DEVELOPMENT OF A NUCLEAR INDUSTRY SAFETY CULTURE INVENTORY (NISCI)

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INTRODUCTION

Organisational safety culture is critical to maintaining nuclear safety in the nuclear industry and, as such, is a key focus for its safety regulator: the UK's Office for Nuclear Regulation (ONR). This report provides an overview of research commissioned by ONR and undertaken by academics from The University of Manchester's Alliance Manchester Business School with the support of the Thomas Ashton Institute for Risk and Regulatory Research: to develop a model and measure of safety culture that will enable dutyholders within Great Britain's (GB's) nuclear industry to accurately measure their safety cultures, benchmark their results, and learn from good practices.

Investigations into several high-profile nuclear accidents, such as Three Mile Island (IAEA. 1980; Erp, 2002), Chernobyl (IAEA, 1992), Davis Besse (NRC, 2003; Haber, 2003) and Fukushima (IAEA, 2015), have highlighted failings in nuclear safety culture as contributing to these. The IAEA defines safety culture 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). But, despite considerable research and attention within the industry, the construct remains largely intangible and difficult to quantify. This can make it challenging for nuclear dutyholders to evaluate, develop and maintain their safety culture. Existing guidance for nuclear dutyholders provides a framework for understanding safety culture (e.g., Harmonised Safety Culture Model published by the IAEA, 2020) but critiques of existing safety culture models point to the lack of conceptual grounding, and difficulty in operationalisation (e.g., De Castro et al., 2013). Building on existing work, we aim to develop a novel conceptual model of safety culture for GB's nuclear industry and operationalise the model to create a quantitative measure of safety culture.

MODEL DEVELOPMENT

Theoretical background

Our theorising is based on the Schein (1985) model of organisational culture, with safety as a content-specific aspect of culture, integrated with Reason's (1997) 'informed' model of safety culture. We conceptualised culture as driven by underlying basic assumptions, but manifest in visible artefacts, behaviours, norms, and attitudes. We focus on the enacted values (as opposed to the espoused values) which drive behaviours in practice and are most strongly predictive of safety performance (e.g., Grote & Kunzler, 2000; De Castro et al., 2017). Our model draws on Reason's (1997) conceptualisation of safety culture, which comprises elements of reporting (i.e., creates a climate in which reporting is encouraged), just (i.e., appropriate allocation of blame), flexible (i.e., adaptable approach to safety), and learning (i.e., willingness, competence and motivation to reform based on safety information). Together these four elements comprise an 'informed' culture, that reflects a culture in which:

> *"those who manage and operate the system have current knowledge about the human, technical, organizational, and environmental factors that determine the safety of the system as a whole"*
>
> (Reason, 1997, p.195).

Methodology

We used a mixed-methods approach to the development of the safety culture model, combining a targeted literature review which included existing academic (e.g., Reason, 1997; Lee, 1998; Lee & Harrison, 2000; Grote & Künzler, 2000; Martinez-Corcoles et al., 2011; Navarro et al., 2013; Morrow et al., 2014; De Castro et al., 2017) and industry models of safety culture (e.g., IAEA, 2006, 2020; WANO, 2006; NRC, 2011; INPO, 2011; HSE, 2005; Findley, 2007; Ostrom, et al., 1993) and semi-structured interviews with 10 subject-matter experts. Reading and re-reading the interview transcriptions led to the identification of themes and subthemes within the data. These were cross-checked with the themes emerging from the literature review.

Findings

Based on the subject-matter expert interviews and literature review, we developed an initial model of nuclear safety culture (see Figure 1). The safety culture model, which emerged through the analysis, has six dimensions, and 16 sub-dimensions. The model differentiates between the underlying foundations of culture, in terms of policies, processes, training, and communications, which organisations have in place to support the safety culture, and the elements of the culture which reflect the underlying values, beliefs, and attitudes towards safety. The latter comprise dimensions of Leadership, Immersion, Accountability, Challenge, Reporting, and Compliance, where each element lays the foundation of the next.

The model builds on the IAEA's Harmonised Safety Culture Model (IAEA, 2020) and encompasses those attributes that align with the focus on underlying values, beliefs, and attitudes towards safety. Due to the multi-level nature of attributes such as decision making, and continuous learning, these are located at the relevant level of reflection (i.e., individual, group, leadership, or broader organisational) within sub-dimensions, thus addressing previous issues relating to discriminant validity of the IAEA model. For example, while it is difficult for individuals to accurately reflect on the decision-making process of others, this model assesses leaders' and managers' observable behaviours and interactions which reflect their decision making regarding the relative importance of safety. On an individual level, it assesses one's approach to safety related activities including the assessment of relevant risks and subsequent behaviours (i.e., to challenge, to report, or to comply). The model also encompasses assumptions of the organisational environment that can affect individuals' decision-making regarding safety (i.e., whether individuals feel rewarded to engage in safety related activities, whether individuals are held accountable, whether there is a safe environment for reporting, and a degree of confidence that reports are acted upon appropriately). Similarly, it assesses elements of learning across multiple dimensions. For example, through individuals' assumptions, beliefs and attitudes of their leaders' and managers' openness to feedback, the organisation's approach to mistakes and safety failings (i.e., are individuals blamed or is there a fair and rigorous investigation), as well as the effectiveness of safety reporting. This is consistent with Reason's (1997) definition of a 'learning culture', which relies on taking notice and reflecting on the meaning of safety information, and (critically) acting on that information. The model reflects learning culture throughout its dimensions, but most especially through the Leadership dimension. This includes leader behaviour at senior levels that is visible and consistent with safety values, alongside an openness to new ideas. These are prerequisites for a learning culture.

Figure 1: Initial model of safety culture in GB's nuclear industry.

MEASURE DEVELOPMENT

The initial model formed the basis of a quantitative measure to identify elements of safety culture, and support efforts to monitor and improve safety culture.

Methodology

We applied the AA-model of scale evaluation (Hughes, 2018) which is a two-step approach that outlines the type of evidence required to claim validity of a new measure. Step 1 is concerned with the 'accuracy' of the tool, which ensures that our measure precisely captures safety culture. In step 2, we establish whether our measure is 'appropriate' for its purpose, population, and context. Here we will look at whether it predicts important safety outcomes, whether this prediction holds across groups, and how to best apply it in practice (e.g., length of scale). This approach requires a mixed methods design, and we used qualitative interviews and two quantitative surveys conducted across the nuclear industry to test and refine the model and associated measure.

