FROM NUCLEAR SAFETY CULTURE TO RAILWAY SAFETY CULTURE:

SOME LESSONS LEARNED FROM THIRTY YEARS OF THEORETICAL AND PRACTICAL DEVELOPMENTS

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Abstract. The term safety culture was first introduced after the Chernobyl disaster in 1986, where it became apparent that behaviours of individuals at all levels played a key role in the lead-up to the accident. In the nuclear industry, thirty years of extensive international cooperation have led to the establishment of the nuclear safety culture concept. By describing the main steps of the development of this concept, the purpose of this paper is to share several lessons learned. Three areas for improvement are proposed to nurture the fledgling concept of *railway safety culture*: firstly, further work is needed to reach a common understanding of organisational culture and safety culture in the railways sector; secondly, international cooperation is to be fostered to devise appropriate assessment methodologies in order to evaluate and enhance safety culture and finally, the role of national safety authorities with regard to railway safety culture should be clearly stated and further described. The European Union Agency for Railways has already engaged in these three global challenges.

Over the decades, continuous efforts to avoid accidents in high risk industries have led to significantly improved safety performance. A wide historical view on the doctrinal evolution of safety often identifies three main stages [1], as illustrated in Figure 1.

The prevention of accidents firstly focused on technical design: improved engineering has made it possible to better maintain facilities in unusual situations.

Major industrial accidents led to the reinforcement of regulatory requirements and the implementation of safety management systems (SMS). These technical and structural organisational actions brought progress. However, safety performance of many organisations in all industries has reached a plateau. Focusing on technical design and strengthening procedures is no longer resulting in a reduction of failures. It has also become paramount to focus on the informal organisational aspects and behaviours: in order push the boundaries, organisations need to *act* on their *culture*, to enhance their *safety culture*.
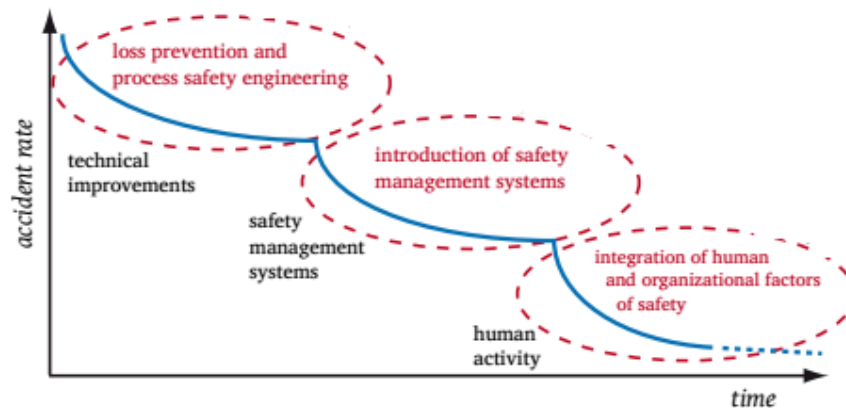

Figure 1: Successive approaches to safety [1]

In the nuclear industry, where organisations are sometimes designated as "high reliability" [2], safety culture greatly expanded after its emergence in the 80s. While it remains complex to approach in operating companies, a concerted effort on the part of the international nuclear community resulted in the achievement of the *nuclear safety culture* concept. By describing the main steps of the development of nuclear safety culture (1.), the purpose of this paper is to share several lessons learned. Three areas for improvement are proposed to nurture the fledgling concept of *railway safety culture* (2.) Like in the nuclear domain, there is little doubt that international cooperation is required to reach a high level of maturity.

1. AN HISTORICAL OVERVIEW OF NUCLEAR SAFETY CULTURE

With its 168 Member States, the International Atomic Energy Agency (IAEA) particularly influences safety doctrines in the global nuclear industry[1]. Within the IAEA, the International Nuclear Safety Group (INSAG) is a group of experts whose objective is "to provide authoritative advice and guidance on nuclear safety approaches, policies and principles."[2] Since the publication of the first INSAG report after the Chernobyl disaster [3], IAEA publications have brought important theoretical and practical developments related to safety culture.

Following Chernobyl, a definition along with fundamental properties has been established (1.1.) The first attempts to monitor safety culture in nuclear organisations were then formalised, mainly through indicators (1.2.) The concept gained maturity with the development of models and frameworks that constitute the pillar of a nuclear safety culture assessment methodology and that have been raised to the level of international standards (1.3.) Among the most debated questions, the role of regulatory bodies has been extensively discussed (1.4.) With thirty years of experience, the nuclear industry has proved the validity of high-level principles that could support the development of railway safety culture (1.5.)

