in excess of the statutory annual limits.	- Radiation levels in an operating area of more than 50 mSv/h. - Significant contamination within the facility into an area not expected by design.	- Significant failures in safety provisions but with no actual consequences. - Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. - Inadequate packaging of a highly radioactive sealed source.
Anomaly Level 1			- Overexposure of a member of the public in excess of statutory limits. - Minor problems with safety components with significant defence in depth remaining. - Low activity lost or stolen radioactive source, device or transport package.
	No safety significance (Below scale/Level 0)		

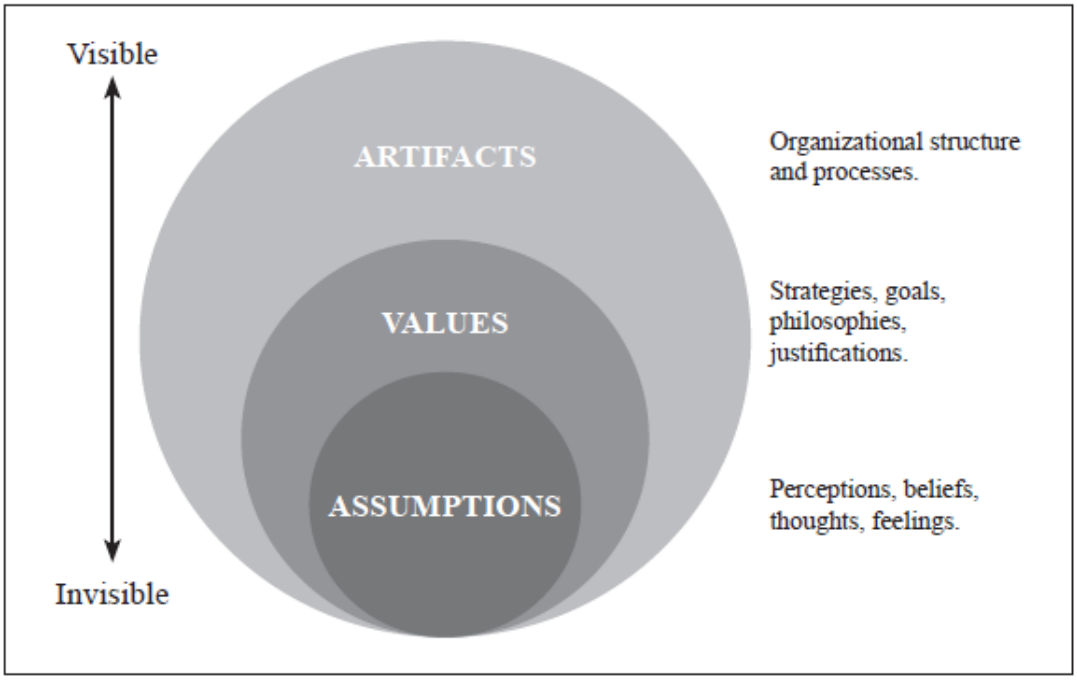
Source: IAEA, 2013

Annex 4. Rasmussen's sociotechnical model



Source: Rasmussen & Svedung, 2000

Annex 5. Schein's model of organizational culture



Source: Schein, 2004

Annex 6. Human Synergistics, Inc. permission letter for the reproduction of the OCI styles descriptions