Phase 1: Accuracy

Content representation and response process

First, we focused on theoretical construct representation which is concerned with the degree to which the content (i.e., items) of a psychometric measure comprehensively captures the target construct (safety culture). We conducted 15 semi-structured interviews across eight of GB's 17 licensees to discuss participants' lived experience of elements deemed important to safety culture and undertook a review of previous safety culture surveys to develop an initial pool of items. Next, we investigated the response process to understand how participants interpret the items and what information they draw upon to answer. We used 14 cognitive interviews (think-aloud protocols) where employees and contractors from across the industry complete the survey and describe what comes to mind while they are responding. This process highlights whether participants follow the expected response process, whether there are any misunderstandings, to ensure that the content is relevant, representative, specific and clear. The results led to the clarification of wording (e.g., changing 'front-line workers' to 'workers') and the more nuanced assessment of the leadership dimension. Specifically, participants consistently stated that their responses would differ depending on the level of leadership on which they were reflecting. Thus, we amended leadership items to capture reflections at 'senior leadership' and at 'line management' level. The resultant survey consisted of six dimensions, 20 sub-dimensions, and 90 items.

Internal reliability and validity (Survey 1)

To test the internal reliability and validity of the model and measure, we administered the first survey across eight of GB's 17 licensees (N=952) and included fuel cycle facilities, decommissioning sites, defence sites, and a new nuclear facility under construction.

Results

A series of confirmatory factor analyses were carried out to assess whether the empirical factor structure deviates from the developed theoretical structure. The initial analyses highlighted several issues which lowered model fit (e.g., high cross-loadings between dimensions). We addressed the most prominent concerns at this stage by merging and revising sub-dimensions (e.g., leadership behaviour) which led to the removal of 22 items. We flagged a small number of remaining concerns for further examination in the next phase of data collection. The resultant revised model and measure consisted of seven dimensions, with 17 sub-dimensions and 68 items and displayed good model fit (Table 1).

Discriminant validity checks demonstrated that all dimensions are discriminant and thus assess distinct elements of safety culture. Although there is a relatively high degree of inter-correlation between all variables, the correlations between dimensions (.33 - .85) were smaller than within dimensions (.49 - .90). This provides further support to the model fit estimates and that the sub-dimensions reflect coherent units of safety culture elements.

We conducted convergent validity checks by examining the correlations with an existing safety climate scale (Beus et al., 2019) and we tested whether the sub-dimensions' of our measure relates to this scale in a theoretically coherent manner. The results showed evidence of strong convergent validity and revealed that the sub-dimensions of our model correlate with the safety climate measure but not to such a level that we can consider them as indistinguishable. Furthermore, as we would expect with a safety climate measure, the Line Management sub-dimensions (.78-.84) were more highly correlated with safety climate than the Senior Leadership sub-dimensions (.54 - .58). Overall, the result show that the safety culture model we developed works and that measure accurately captures the underlying model.

Table 1: Model fit of the full and revised safety culture model

	X^2 (df)	CFI	TLI	RMSEA	SRMR
20 sub-dimensions	NC				
17 sub-dimensions	7552 (2141)	.94	.93	.05	.05

Note: N= 952; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

Phase 2: Appropriateness

Structural and Predictive Validity

We conducted a second phase of data collection to confirm the structural validity of the measure across GB's nuclear industry and to test its explanatory and predictive external validity by showing that it relates to enabling factors (e.g., safety leadership) and outcomes (e.g., safety performance) in expected ways. We administered the second survey across 15 of GB's 17 licensees (N=3480) including operating reactors, fuel cycle facilities, decommissioning sites, defence sites, waste treatment and storage sites, and a new nuclear facility under construction.

Enabling Factors

Previous research has established the nomological net of safety culture and highlights enabling factors (antecedents) which shape safety culture by contributing to the development of employees' underlying assumptions, values, and norms (Bisbey, et al., 2020). We selected one enabling factor from each level (Figure 2). Organisational level antecedents included transformational (Carless et al. 2000), instrumental (Antonakis & House, 2014) and directive leadership styles (Li et al., 2018). The group-level antecedent was psychological safety (Edmondson, 1999) and the individual-level antecedent was safety knowledge (Neal et al., 2000).

