Safety climate in high safety maturity organisations: development of a multidimensional and multilevel safety climate questionnaire

Niccolò Maria Todaro[a], Francesco Testa[a], Francesco Rizzi[b], Felipe Vizzoto[c], Matteo Curcuruto[d]

[a]Institute of Management, Sant'Anna School of Advanced Studies
Piazza Martiri della Libertà, 33 - 56127, Pisa, Italy

[b]Dipartimento Di Economia, Università degli Studi di Perugia
Piazza dell'Università, 1 - 06123 Perugia, Italy

[c]INSEAD Business School
Boulevardd de Constance - 77300 Fontainebleau, France

[d]Psychology Applied to Safety and Health, Leeds School of Social Sciences, Leeds Beckett University
Queen Square House, G31, City Campus, Leeds LS1 3HE, United Kingdom

Abstract

The proliferation of operationalisation approaches to safety climate has failed short of establishing a common set of dimensions and measurement items. Furthermore, extant measures are designed to accommodate all organisations regardless of safety management maturity; thus, a safety climate measurement scale suited to high-maturity organisations is still missing. Drawing on a systematic review of safety climate measurement literature, the article reports the development and validation of a multi-dimensional and multi-level safety climate measurement scale, suited to organisations with high safety management maturity. To corroborate the validity of the measure, the study was conducted in cooperation with health & safety managers from 15 large companies with a mature safety management system. Following initial questionnaire development, a multi-stage validation procedure was implemented on data from four large companies (totalling 880 participants) operating in the electric power distribution, oilfield services, manufacturing, minting and printing sectors in Italy. Exploratory factor analysis was used for the identification of the underlying structure of the set of items. Confirmatory factor analysis was undertaken to evaluate the model fit at the validation stages. The final version of the questionnaire consists of eight safety climate dimensions and 60 items. A short version of the scale is also validated to provide a more balanced, while complete and reliable, measurement tool (totalling 40 items). Lastly, implications for safety practitioners are discussed, providing directions on how to utilise the scale for identifying safety improvement opportunities.

Keywords: Safety climate; Safety management; Occupational safety; Safety climate questionnaire; Scale development and validation;

1. Introduction

The tragic events of Seveso, Chernobyl and Bhopal underscored the role of safety management practices in improving safety of work environments (Barling et al., 2003; Neal & Griffin, 2006). The need to integrate safety practices within a holistic framework of organisational management systems informed the development of regulatory initiatives from public and private institutions. A prominent example is the 1982 Seveso Directive of the European Union, which emphasised the importance of adopting a management system to prevent major accidents (Swuste & Reniers, 2017). In 1999, the British Standard Institution introduced the first global standard for occupational health and safety management systems: OHSAS (Occupational Health and Safety Assessment Series) 18001 (Fernández-Muñiz et al. 2012a).

Early research found the adoption of OSHAS 18001 to benefit both safety and competitive performance (Fernández-Muñiz et al., 2009; Vinodkumar & Bhasi, 2011; Abad et al., 2013; Lafuente & Abad, 2018). More recently, scholars have increasingly challenged the effectiveness of occupational health and safety (OHS) management systems, claiming that the adoption of such tools is an inadequate effort for improving workplace safety (Ghahramania & Salminen, 2019; Heras-Saizarbitoria et al., 2019), as safety improvement is contingent upon the substantial internalisation of management standards' requirements in daily routines and behaviours (Madsen et al., 2020).

In this view, scholars have frequently highlighted safety climate as a crucial factor in the substantial internalisation of OHS management systems (Fernández-Muñiz et al., 2012b; Griffin & Curcuruto, 2016; Kim et al., 2019; Madsen et al., 2020; Ismail et al., 2021). Safety climate is often defined as the "*shared perceptions with regard to safety policies, procedures and practices*" (Zohar, 2011, p.143), or as the *"perceptions of the middle and outer layers"* – i.e. values, artefacts and behavioural manifestations (Guldenmund, 2000) – *"of safety culture at a given point in time"* in an organization (Casey et al., 2017 p.349). The importance of safety climate is evident in ISO 45001 standard, which replaced OSHAS 18001 in 2018. The standard stresses safety climate as a success factor for the effective implementation of the OHS management system (see clause 0.3, ISO

45001), as a key driver of continuous improvement (see clause 10.3, ISO 45001), and as an objective that managers should pursue to support the OHS management system (see clause 5.1, ISO 45001). In addition, several dimensions of safety climate are inherently connected to key requirements of ISO 45001, such as management commitment, training, information sharing, and workers' involvement.