1.1. Definition and Fundamental Property of Safety Culture

In 1991, the INSAG group published a report exclusively dedicated to the concept of safety culture, and proposed the following definition: *"Safety culture is that assembly of **characteristics** and **attitudes** in **organisations** and **individuals** which established that, as an overriding priority, nuclear plant[3] safety issues receive the attention warranted by their significance."* [4]

As specified in the same report, a fundamental property of safety culture appears in this important statement: **"safety culture is *attitudinal* as well as *structural*"**. Indeed, safety culture has two general components: "The first is the necessary *framework* within an organization and is the responsibility of the management hierarchy. The second is the *attitude* of staff at all levels in responding to and benefiting from the framework."

In following IAEA documentations, this property was further enriched with inputs from research and study in the domain of *organisational culture*, in particular the work of Schein [5], an organisational psychologist and management consultant. According to him, any organisational culture should be studied at three levels, which go from the very visible to the tacit and invisible ones: *artefacts*, *espoused values* and *basic assumptions*. A description of the three levels is provided in a notable IAEA guidance [6]:

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[1] Among others, the World Association of Nuclear Operators (WANO), the OECD Nuclear Energy Agency (NEA) and the Institute for Nuclear Power Operations (INPO) are also players that contribute to influence nuclear community's practices.
[2] See IAEA website.
[3] The terms "nuclear plant safety issues" have then been changed into "protection and safety issues", in particular to enlarge the scope of application.

"The easiest level to observe is that of artefacts: what you see, hear and feel. Entering an organisation, the most obvious artefact is the architecture and design of the building (…) Espoused values are those values that are adopted and supported by a person or an organisation. (…) Examples of espoused values often quoted in organisations are, equality of opportunity, teamwork, empowering employees, safety is a priority etc. (…) [Basic assumptions] lie at the deepest level of culture. They are fundamental beliefs that are so taken for granted that most people in a cultural group subscribe to them but not in a conscious way. (…) An example of a basic assumption is the underlying assumption about human nature. Are people basically good or evil? Other basic assumptions deal with fundamental aspects of life – the nature of time and space; human activities; the nature of truth and how one discovers it; the correct way for the individual and the group to relate to each other; the relative importance of work, family and self-development."

The importance of this third level is underlined: "To understand any culture you must unearth these basic assumptions that are operating."
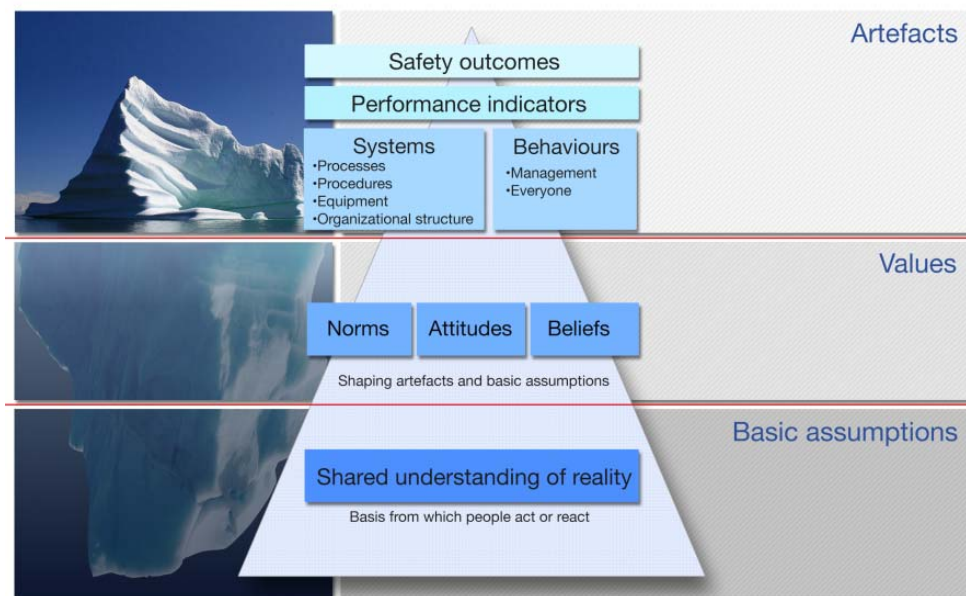

Figure 2: Three levels to inquire into organisational culture [7]

As illustrated by the iceberg metaphor in Figure 2, espoused values and basic assumptions represent larger areas of culture beneath the surface making them increasingly difficult to access.