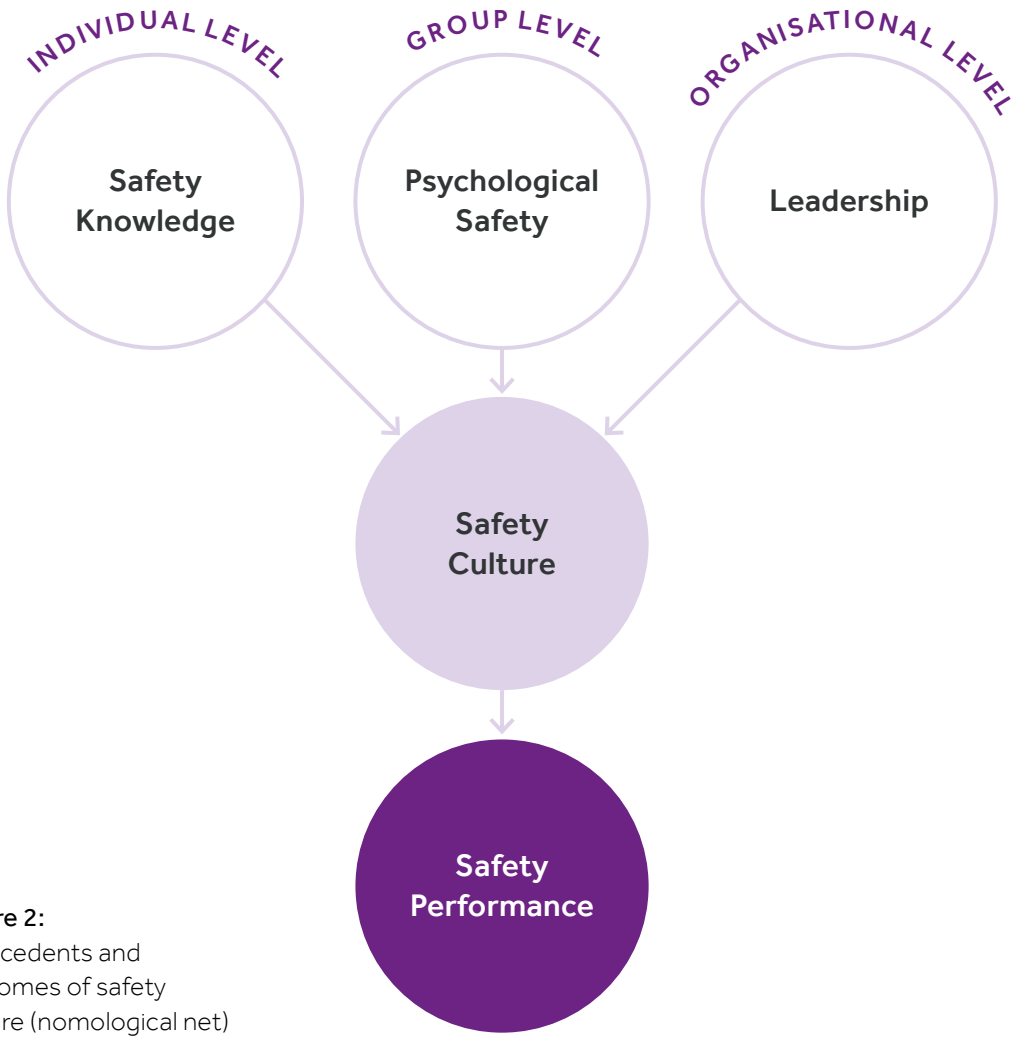


Figure 2:
Antecedents and outcomes of safety culture (nomological net)

Safety Outcomes

We examined safety outcomes in the form of employee ratings of their individual and their organisation's safety performance as well as through ONR inspector ratings of dutyholder safety performance. We did not use safety performance data (e.g., KPIs or RIDDOR) when analysing the links between the safety culture measure and safety performance. Devising reliable and valid methods for obtaining judgements about employee performance is a challenge (Murphy et al., 2018). The measurement of performance across organisations can be even more difficult, for example due to non-standardised data, different levels of technological integration, differences in organisational policy and a lack of agreed upon metrics (Hervani et al., 2001). In the context of safety performance in the nuclear industry, we face a further hurdle in that key reactive indicators (such as accidents and incidents) are rare. Therefore, proactive safety measures such as employee surveys of safety compliance and participation, or results from safety audits and observations, are deemed more appropriate when assessing the status of an organisation than reactive criteria (e.g., accident or incident rates) which were found to lack sufficient accuracy to compare between organisations or projects (Kalteh et al., 2021).

We engaged with ONR and dutyholders to explore whether we could overcome these limitations, however there was no common criterion that we could use as a basis for judgement and quantitative comparison (Austin & Villanova, 1992). Thus, it was not possible to create a reliable set of indicators that we could apply to compare sites across the industry without introducing undue biases (e.g., the influence of the internal reporting culture and relationship with the regulator) which resulted in the exclusion of safety performance data. However, as discussed in the following section, we were able to use ONR inspector ratings of safety performance as a proxy measure.

Known Group Differences

The establishment of known group differences is an important piece of validity evidence that demonstrates the extent to which a psychometric measure correctly discriminates between those known to be low and those known to be high in a construct (Hughes, 2018, p. 36). In this case, we are assessing the extent to which the safety culture measure correctly discriminates between dutyholders who are known to have low, medium, or high safety performance. To establish the known groups, we applied expert ratings from ONR inspectors. For this purpose, a safety performance scale was developed through qualitative focus groups with senior ONR inspectors and a targeted literature search on safety performance measurement in high-reliability industries (e.g., Kalteh et al., 2021; Burke et al., 2002; Mengoli & Debarberis, 2007; Morrow et al., 2014; Smith-Crowe et al., 2003; Neal & Griffin, 2006; Hollnagel, 2018; Haage, 2021; ONR, 2018, 2020). The measure comprised of 11 safety performance indicators which ONR inspectors (N=67) used to rate the safety performance of the participating dutyholder that they inspected, which equated to a total of 186 ratings. Readers can find the ONR safety performance survey in Appendix A.

Results

Structural Validity

We conducted confirmatory factor analyses to assess the internal reliability and structural validity of the revised model and measure. The data revealed an overall good model fit, confirming the seven-dimensional model (Table 2). The results confirmed several issues consistent with the concerns flagged in survey 1 which lowered model fit (e.g., high cross-loadings between dimensions). We addressed these by merging and revising sub-dimensions (e.g., Reporting and Compliance, Energised) which led to the removal of eight items. The resultant final model and measure consisted of six dimensions of Senior Leadership, Line Management, Immersion, Accountability, Challenge, and Reporting, with 15 sub-dimensions and 60-items. The full model is psychometrically robust, and all factors are discriminant.

Readers can find an overview of the safety culture dimensions, definitions, and example items in Appendix B. We have included a full set of items and the measure's psychometric properties in the Technical Appendix of the User Manual.

Enabling Factors

Analysing the 'nomological net' of the safety culture measure, we expected that it would relate to enabling factors in theoretically coherent ways.

We first examined three broad leadership styles: transformational leadership, instrumental leadership, and directive leadership. We assessed transformational and instrumental leadership at the senior leader level, and found that they were consistently, positively, and strongly correlated with the dimensions of safety culture, but did share stronger correlations with senior leader contributions to safety culture than line manager contributions to safety culture. We assessed directive leadership at the line manager level and this was again positively correlated with all dimensions of safety culture, but to a much weaker degree.

Team psychological safety was related to all safety culture dimensions but shared its largest association with line manager contributions to safety culture. Finally, self-rated safety knowledge was most strongly correlated with the dimensions of Challenge, Compliance, and Reporting.

Table 2: Model fit of the full and revised safety culture model

	CFI	TLI	RMSEA	SRMR
7 factors,17 dimensions	.90	.89	.07	.06
6 factors,15 dimensions	.92	.92	.06	.05

Note: Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values ≥ .90 and Root Mean Square Residual (RMSEA) and Standardized Root Mean Residual (SRMR) values of < .06 were taken as indicative of acceptable model fit (Hu & Bentler, 1999; Marsh, et al., 2005).