Organisations that pursue substantial compliance with ISO 45001 requirements and the continuous improvement of safety outcomes have an obvious interest in nurturing a positive safety climate. This ambition leads to the question: how to assess safety climate? Practitioners may wonder what safety climate measurement tool to use for obtaining complete and reliable information with regard to their organisations' safety climate. However, despite the proliferation of safety climate measurement scales, research has failed short of defining "*a standard set of dimensions or measurement items*" (Hofmann et al., 2017 p. 383). The profusion of operational instruments may also constitute a barrier for practitioners wanting to approach this research domain, aggravating the "gap" between research and practice (Sharma & Bansal, 2020). Moreover, existing safety climate measurement tools are conceived to be applicable in any organisation, regardless of the level of safety management maturity (Goncalves Filho et al., 2010; Goncalves Filho & Waterson, 2018), constraining the utility of such tools in organizations characterized by high safety commitment. According to Fleming (2001) and Hudson (2007), organizations with high safety management maturity are characterized by a collective commitment to safety (i.e. interdependence) and full embeddedness of safety in the organization's activities (i.e. generativeness).

Defining a reliable and complete safety climate measurement tool constitutes a priority for those organisations that, despite having achieved a certain level of safety maturity, still want to go the "extra-mile" on safety performance. However, to the best of our knowledge, a safety climate measurement scale suited to the specificities of organisations with high safety maturity is still missing. Accordingly, the present study draws on a systematic review of safety climate operationalisations to develop a multi-dimensional and multi-level safety climate measurement scale. The study was conducted in cooperation with a community of 30 HSE managers from 15 large Italian companies with mature safety management systems in order to further corroborate the validity and practical applicability of the measurement tool. The scale was validated on a sample of 1,688 workers from 4 large companies operating in the electric power distribution, oilfield services, manufacturing, minting and printing sectors in Italy.

The contribution of the study is twofold. First, the study contributes to answer Hofmann and colleagues (2017) call to establish the dimensionality of safety climate by combining academics and practitioners' views through a participatory approach to research. Drawing on Bansal & Sharma (2022), the study paired methodological rigour and practical relevance in co-creating an actionable measurement tool aimed at guiding the identification of safety climate improvement opportunities in organisations with high safety maturity. Second, the article contributes to research on OHS management systems by advancing an operational approach to assess the internalisation of OHS standards' requirements, by examining those "soft" elements that are critical success factors of management systems (Lülfs & Hahn, 2013).

2. Theoretical background

Maturity models involve defining maturity stages or levels which assess the completeness of the analysed objects, usually organisations or processes, via different sets of multi-dimensional criteria (Wendler, 2012; Becker et al., 2009). They consist in descriptive models in the sense that they describe essential attributes that would be expected to characterise an organisation at a particular level. The application of this concept is not limited to any particular domain (Wendler, 2012) and maturity models can be used both as an assessment tool and as an improvement tool (Maier et al., 2012). In the field of safety management, maturity models are seen in terms of a continuum ranging from organisations that have unsafe cultures ('pathological' organisations) through to those who manage safety proactively ('generative' organisations) (Hudson, 2007). Therefore, organisations are seen as progress sequentially through the stages, by building on the strengths and removing the weaknesses of the previous levels (Fleming, 2001). One of the first maturity model developed to assess safety was Dupont Bradley Curve which was used by Fleming (2001) to develop a safety culture maturity model. The four stages in this model are: (i) reactive; (ii) dependent; (iii) independent; and, (iv) interdependent (Foster and Hoult, 2013). In the first reactive stage of maturity people do not take responsibility. They believe that safety is more a matter of luck than management, and that "accidents will happen". In a dependent maturity stage there is an emphasis on management and supervisory control with a heavy focus on written rules and procedures. An independent maturity stage the focus is on a personal commitment to and responsibility for safety. The final maturity stage is interdependent, where there is a shared collective commitment to safety with everyone having a sense of responsibility for safety beyond their own work and by caring for the safety of others.