1.2.   The Pitfalls of Safety Culture Measurement

Facing this difficulty, the first attempts to characterise a nuclear installation' safety culture mainly focused on the structural aspects of safety culture. In 1999 an INSAG report was published [8] that delivered the features of an effective safety management system (SMS), of which the relationship with safety culture is clearly stated:

"organisations having a strong safety culture will have an effective safety management system with the support and ownership of all staff. However, the safety management system has a broader role in that it provides a framework by means of which the organisation ensures good safety performance throughout the planning, control and supervision of safety related activities. The safety management system, in turn, provides a means by which the organisation promotes and supports a strong safety culture."

Attributes of an effective SMS are outlined. "These attributes should be observable in the way the organisation manages safety to ensure high safety standards and a strong safety culture". A set of questions "covering the observable features of an effective SMS" are also provided in an appendix on "safety management indicators". While such guidelines are of first importance to monitor safety and identify weaknesses in the organisation, they mostly enable the collecting of information at the "artefact" level of safety culture.

The above-mentioned IAEA guidance [6] takes into account the multilevel nature of culture and proposes indicators to approach the organisation's espoused values (e.g. "frequency of senior manager plant tours, number of safety inspections, percentage of managers trained in root cause analysis") and basic assumptions (e.g. " frequency of reporting of near misses, number of safety improvement teams, percentage of employees who have a basic understanding of the safety culture concept and its importance"). They classify these indicators into characteristics of safety culture for the three levels namely artefacts, values and basic assumptions (e.g. top management commitment to safety, demonstrates high priority to safety, organisational learning, view of mistakes).

Despite these first interesting attempts, the authors warn of the limits of measuring safety culture: "Safety culture is complex and no obviously satisfactory measures exist, thus any attempt at measurement must be indirect. Some elements of safety culture such as basic assumptions may be unconsciously held and present great difficulties for measurement".

1.3. IAEA Safety Culture Model and Assessments

Such a complexity did not prevent the concept being raised to the level of IAEA safety standards[4] in 2006, made up of the three following decreasing grades: safety fundamentals ("must"), safety requirements ("shall"), safety guides ("should").

Safety culture became part of the ten safety fundamentals [9]. It is explicit in the third principle, which *emphasises its link with leadership*: "Leadership in safety matters has to be demonstrated at the highest level in an organisation (…) The management system also has to ensure the promotion of a safety culture (…) A safety culture that governs the attitudes and behaviour in relation to safety of all organisations and individuals concerned must be

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[4] "The IAEA safety standards provide a system of and Safety Fundamentals, Safety Requirements and Safety Guides for ensuring safety. They reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. The IAEA safety standards are applicable throughout the entire lifetime of facilities and activities – existing and new – utilized for peaceful purposes, and to protective actions to reduce existing radiation risks."(IAEA website)

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integrated in the management system. Safety culture includes: - individual and collective commitment to safety on the part of the leadership, the management and the personnel at all levels; accountability of organisations and of individuals at all levels for safety; measures to *encourage a questioning and learning attitude* and to *discourage complacency* with regard to safety."

Below, at the level of the safety requirements, safety culture is developed in the requirements related to the management system [10,11]: "Individuals in the organization, from senior managers downwards, shall foster a strong safety culture. The management system and leadership for safety shall be such as to foster and sustain a strong safety culture."

It is at the level of guidance that the *IAEA safety culture model* is presented [12]. The five characteristics in Figure 3 are broken down into thirty-seven attributes (see Appendix) that further describe important cultural aspects and provide a more detailed framework.

Figure 3: IAEA Characteristics of a strong safety culture

This IAEA framework is the pillar of the safety culture assessment service proposed by the IAEA to its Member States [13,14].

In order to avoid the pitfalls of a check-list approach that would only permit access to the artefact level, the assessment methodology comprises different qualitative data collection methods such as interviews, focus groups and observations. The team of trained reviewers first focus on describing the organisation's culture; the assessment against the framework is only done in a second phase.