Safety Outcomes

To explore the relationship of the safety culture model with safety outcomes, we estimated two sets of regression models, explaining individual-level safety performance and employee rated organisational performance. Given that the safety culture model assesses organisational culture, we would anticipate organisational performance to explain a greater proportion of variance than individual-level performance.

Organisational Safety Performance. All six safety culture dimensions significantly positively predicted participants' ratings of organisational safety performance and together accounted for 48% of the variance. This indicates that employees who perceive a stronger safety culture evaluated their organisation's safety performance more positively. Of the fifteen sub-dimensions, the strongest predictors of organisational safety performance were Senior Leader Communication, Presence of Accountability, Confidence, and Informed Compliance.

Individual Safety Performance. The six safety culture dimensions significantly positively predicted participants' ratings of their own individual safety performance and together explained 17% of the variance in individual performance. This is notably less than for organisational level performance, with the sub-dimensions of Sensitivity to Weak Signals, Questioning Attitude, and Informed Compliance having the strongest effects.

Overall, the major conclusions from these regression analyses are: first, the safety culture model explains a non-trivial proportion of variance in employees' own estimates of the overall quality of their organisations' safety performance; and second, the tool explains more variance in organisational level performance than individual-level performance, suggesting that the tool captures shared perceptions of organisational culture.

Known Group Differences: Inspector-Rated Safety Performance

To examine whether the safety culture measure correctly discriminates between those known to be low in safety performance and those know to be high in safety performance, we conducted known group analysis. To establish these known groups, ONR inspectors (N=67) rated the safety performance of the 15 organisations who participated in this validation study. We used these ONR inspector ratings to identify high and low performing organisations (operationalised as a mean score split, M=3.29). The results revealed that high performing organisations scored significantly higher than low performing organisations on the total safety culture score and on all six dimensions.

As a further test, we separated the 15 organisations into three groups, representing low, medium, and high performance. Here high and medium performance organisations scored significantly higher than low performing organisations on the total safety culture score and all its six dimensions. The comparison between high and medium performing organisations was more nuanced, with high performing organisations scoring significantly higher than medium performing organisations on three dimensions: Senior Leadership, Accountability and Reporting, and scoring similarly for the remaining dimensions.

There are three important conclusions from this analysis. First, the safety culture measure captures differences in inspector-ratings of organisational safety performance. Second, each dimension is sensitive to differences between organisations rated as having a high and low safety performance, and between organisations rated as having a medium and low safety performance. Third, the safety culture dimensions of Senior Leadership, Accountability and Reporting distinguish between organisations rated as having high and medium safety performance.


Image courtesy of EDF

Feasibility

To address concerns of feasibility and survey fatigue, we validated the safety culture measure in three different lengths: long form (60-items), short form (30-items) and super-short form (15-items). The results demonstrate that using a shorter form comes at no detriment to measurement validity (see Technical Appendix in the User Manual) and therefore provide appropriate alternatives. Nevertheless, the full form provides greater information for potential intervention and follow-up, and remains preferred, especially if dutyholders are to use the safety culture measure to facilitate decision-making or policy development.

Lastly, each dimension can be used as a stand-alone measure to assess change if shortfalls are identified and targeted interventions are implemented. This allows improved opportunities for the intervention evaluations and learning.

We have included the full statistical analysis in the Technical Appendix of the User Manual.

FINAL SAFETY CULTURE MODEL AND MEASURE – THE NUCLEAR INDUSTRY SAFETY CULTURE INVENTORY (NISCI)

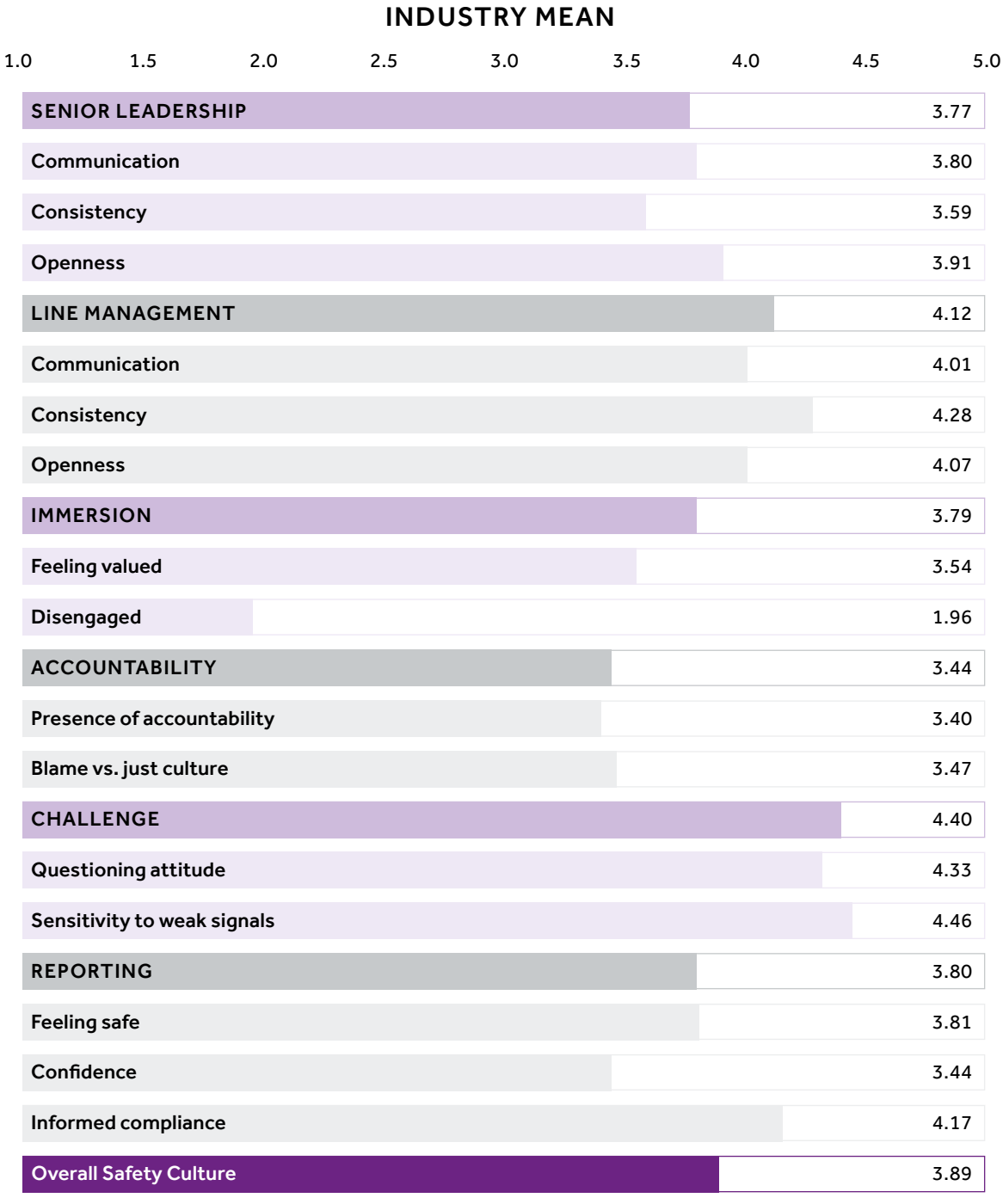
From here, we will refer to the final safety culture measure as the Nuclear Industry Safety Culture Inventory (NISCI).