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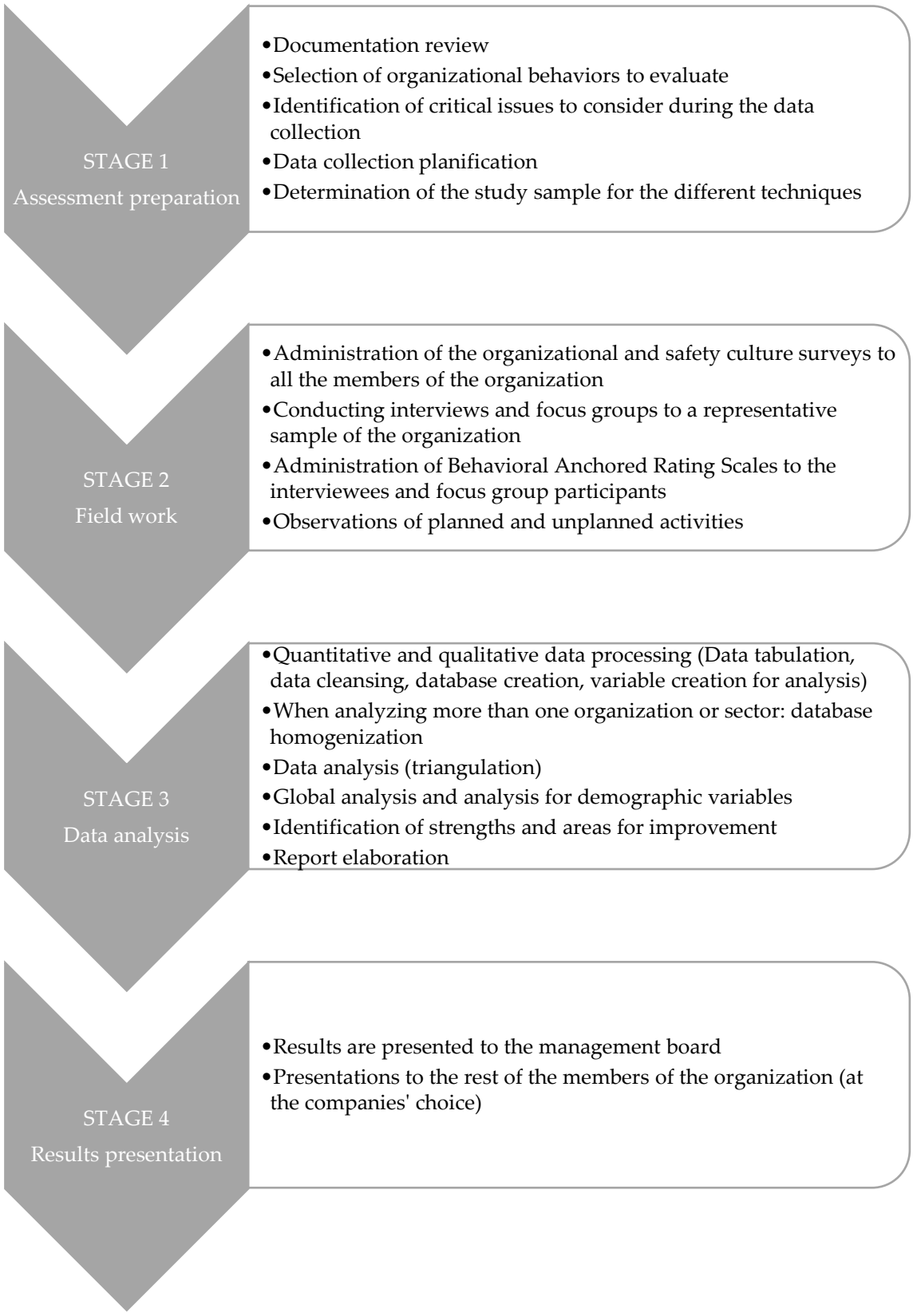
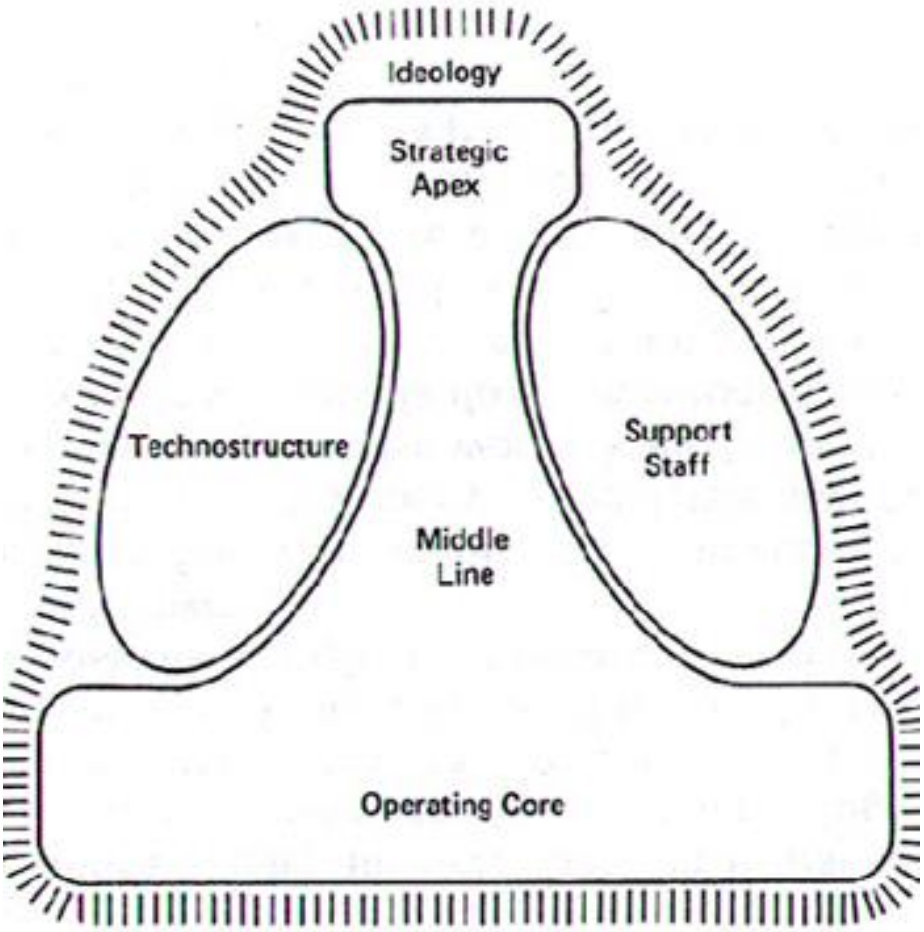
Sincerely,