"A descriptive view of culture means to try to describe what the culture is like and how it operates in the organization, while a normative view of culture refers to what the culture should be like. It is therefore of utmost importance to separate the 'is' from the 'should' in the process of capturing data and in the analysis of culture. If the image of how the culture 'is' becomes affected by what the interpreter thinks it 'should be', it is more difficult to carry out a well-founded analysis of the relation between 'is' and 'should'." [14]

Such a process is clearly resource demanding: besides preliminary phases that include a documentation review and a specific survey, the team of reviewers spend three weeks in the field. Nevertheless it constitutes a unique opportunity to support an organisation in creating a common image of its safety culture, to determine strengths and improvement opportunities. For any nuclear organisation, performing safety culture *self-assessments* and safety culture *independent assessments* is a requirement [11]: "senior management shall regularly commission assessments of leadership for safety and of safety culture in its own organization." Important features of such evaluations are then detailed.

The IAEA framework firstly, states that any self-assessment "includes assessment *at all organizational levels and for all functions in the organization.*" Secondly, "senior management shall ensure that such self-assessment makes use of recognized experts in the assessment of leadership and of safety culture". The third one relates to the use and communication of the safety culture assessments results: "the results of self-assessments and independent assessments of leadership for safety and of safety culture *shall be communicated at all levels in the organization.* The results of such assessments shall be *acted upon to foster and sustain a strong safety culture, to improve leadership for safety and to foster a learning attitude within the organization.*"

The nuclear industry has developed a large experience with regard to safety culture assessment. Peer reviews among operators have been implemented worldwide by the IAEA and the World Association of Nuclear Operators (WANO) and are conducted by all operators on a regular basis.

1.4. Regulatory Oversight of Nuclear Safety Culture

The role of regulatory bodies with regard to safety culture has also been debated in the nuclear industry. In 2007, in a landmark workshop jointly organised by the IAEA and the OECD Nuclear Energy Agency the following principles were highlighted [15]:

- "Regulators should look at attitudes, values, assumptions, perceptions and behaviours in addition to systems and processes because they influence the way in which formal systems are implemented";
- "Regulators can more easily gather data at the top two levels of the Schein model (Artefacts and Espoused Values), but it is possible to probe selected underlying assumptions through methods such as interviews";
- For maintaining oversight of licensee safety culture, "regulatory strategy should (…) reflect the need for inspector training, a structured data gathering and analysis process (including roles, responsibilities and interfaces between different regulatory groups). Sufficient resources also need to be allocated to support data collection and analysis";
- "The need for periodic gathering of safety culture information was also highlighted, some proactive (e.g. site inspector observations, review of licensee self-assessments), some reactive (e.g. response to events and performance degradations)";

- "Increased emphasis should be given to *multi-disciplinary regulatory teams*, improved capture of safety culture during routine inspections and reinforcing safety culture through interactions with licensee senior management";
- "Numerical rating of safety culture has limited meaning, especially a drive to a single number. Existing methods are not mature and there are risks that licensee behaviour may become focused on achieving a better score, rather than a stronger safety culture."

These strong statements were then enriched with high-level good practices provided in a dedicated IAEA technical document [16], to be considered by regulatory bodies to implement a safety culture oversight program:

- "Avoid vague conclusions about a licensee's safety culture as a whole, such as 'safety culture is good or bad';
- Use of a structured framework for safety culture oversight;
- Promote proactive approach in order to identify and influence the need to reinforce both individual and organizational behaviours for the continuous enhancement of nuclear safety;
- Encourage the development of an agreed policy document expressing the regulatory positions regarding the safety culture of the licensees."

The document also specifies the appropriate level of regulatory requirements: "with regard to safety culture, the regulatory body should develop general requirements and enforce them in order to ensure the authorized parties have properly considered these requirements. On the other hand, the regulatory body should avoid prescribing detailed level requirements."

Nevertheless, it is important to notice that no "one best way" has been established as the universal safety culture regulatory oversight model.

1.5.   Conclusion: Learning from Nuclear Safety Culture

The description above was not aiming at completeness: the list of documentation could be completed with other sources and interviews with contributors could help qualify those developments. Rather, this overview intends to draw fundamental principles and good practices resulting from thirty years of theoretical and practical developments involving the international community, through which the concept of nuclear safety culture has significantly matured. Figure 4 gathers high-level principles that could contribute to establish the concept of railway safety culture within the railway industry.