A second well-established typology of organizational maturity model in safety management is the one proposed by Hudson (2007). Hudson's model distinguished five types of maturity levels: pathological, reactive, calculative, proactive and generative. The descriptions of each maturity stage of development of safety culture according to Hudson (2007) are as follows: Pathological: safety is usually seen as a problem caused by workers. The main drivers are the business and a desire not to get caught by the regulator. Reactive: organisations start to take safety seriously but there is only action after incidents. Calculative: safety is driven by management systems, with much collection of data. Safety is still primarily driven by management and imposed rather than looked for by the workforce. Proactive: with improved performance, the unexpected is a challenge. Workforce involvement starts to move the initiative away from a purely top down approach. Generative: there is active participation at all levels. Safety is perceived to be an inherent part of the business. Furthermore, organizations operating at the higher maturity levels are characterized by chronic unease, an ongoing state of managerial watchfulness (as opposite to compliancy) aimed to address in advance any weak signal or minor breach of safety standards as something that need immediate attention before they develop in something dangerous for the safety of people and the workplace.

All these maturity models share common characteristics and present distinct stages of maturity with distinct nomenclature. These models serve as diagnostic tools that assist organisations in determining the effectiveness of their current safety culture dimensions or the factors, they need to acquire next to improve their OHS performance. As reported by Ayob et al. (2022) in a recent systematic literature review, in spite of the diffuse usage of maturity models in safety critical organisations, the evaluation of the validity of the measurement tools deployed to collected employees' perceptions about their company maturity still remain an open issue. Even if there is a general consensus about the usage of surveys and questionnaires as reliable tool to collect large amount of data, contingent elements such as the typology of business and the size of the company may affect the appropriateness of the methodology and measurement in a given context. As reported by Ayob et al. (2022), the majority of the publications on safety culture maturity models are concerned with the conceptual development of a maturity model that fits with the features of a single specific industry, rather than on the evaluation of the validity of the measurement tools adopted to assess the maturity of safety culture.

In the light of this open issue reported in literature, the present study aims to offer a systematic validation process of a questionnaire survey which can help researchers and managers to evaluate the predisposition of a company to operate accordingly with the principles of a high safety maturity. Based on the two well-established maturity models developed by Fleming (2001) and Hudson (2007), in our study we will consider two characterizing elements of an high safety maturity: the degree of 'interdependence', which identifies a collective commitment to safety with everyone having a sense of responsibility for safety beyond their own work and by caring for the safety of others (Fleming, 2001), and the degree of 'generativeness' which indicates the reciprocal embedment of safety culture and the business of the company, which supports a managerial mindset of 'watchfulness' aimed to address in advance any weak signal that may threat the safety of the operations.

3. Method

The development and validation of a safety climate measurement tool followed five consequential steps (Figure 1). The following paragraphs detail the procedures and outputs of each step.

:::::::::::::INSERT FIGURE 1 HERE::::::::::::

3.1. Bibliographic research

The first step consisted in retrieving studies concerning the definition and measurement of safety climate. The bibliographic research followed the steps of a systematic literature review (Tranfield, Denyer, & Smart, 2003; Denyer & Tranfield, 2009): locating studies based on selected keywords and inclusion criteria; screening and selecting studies based on a set of exclusion criteria. Keywords "*safety climate*" and "*survey*" were selected to perform search queries on two bibliographic databases, ISI Web of Science and Scopus. A search string composed of two blocks connected by the Boolean operator "AND" was built: the first block included the term "*safety climate*", while the second encompassed "*survey*" and related words (e.g. questionnaire, measurement etc.) connected by the operator "OR". Inclusion criteria regarding the type of publication (journal articles), timespan (from 2000 onwards), language (English) and subject area (Business / Management) were added to source only recent international academic publications within the organisational and business management fields and safety-related journals. No geographical criteria were applied in order to preserve the comprehensiveness of the identification of measurable aspects and their relevance for companies worldwide. A total of 894 articles were located.