Cheryl A. Boglarsky, Ph.D.
Human Synergistics, Inc.

Annex 7. Organizational and safety culture assessment process outline



Annex 8. Mintzberg's organizational components



Source: Mintzberg, 1989

Annex 9. Dissertation sample

SAMPLE					
		N 1st study (Nuclear industry)		**N 2nd study (Nuclear power plants)**	**N 3rd study (Nuclear public company)**
Instrument		Organizational culture	Safety culture	Behavioral anchored	Focus groups
Nuclear public companies (NPC)	NPC1	437			
	NPC2	326			
	NPC3	444			48
Nuclear power plants (NPP)	NPP1	292			
	NPP2	533	533	126	
	NPP3	1975	1975	175	
	NPP4	1818	1818	180	
Total N		5825	4326	481	48

Annex 10. Dissertation methods

METHODS				
Author	**Instrument**	**Items**	**Rating**	**Thesis Study**
Cooke R.A. & Lafferty J.C., 1987	Organizational Culture Inventory	120	1 to 5	1
Roberts, K.H., 1989*	Safety scale	40	1 to 7	2
Roberts, K.H.,1990*	Hazard Perception scale	4	1 to 7	2
Haber, S.B., 2006	Safety Conscious Work Environment scale	7	1 to 7	2
Whitman, Z.R. et al., 2013	Organizational Resilience scale	13	1 to 7	2
Haber, S.B.et al., 1990	Attention to Safety BARS	5	1 to 5	2
Haber, S.B.et al., 1990	Resources Allocation BARS	5	1 to 5	2
Haber, S.B.et al., 1990	Formalization BARS	5	1 to 5	2
	Focus groups			3

(*as cited in Haber & Shurberg, 1996)