- Safety culture is part of organisational culture;
- There is a strong relationship between organisational culture and the safety management system;
- Leadership influences safety culture;
- There is no simple indicator to measure safety culture;
- Evaluation of an organisation's safety culture is based on a detailed description of the organisational culture that takes into account its deepest components (i.e. shared values and basic assumptions). This description is then assessed against a framework of a (positive) safety culture that consists in a set of attributes;
- Regulatory bodies have a role vis-à-vis safety culture and should develop a specific process for collecting, analysis and reporting safety culture data.

Figure 4: High-level principles of safety culture

2. TOWARDS THE RAILWAY SAFETY CULTURE CONCEPT

Based on these high-level principles, three lines of development should help establish the concept of railway safety culture. Further work is first needed to reach a common understanding of complex notions such as organisational culture and safety culture in the railway sector (2.1.) International cooperation should be fostered to devise appropriate assessment methodologies in order to evaluate and enhance safety culture (2.2.) While taking into account national peculiarities, the role of national safety authorities with regard to railway safety culture should be clearly stated and further described (2.3.) The European Union Agency for Railways has already engaged in these three challenges (2.4.)

2.1. Building Theoretical Foundations of Railway Safety Culture

To achieve a better shared understanding it is necessary to clarify the meaning of safety culture. Definitions of safety culture should reflect its strong relationship with the organisational culture on one hand and with the safety management system on the other.

The European Union Agency for Railways has adopted the following definition: *Safety culture refers to the interaction between the requirements of the safety management system, how people make sense of them, based on their attitudes, values and beliefs and what they actually do, as seen in decisions and behaviours. A positive safety culture is characterised by a collective commitment by leaders and individuals to always act safely, in particular when confronted with competing goals.*

The first part of the definition is directed towards the description of the organisational culture (actual attitudes, decisions, and behaviours) and states the influence of the safety management system in the organisation. The second

part is more normative: if the actual organisational culture leads to a positive safety culture, it should be reflected in daily routines and arbitrations at all levels of the organisation.

Such a definition may support initiatives that aim at raising awareness of the importance of safety culture. However, as we already said, it is not enough to characterise it. A model needs to be developed [17,18]. As an example, the Institute for an industrial safety culture has proposed an interesting framework that is comprised of seven attributes of a positive safety culture [19], as Figure 5 shows.
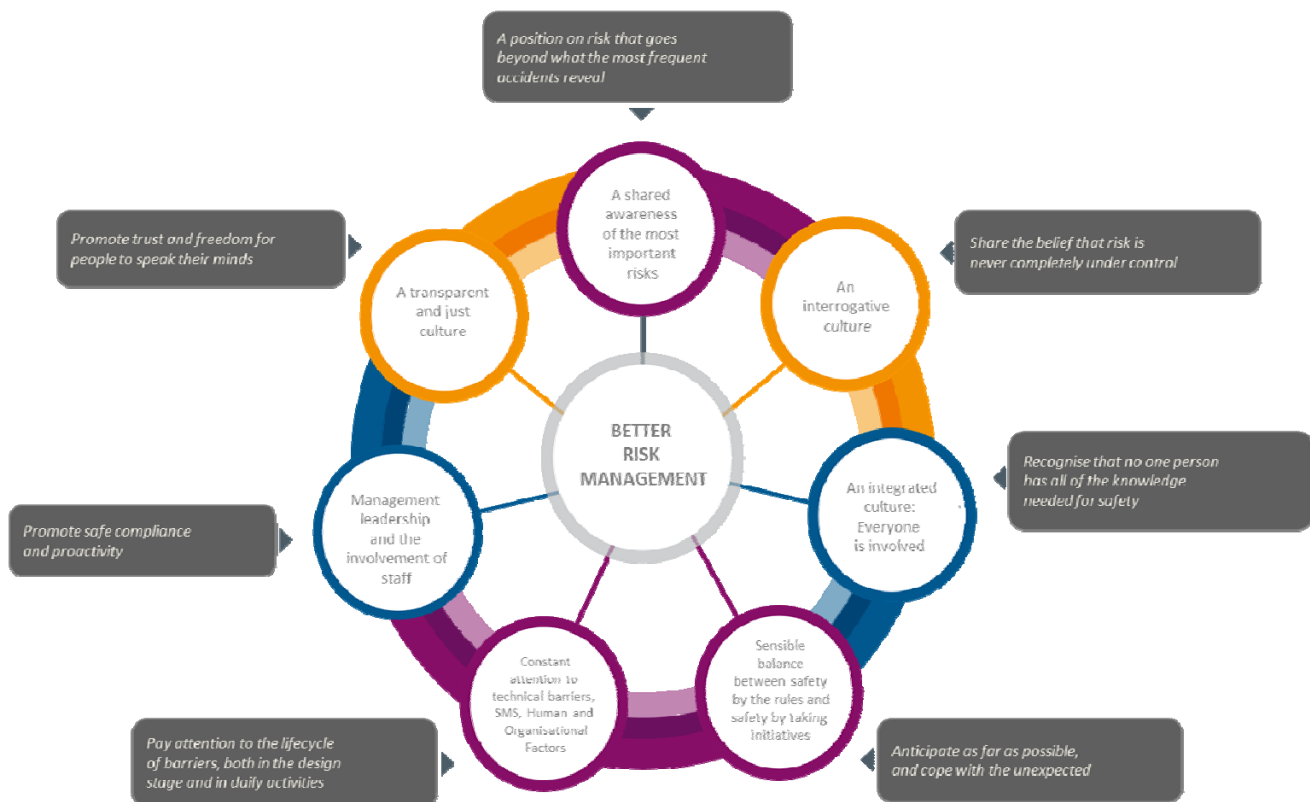