This section introduces the NISCI results based on the responses of 3,480 workers from 15 nuclear dutyholders provided during the April 2023 assessment window (the second phase of data collection). The NISCI provides a tool for GB's nuclear industry dutyholders to assess their safety cultures in an accurate, nuanced, and contextually appropriate manner. The NISCI assesses six broad dimensions and 15 sub-dimensions of safety culture (Figure 3) and is available in three formats: full form (60-items), short form (30-items), and super-short form (15-items).

Figure 3: NISCI dimensions and sub-dimensions

The NISCI results at a glance

Scores range from a lowest possible score of 1 to a highest possible score of 5, on all dimensions expect Disengaged, where lower scores indicate better safety culture. It is important to note that the scores on each safety culture dimension are relatively high which reflects the high standard of safety in GB's nuclear industry. For example, overall levels of challenge within the industry are very high, as indicated by the overall industry mean of 4.4 for the Challenge dimension. Nevertheless, there are still variations between organisations that dutyholders can assess using this tool and compare to an industry mean.

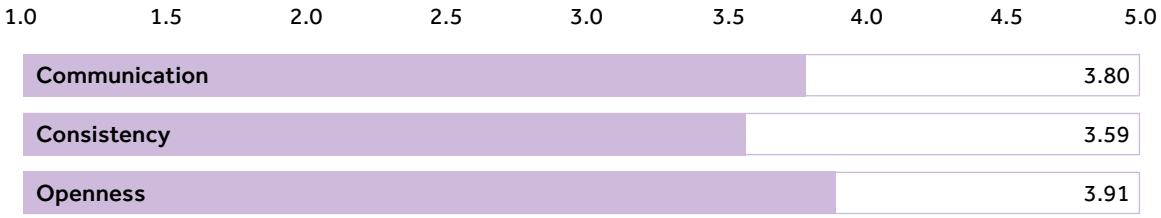


The NISCI industry results in detail

SENIOR LEADERSHIP

Strong safety leadership is of the upmost importance to organisational safety culture. The NISCI assesses three sub-dimensions of senior leadership: Communication, Consistency and Openness.

Industry Results



Unhealthy Culture

- Infrequent communication regarding safety.
- Avoidance of difficult conversations.
- No clear safety standards are set.
- Safety walks are not or rarely performed.
- Safety issues are not acted on.
- Safety rules can be ignored.
- Safety ideas are not listened to.
- Safety feedback not taken seriously.

Healthy Culture

- Clear communication of safety.
- Frequent and engaging communication about safety.
- Regular safety walks.
- Actions are taken to uphold safety standards (walking the talk).
- Consistent prioritisation of safety issues.
- Workers' safety ideas are heard and taken seriously.
- Implementation of changes based on safety feedback.

Senior Leader Communication (M = 3.80) describes the extent to which participants perceive that senior leaders communicate the importance of safety in a clear, consistent, and frequent manner. This dimension not only considers whether communication takes place but also how it takes place (e.g., are leaders visible and do they talk to workers in a way that upholds safety standards?).

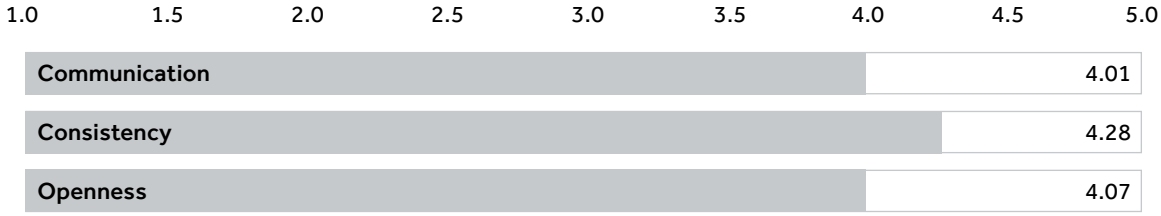
Senior Leader Consistency (M = 3.59) assesses the extent to which the behaviour of senior leaders is seen as consistent with their messaging. This is also referred to as 'walking the talk' and 'practicing what they preach' when it comes to safety.

Senior Leader Openness (M = 3.91) describes the extent to which senior leaders are open to employees' feedback and ideas regarding safety. This includes elements that foster opportunities to provide feedback (e.g., encouragement) and the reaction to such feedback/ ideas (e.g., actions taken).

LINE MANAGEMENT

Line managers play an important role in workers' daily experiences. The main attributes that shape safety culture from a line management perspective are the same as those for senior leaders: Communication, Consistency, and Openness. However, they manifest through different actions. Workers often perceive senior leaders and line managers very differently and it is important to differentiate between managerial levels.

Industry Results



Unhealthy Culture

- Safety issues are not discussed with workers.
- No clear safety standards are set.
- No safety 'checks' are done with workers.
- Safety behaviours do not match the safety messages.
- Organisational safety standards are not upheld.
- Workers are not involved in safety improvements.
- Safety feedback is not acted upon.

Healthy Culture

- Safety messages are communicated in engaging ways.
- Safety checks always take place prior to starting work.
- Difficult conversations are embraced to uphold safety standards.
- Safety is consistently prioritised.
- Workers are asked for ideas to improve safety.
- Appropriate changes are made based on safety feedback.