Relevant studies were selected using two distinct screening processes. The first screening excluded studies based on research methods other than surveys (e.g. qualitative studies) and studies using sector-specific measurement tools (e.g. healthcare, fishing, retail, or agricultural sectors), by analysing titles and abstracts. This screening excluded 793 studies. The second screening process examined the full texts of the remaining 101 studies to exclude articles that did not disclose the questionnaire: 22 articles were excluded, resulting in a final sample of 79 studies. All the authors analysed the studies separately and equally contributed to achieve a common agreement on the exclusions. The systematic literature review is summarised in Figure 2.

::::::::::::INSERT FIGURE 2 HERE::::::::::::

3.2 Analysis & Coding

The second step focused on: (1) mapping safety climate dimensions found in the selected studies; and (2) extracting questionnaire items from each dimension. Operationalisations of safety climate considerably differed across papers: while some studies treated safety climate as a single construct (e.g. Neal et al., 2000), some studies focused on sub-constructs or specific dimensions of safety climate (such as “open communication”, “safety training”, etc.) (e.g. Vinodkumar & Bhasi, 2009). This information was included in a datasheet: for each study, the datasheet recorded the name of the safety climate constructs, the questionnaire items associated with each construct, the title of the study, authors, year of publication and name of the journal. This process identified 301 constructs and 1146 questionnaire items.

The questionnaire items were screened according to the following exclusion criteria: (1) items that were duplicates or highly redundant; (2) items with an ambiguous meaning, unclear formulation or confusing syntax; (3) items that focused on organisations’ regulatory compliance (e.g. “*Safety regulations are respected in my workplace*”) as compliance with HSE procedures and individual safety-related behaviours are usually considered criteria variables, and not internal components of safety climate (Griffin & Curcuruto, 2016); (4) items that implied a self-assessment of HSE- or safety-related behaviours, such as compliance (e.g. “*I always use the correct safety procedures to carry out my job*”) and participation (e.g. *“I proactively join safety activities in my* *organisation”*). These criteria responded to the aim of delineating a safety climate measurement tool suited to organisations with high safety maturity. To reduce subjectivity in the screening of questionnaire items, all items were assessed by four researchers in parallel. The outputs of the selection processes were discussed to reach an agreement on the evaluation of each item. As a result, 1029 questionnaire items were excluded.

117 questionnaire items were retained for the thematic analysis. In line with the Griffin & Neal (2000) conceptualisation of safety climate as *“a higher-order factor comprised of more specific first-order factors”*, this process aimed at bringing out the dimensions – or first-order factors – of safety climate from the selected literature. In line with the prevailing approaches from the extant literature, these dimensions were conceived as reflective constructs, i.e. their items are caused by the constructs, which serve as theoretically independent building blocks of safety climate, which is thus conceptualized as a multidimensional score.

The thematic analysis relied on a two-step abductive coding process (Dubois & Gadde, 2002), which iteratively combined deductive and inductive coding. The inductive nature of this approach implied that each item was coded regardless of its original construct – i.e. how the item was categorised in its original questionnaire – so that codes could lead to the definition of novel and unprecedented safety climate dimensions that were not consistently explored in previous studies. The deductive approach allowed grounding the coding process on a solid theoretical foundation, supporting the interpretation of measurement items especially when disagreements between researchers occurred. In the first step, codes were inductively assigned to questionnaire items based on their thematic content (Gioia et al., 2013). In the second step, axial coding was applied to examine conceptual relationships among the codes and deductively aggregate conceptually-related codes into second-order dimensions (i.e. the safety climate dimensions) (Strauss & Corbin, 1998). This process was carried out by four researchers in parallel to reduce subjectivity. Both second-order dimensions and items’ codes were then compared and discussed to reach consensus about the number, content and naming of the constructs. As a result, nine safety climate dimensions – illustrated in Table 1 – emerged from the coding process.