Figure 5: ICSI seven attributes of a positive safety culture [19]

In any company, safety culture initiatives may be seen as a means to improve one or several of these attributes, for example:

- Developing a simple system for sharing safety concerns – Interrogative culture, transparent and just culture;
- Using procurement and contract terms to emphasise safety when working with contractors and suppliers – Integrated culture;
- Defining and communicating expectations for managers on safety leadership – Management leadership and the involvement of staff.

2.2. Fostering International Cooperation to Improve and Assess Safety Culture

Such a model may also constitute a framework for safety culture assessment purposes. In the nuclear industry, international organisations such as IAEA and WANO have played a paramount role in establishing an "assessment cycle": around the world, any nuclear power plant's safety culture is evaluated on a regular basis, as part of a continual improvement strategy. The assessment cycle usually consists of WANO peer review, IAEA peer review, self-assessment, other independent assessment, etc. Top management generally shows commitment to such assessments and results are to be disseminated throughout the organisation.

Developing an "assessment cycle" in the railways sector will definitely contribute to enhancing global railway safety culture. Of course, it demands resources, time and cooperation. The Human Factors Working Group of the *Union internationale des chemins de fer (UIC)* has developed useful documentation that could feed a future methodology for railway safety culture assessment.

At the European level, a current promising initiative could also be a catalyst. The European Commission has provided a grant to conduct a *twinning programme* to look at improving safety culture across Europe's railway infrastructure managers. Network Rail has been acting as the coordinator for the consortium of countries involved in this activity that mainly took place in 2017. The following organisations, members of the Platform of Railway Infrastructure Managers in Europe (PRIME) are taking part in the twinning programme: OEBB (Austria), Infrabel (Belgium), HZI (Croatia), SNCF Réseau (France), Irish Rail (Ireland), RFI (Italy), Prorail (Netherlands), PLK (Poland), CFR (Romania), ADIF (Spain), Trafikverket (Sweden), Network Rail (UK). One-week twinning visits have been set up. The different activities and meetings have enabled the participating organisations to identify good practices related to safety culture. The final report that will gather these practices is to be issued at the end of this year. By creating a community of railway safety culture experts among the European infrastructure managers, the twining initiative could be a first stage towards the development of a common framework and railway safety culture assessment methodology.

2.3. Clarifying the Role of the National Safety Authorities

Railways cannot dispense with tackling the thorny issue of the role played by the national safety authorities. In the nuclear industry, addressing the question often goes hand in hand with reminding oneself of the IAEA Safety Fundamentals – Principle 1: *"the prime responsibility for safety must rest with the person or organisation responsible for facilities and activities that give rise to radiation risks."* While the prime responsibility for safety must remain on the operating company side, national safety authorities should encompass safety culture within their missions. Principles and good practices mentioned in section 1.4. may be exported to railways. Hence, general regulatory requirements related to safety culture should be issued; a tailored process for evaluating safety culture should be implemented and inspectors should be properly trained on these topics.

At present, the European Union Agency for Railways is writing secondary legislation on safety management systems that addresses safety culture. The following specific requirements underline the important role played by top management and the need for continual improvement:

"Top management shall demonstrate leadership and commitment to the development, implementation, maintenance and continual improvement of the safety management system by: (…) promoting a positive safety culture."