Line Manager Communication (M = 4.01) describes the extent to which participants perceive their line manager to communicate the importance of safety in a frequent, clear, and engaging manner. This dimension not only considers whether communication takes place but also how it takes place (e.g., engaging in difficult conversations to uphold safety standards, and proactively checking-in with workers regarding safety).

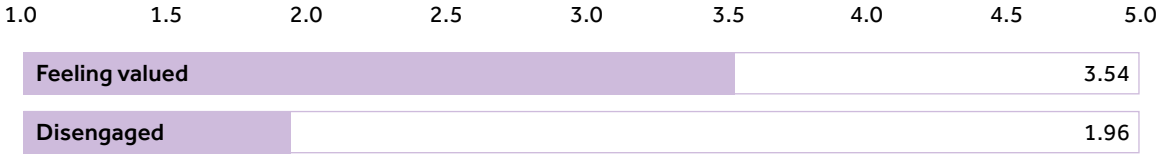
Line Manager Consistency (M = 4.28) outlines the extent to which the behaviour of line managers is seen as consistent with their messaging and whether line managers live up to the safety standards set at the organisational level by senior leaders.

Line Manager Openness (M = 4.07) represents the extent to which line managers are open to, create opportunities for (e.g., asking for it), and take seriously (e.g., implementation / behaviour change) workers' safety ideas and feedback.

IMMERSION

Immersion is an emotional component of safety culture that comprises of two sub-dimensions: Feeling Valued and Disengaged with regards to safety. The degree to which workers feel immersed within the organisation is a crucial component that influences safety culture in the nuclear industry.

Industry Results



Unhealthy Culture

- Workers do not feel valued.
- Workers feel that their organisation has doubt in their ability.
- Good safety behaviour goes unnoticed.
- Workers switch off when safety is talked about.
- Safety is seen as a tick-box exercise.

Healthy Culture

- Workers feel trusted to do a good job.
- Individual efforts are recognised.
- Good safety behaviour is rewarded.
- Workers perceive that their contributions to safety make a difference.
- Employee's minds are always focused on safety.

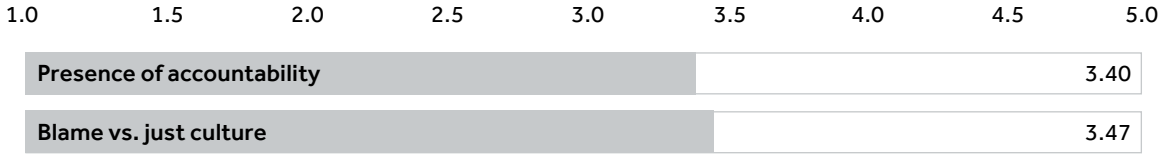
Feeling valued (M = 3.54) describes the extent to which employees feel respected, trusted, and valued within the organisation. This includes whether the organisation recognises and rewards individual efforts and good safety behaviours.

Disengaged (M=1.96) relates to the extent to which employees feel detached and withdrawn from the safety culture. This comprises whether workers are switched-off and see safety as a tick-box exercise rather than an overarching priority that they actively contribute to. This sub-dimension is interpreted as a 'reversed' dimension, where lower scores reflect a more positive indicator of safety culture, and therefore data needs to be interpreted accordingly.

ACCOUNTABILITY

In the nuclear industry, it is essential that individuals are accountable for their safety behaviour. Accountability has two sub-dimentions that describe key features of accountability: Presence of Accountability and a Blame vs. Just Culture.

Industry Results



Unhealthy Culture

- Workers get away with poor safety behaviour.
- Workers are not disciplined for breaking safety rules.
- Blame is attributed to individuals when safety failings occur.
- There is little faith that admitting an honest mistake would result in a fair treatment.

Healthy Culture

- Workers at all levels are held to account when it comes to safety.
- Managers always take action to deal with unsafe behaviour.
- Safety incidents are investigated fairly and without blame.
- An environment that encourages workers to own up to mistakes rather than cover these up.

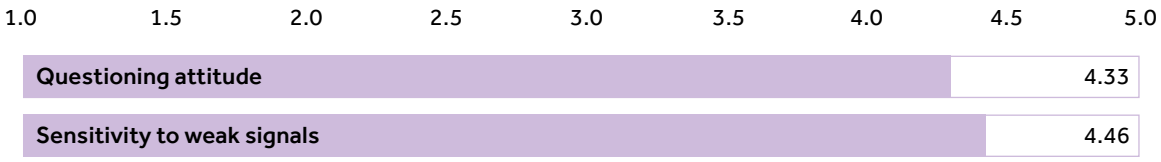
Presence of Accountability (M = 3.40) outlines the extent to which individuals are held accountable for their actions regarding safety. This requires appropriate action when poor safety behaviours are displayed and is applicable to people at all levels of the organisation.

Blame vs. Just Culture (M = 3.47) refers to the extent to which individuals are held to account in a fair way, without undue blame, and by adopting a learning approach to accountability.

CHALLENGE

A crucial component of safety culture in the nuclear industry is recognising and challenging behaviours and assumptions that could adversely impact safety immediately or in the future. Due to the high standard of safety within this industry, accidents or disasters occur rarely. However, remaining vigilant to spot and communicate warning signs early remains essential. Challenge includes two sub-dimensions: Questioning Attitude and Sensitivity to Weak Signals.

Industry Results



Unhealthy Culture

- Unsafe procedures would not be challenged.
- Workers feel uncomfortable challenging others on safety issues.
- It is not recognised that non-nuclear activity can impact nuclear safety.
- If workers notice something unusual, they would not ask others for advice.

Healthy Culture

- If something feels unsafe, workers always stop and question why.
- Even senior leaders would be challenged on their safety behaviour.
- It is regularly encouraged to keep a look out for any potential threats to safety.
- A high level of attention is paid to small issues in case they lead to serious safety events.