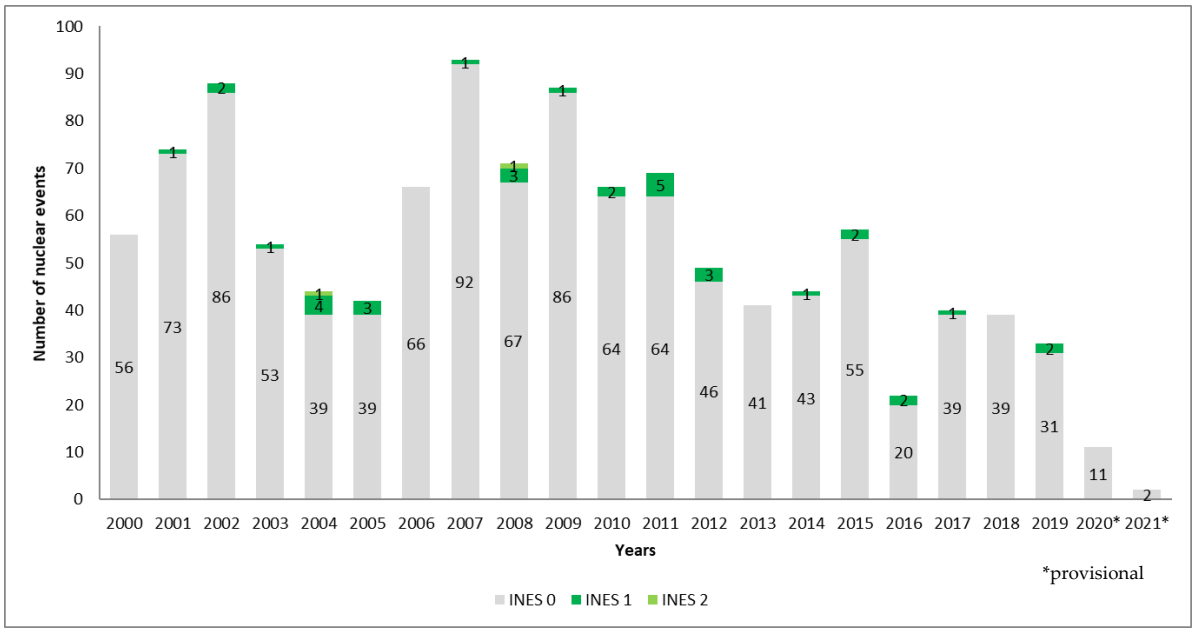
Annex 11. Study 1 data matrix

STUDY 1 MATRIX		
Survey code		
120 items organizational culture inventory (OCI)		
Sociodemographic variables	Organization	Nuclear Power Plant 1
		Nuclear Power Plant 2
		Nuclear Power Plant 3
		Nuclear Power Plant 4
		Nuclear Public Company 1
		Nuclear Public Company 2
		Nuclear Public Company 3
	Sector	Nuclear Power Plants
		Nuclear Public Companies
	Location	Plant
		Corporation
	Contractual Relationship	Own Staff
		Contractors
	Organizational components Mintzberg (NPP1)	Strategic Apex
		Middle Line
		Operating Core
		Technostructure
		Support Staff
Analysis variables	12 Cultural Styles	Humanistic-Encouraging
		Affiliative
		Achievement
		Self-Actualizing
		Approval
		Conventional
		Dependent
		Avoidance
		Oppositional
		Power
		Competitive
		Perfectionist
	3 Organizational Cultures	Constructive
		Passive/Defensive
		Aggressive/Defensive

Annex 12. Study 2 data matrix

STUDY 2 MATRIX		
Survey code		
40 items Safety scale		
4 items Hazard Perception scale		
7 items Safety Conscious Work Environment scale		
13 items Organizational Resilience scale	5 items Planning scale	
	8 items Adaptive Capacity scale	
3 Behavioral Anchored Rating Scales	Attention to Safety	
	Formalization	
	Resources Allocation	
Sociodemographic variables	Organization	Nuclear Power Plant 1
		Nuclear Power Plant 2
		Nuclear Power Plant 3
	Location	Plant
		Corporation
	Contractual Relationship	Own Staff
		Contractors
Analysis variables	Safety	
	Hazard Perception	
	Safety Conscious Work Environment	
	Global Organizational Resilience	
	Planning	
	Adaptive Capacity	
	Attention to Safety	
	Formalization	
	Resources Allocation	

Annex 13. Historical record of events reported by nuclear power plants to the CSN (classification according to INES scale)



Source: Own elaboration from the annual reports of the Nuclear Safety Council (CSN).