"The organisation shall provide a strategy to continually improve safety culture, relying on the use of expertise and recognised methods from the field of safety culture to identify behavioural issues affecting the different parts of the safety management system and to put in place measures to address these."

As suggested by the IAEA, these requirements are general and not too detailed.

Besides, as part of a safety culture programme [20], an Agency project aims at designing and implementing a specific process for safety culture data collection, analysis and report. Such a project fits the upcoming responsibilities of the Agency in, among others, issuing vehicle authorisations and granting safety certificates. The project purpose is also to fulfil the Agency's task as set out in Article 29 of the European Railway Safety Directive[5] : "The Agency shall evaluate the development of a safety culture including occurrence reporting. It shall submit to the Commission, by 16 June 2024, a report containing, where appropriate, improvements to be made to the system."

2.4. Conclusion: Engaging in Railway Safety Culture

The road may be long for railway safety culture to achieve a similar level of maturity to that which has developed within the nuclear industry. Based on the lessons learned from thirty years of international development and on the author's experience, this paper expresses rather strong views. Among these, the emphasis on *safety culture assessment* rather than the use of quantitative indicators may be surprising. The safety culture assessment process should be considered indeed as a unique tool for effective improvement. Here are its major benefits: first, it fosters networking of railway safety culture experts; second, its preparation stage generates collective discussions inside the organisation that raise awareness; third, the assessment is an interactive process between the staff and safety culture experts, which enables organisational learning; lastly, its results, which should be disseminated through the organisation, should be part of a continual improvement programme. It would be an understatement to say that going through such a process may potentially result in more advantages than having the top management focussed on some key performance indicators and distracted by their well-known bad effects.

For such benefits, (at least) two success factors are key. At the organisation level, commitment of top managers is a prerequisite. At the international level, cooperation is to be enhanced to design an appropriate framework and to reinforce necessary expertise. Through its innovative and ambitious programme, the European Union Agency for Railways intends to play a major role to promote a positive railway safety culture.

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APPENDIX: IAEA SAFETY CULTURE ATTRIBUTES [12]

Safety is a clearly recognized value:
- The high priority given to safety is shown in documentation, communications and decision making.
- Safety is a primary consideration in the allocation of resources.
- The strategic business importance of safety is reflected in the business plan.
- Individuals are convinced that safety and production go hand in hand.
- A proactive and long term approach to safety issues is shown in decision making.
- Safety conscious behaviour is socially accepted and supported (both formally and informally).

Leadership for safety is clear:
- Senior management is clearly committed to safety.
- Commitment to safety is evident at all levels of management.
- There is visible leadership showing the involvement of management in safety related activities.
- Leadership skills are systematically developed.
- Management ensures that there are sufficient competent individuals.
- Management seeks the active involvement of individuals in improving safety.
- Safety implications are considered in change management processes.
- Management shows a continual effort to strive for openness and good communication throughout the organization.
- Management has the ability to resolve conflicts as necessary.
- Relationships between managers and individuals are built on trust.

Accountability for safety is clear:
- An appropriate relationship with the regulatory body exists that ensures that the accountability for safety remains with the licensee.
- Roles and responsibilities are clearly defined and understood.
- There is a high level of compliance with regulations and procedures.
- Management delegates responsibility with appropriate authority to enable clear accountabilities to be established.
- 'Ownership' for safety is evident at all organizational levels and for all individuals.

Safety is integrated into all activities:
- Trust permeates the organization.
- Consideration of all types of safety, including industrial safety and environmental safety, and of security is evident.
- The quality of documentation and procedures is good.
- The quality of processes, from planning to implementation and review, is good.
- Individuals have the necessary knowledge and understanding of the work processes.
- Factors affecting work motivation and job satisfaction are considered.
- Good working conditions exist with regard to time pressures, workload and stress.
- There is cross-functional and interdisciplinary cooperation and teamwork.
- Housekeeping and material conditions reflect commitment to excellence.

Safety is learning driven:
- A questioning attitude prevails at all organizational levels.
- Open reporting of deviations and errors is encouraged.
- Internal and external assessments, including self-assessments, are used.
- Organizational experience and operating experience (both internal and external to the facility) are used.
- Learning is facilitated through the ability to recognize and diagnose deviations, to formulate and implement solutions and to monitor the effects of corrective actions.
- Safety performance indicators are tracked, trended, evaluated and acted upon.
- There is systematic development of individual competences.