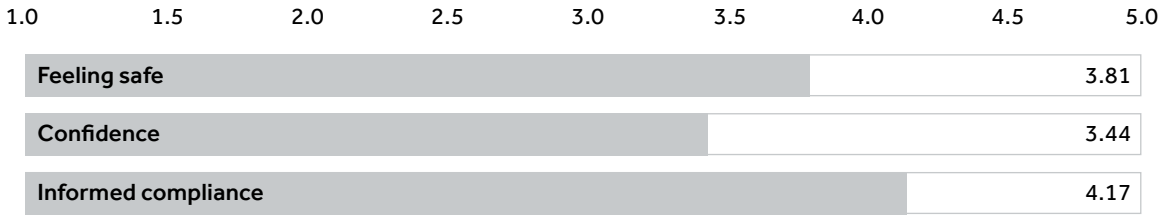
Questioning Attitude (M = 4.33) describes the extent to which individuals are comfortable challenging safety policies, procedures, behaviours, and norms, even if the challenge impacts productivity or questions senior leader actions.

Sensitivity to Weak Signals (M = 4.46) assesses the extent to which individuals remain vigilant for minor issues that may be warning signs or precursors of something more significant (e.g., being mindful that even non-nuclear activities can impact nuclear safety).

REPORTING

Reporting plays a key role in sustaining an organisation's safety culture. Reporting contributes to the identification, tracking, and management of safety events, and to the level of compliance workers exhibit. This dimension has three sub-dimensions: Feeling safe, Confidence and Informed Compliance.

Industry Results



Unhealthy Culture

- Raising safety concerns is seen as 'causing trouble'.
- No rewards for raising important safety issues.
- Safety concerns are unlikely to be investigated if they challenge productivity.
- No feedback is provided on concerns raised.
- Safety procedures are carried out regardless of if they are understood.
- Simple rules are often bypassed.

Healthy Culture

- Speaking up about safety is strongly encouraged.
- Reporting safety issues causes no concern to workers.
- Safety concerns are acted upon as soon as they are raised.
- The formal safety reporting system is used and works effectively.
- Compliance with procedures is always high.
- Workers are always fully informed about the risk and requirements of their work.

Feeling Safe (M=3.81) describes the extent to which employees feel safe to raise safety concerns without fear of personal consequence. This includes whether individuals who raise safety concerns are rewarded or seen as troublemakers.

Confidence (M = 3.44) assesses the extent to which employees are confident that any safety concerns raised will be acted upon. Here, the speed with which concerns are acted upon, even if they challenge other important organisational goals (i.e., productivity), and the effectiveness of the reporting system are important.

Informed Compliance (M = 4.17) represents the extent to which individuals understand the significance of, and comply with, safety rules and procedures. This requires individuals to be fully informed of the safety risks and requirements relevant to their job rather than blindly carrying out safety procedures that are poorly understood.

DISCUSSION

The quantitative measurement of organisational safety culture plays an important role in helping nuclear organisations and nuclear regulators monitor and develop organisational safety culture. Previous attempts to develop a measure of organisational safety culture in the nuclear industry, particularly those based on the use of the IAEA's Harmonised Safety Culture Model, have proven problematic in terms of measure validity and reliability. The aim of this project was therefore to develop a conceptual model of safety culture for GB's nuclear industry from which to develop a quantitative measure of safety culture.

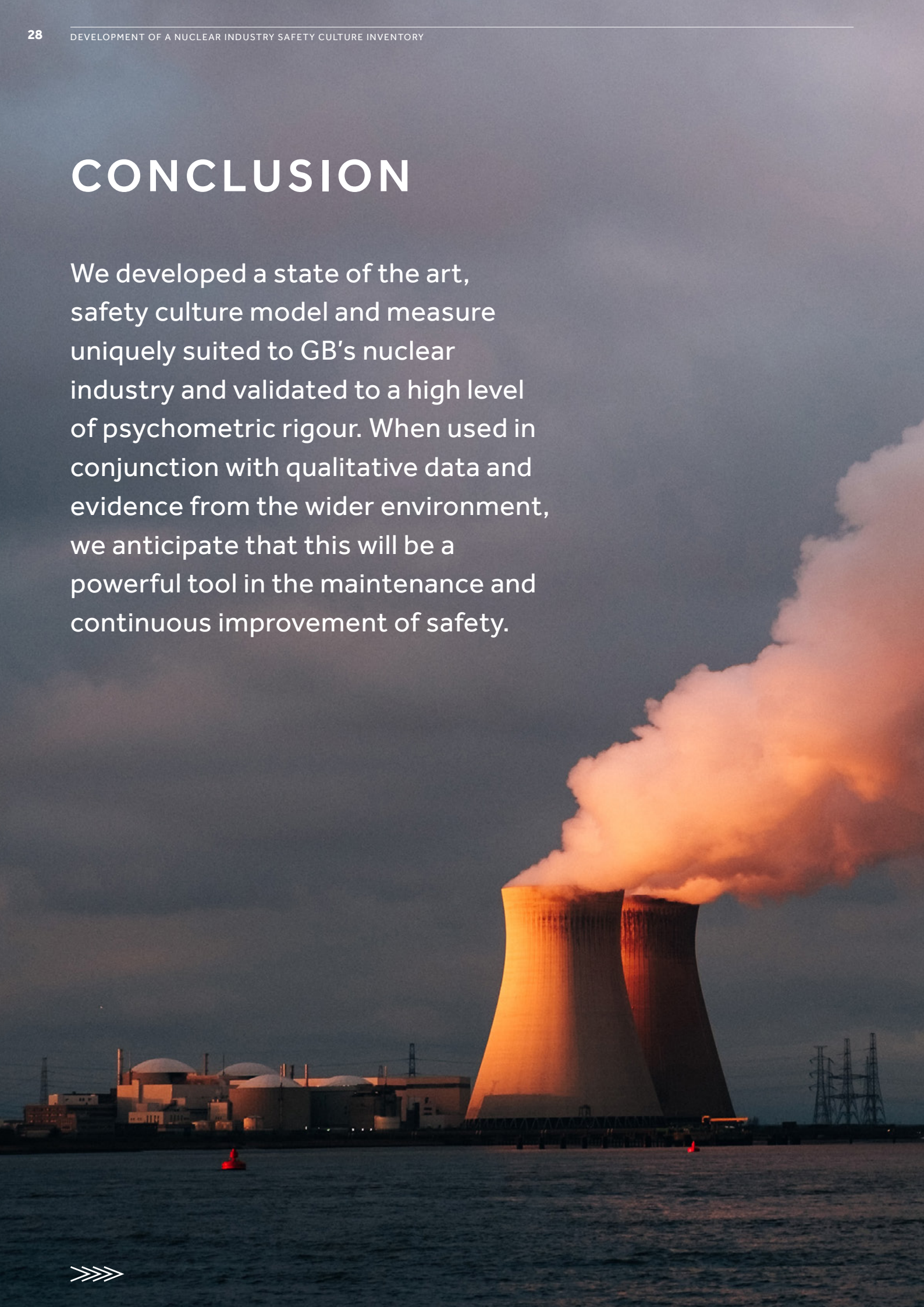
We engaged with academic and industry experts in nuclear safety culture and worked closely with nuclear dutyholders, including operating reactors, fuel cycle facilities, decommissioning sites, defence sites, waste treatment and storage sites, and a new nuclear facility under construction, to develop a conceptual model of safety culture for GB's nuclear industry, which is theoretically sound, and has significant practical use. This formed the basis of a quantitative measure to identify elements of safety culture, and support efforts to monitor and improve safety culture. The validity evidence collected across multiple phases of data collection show that the NISCI accurately captures safety culture in GB's nuclear industry and is appropriate in its application. Specifically, this tool not only provides a rich evaluation of a nuclear dutyholder's safety culture, but the scores generated by the tool also correlate with safety performance as rated by employees in the nuclear industry and by ONR inspectors.

Limitations

We have developed the safety culture model and measure specifically for GB's nuclear industry and they would require further testing to ensure their wider applicability, for example the use by other high hazard industries or the nuclear industry of other nations. Whilst the results provide a useful industry benchmark of safety culture that includes data from 15 out of 17 dutyholder organisations, it is important to bear in mind that the results are based on a sample of 3480 participants. Although this tool provides the most comprehensive and nuanced assessment of safety culture in the nuclear industry to date, we recommend that dutyholders use the tool as a diagnostic in conjunction with qualitative evidence and broader evidence from the environment to develop policy (IAEA 2016, ONR, 2021).

CONCLUSION

We developed a state of the art, safety culture model and measure uniquely suited to GB's nuclear industry and validated to a high level of psychometric rigour. When used in conjunction with qualitative data and evidence from the wider environment, we anticipate that this will be a powerful tool in the maintenance and continuous improvement of safety.



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APPENDICIES

APPENDIX A

ADDITIONAL SCALES

1. SAFETY PERFORMANCE SURVEY ONR

This section asks you to rate the safety performance of X (dutyholder).

Have you worked with X in the past 5 years?

◯ Yes (rate dutyholder) ◯ No (directed to the next dutyholder)

Instruction

Please indicate the extent to which you agree with the following statement ranging from 1 (strongly disagree) to 5 (strongly agree) based on your experience working with X (dutyholder).

1. X maximise learning opportunities from safety-related events.
2. X are open in their approach with ONR.
3. X respond in a timely manner to ONR feedback.
4. X respond well to emergencies.
5. At X. equipment is carefully maintained.
6. At X, operational activities are undertaken reliably.
7. X have an effective internal oversight process.
8. The decision making at X reflects that safety is the number one priority.
9. X manage change effectively.
10. X have a high standard of cleaning.
11. X have a good accident performance record.

APPENDIX B

SAFETY CULTURE DIMENSIONS, DEFINITIONS, AND EXAMPLE ITEMS

Table 3: Safety Culture Dimensions, Definitions, and example items

Dimension	Definition	Example item
1. LEADERSHIP		
Communication	The Leader provides clear, consistent, frequent, and engaging communication of the importance safety.	- Senior leaders set clear safety standards. - Senior leaders regularly perform safety walks.
Consistency	The Leader's behaviour is consistent with messaging. (He/she 'walks the talk').	- Senior leaders do not prioritize safety issues as highly as they say they do. (R) - Senior leaders practice what they preach when it comes to safety.
Openness	The Leader is open to feedback and ideas regarding safety.	- Senior leaders are open to hear about safety-related ideas. - Senior leaders make changes based on safety feedback.
2. LINE MANAGEMENT		
Communication	The Line Manager provides clear, consistent, frequent and engaging communication of the importance safety.	- My line manager has difficult conversations to uphold safety standards. - My line manager checks if there are safety concerns before starting work.
Consistency	The Line Manager's behaviour is consistent with messaging. (He/she 'walks the talk').	- My line manager says one thing about safety but does another. (R) - My line manager does not live up to the organisation's safety standards. (R)
Openness	The Line Manager is open to feedback and ideas regarding safety.	- My line manager takes the safety ideas of employees seriously. - My line manager asks for ideas to improve safety.
3. IMMERSION		
Feeling Valued	Employees feel respected, trusted, and valued within the organisation.	- I feel valued at work. - My organisation rewards employees who exhibit good safety behaviour.
Disengaged	Employees feel detached and withdrawn (switched-off) from the safety culture.	- I tend to switch off when safety is talked about. - My safety behaviour makes little difference.

Dimension	Definition	Example item
4. ACCOUNTABILITY		
Presence of Accountability	The extent to which individuals are held accountable for their actions regarding safety.	- People at this organisation get away with poor safety behaviour. (R) - People at all levels of this organisation are held to account when it comes to safety.
Blame vs. Just Culture	When individuals are held to account it is done in a fair way, with open and transparent arrangements.	- In this organisation, individuals are blamed for safety failings. (R) - People in this organisation would be treated fairly if they admitted an honest mistake.
5. CHALLENGE		
Questioning Attitude	Individuals examine and challenge safety policies, procedures, behaviours, and norms.	- I challenge procedures if they do not seem safe. - If something seems unsafe, I stop and question why.
Sensitivity to Weak Signals	Individuals remain vigilant for conditions which can adversely impact safety and recognise that minor issues may be warning signs of something more significant.	- I pay attention to small issues that could lead to serious safety events. - I am encouraged to keep a look out for any potential threats to safety.
6. REPORTING		
Feeling Safe	People feeling empowered to raise safety concerns without fear of personal consequence.	- People who raise safety issues are seen as troublemakers. (R) - I have no concerns reporting safety issues.
Confidence	People believe that the safety concerns they raise will be acted upon.	- Safety concerns are acted on as soon as they are raised. - Raising safety matters on the formal reporting system feels like waste of time. (R)
Informed Compliance	Individuals strictly follow rules and procedures	- I feel fully informed of the safety risks and requirements relevant to my job. - There is a high level of compliance with procedures.

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