::::::::::::INSERT TABLE 1 HERE::::::::::::

Second, codes were assigned to questionnaire items based on the target of perceptions. Items were categorised according to whom the item is referring to: the organisation, the supervisor or the co-workers. Following Zohar & Luria (2005) conceptualisation of safety climate as a multi-level framework, which discriminates between organisation- and workgroup-level safety climate, this process aimed at delineating the levels of analysis of each dimension of safety climate. According to Huang et al. (2013), organisation-level safety climate refers to perceptions about *"procedures established by the company and top management actions in the promotion of safety"*, while workgroup-level safety climate refers to perceptions about *"direct supervisory and workgroup safety practices"*.

The coding process assumed the organisation or top management as targets of organisational-level safety climate perceptions: items like *"My organisation is interested in continually improving safety in each department"* or *"Top management regularly consults with employees about workplace safety issues"* were categorised as "organisation-level". The direct supervisor and the co-workers were assumed as targets of workgroup-level safety climate perceptions: items like "*My supervisor frequently tells us about the safety hazards in our work"* were categorised as "workgroup-level (supervisor)", while items like *"Co-workers often exchange tips with each other on how to work safely"* were categorised as "workgroup-level (co-workers)".

While most safety climate dimensions are elicited at both organisation- and workgroup-level, some dimensions refer to a single target of perception and thus relate to a single level of analysis. Questionnaire items for OC, PI, SP, MC, PAA, and Tr cover several targets of perceptions – organisation and top management, supervisors, and co-workers – and thus relate to both levels of analysis. PSP and PS instead elicit perceptions about the organisation's safety management system and procedures and thus were solely associated with the organisation-level. The items for WS&S were coded as "co-workers", as they refer to co-workers' well-being, work security and satisfaction; thus, this dimension is only elicited at the workgroup level. Step 2 is summarised in Figure 3.

::::::::::::INSERT FIGURE 3 HERE::::::::::::

3.3 Selection and fine-tuning.

The third step aimed at selecting the items that provided the most valid measure for each safety climate dimension, by consulting 30 HSE managers from 15 large Italian companies and two experienced HSE consultants. Consultation with HSE managers aimed at grounding items selection on practitioners' knowledge of workplace safety management (Hardesty & Bearden, 2004). These companies were selected according to the following criteria: high commitment to participate in the research activities, high safety management maturity, and experience in operating internationally. These participants adequately represented the needs and expectations of western companies and reported considerations on the geographical or sectoral limitations of the scale, if any.

In the frame of a 4-hour long focus group, HSE managers were asked to rank questionnaire items, for each dimensions, according to face validity, i.e. *"the extent to which a measure reflects what it is intended to measure"* (Hardesty & Bearden, 2004). Participants ranked items within levels of analysis, distinguishing between organisation-level and workgroup-level. At the workgroup-level, a further distinction between supervisor- and co-workers-level was made (Lingard et al., 2011; Brondino et al., 2012). Items with the poorest scores were discarded to retain the three most valid items per level of analysis in multi-level dimensions (i.e. OC, PI, SP, MC, PAA, and Tr), and the four most valid items in dimensions with a single level of analysis (i.e. PSP, PS and WS&S). As a result, 51 items were discarded because of unsatisfactory face validity.

HSE practitioners were also asked to evaluate the content validity – i.e. "*the degree to which a measure's items represent a proper sample of the theoretical content domain of a construct"*

(Hardesty & Bearden, 2004) – of each safety climate dimension. HSE consultants also supported HSE managers in assessing the theoretical clarity of the dimensions. When items were considered not representative of a dimension, participants re-assessed the previously-discarded items and re-integrated some of them in the scale. This process led to reintroduce nine items in the scales for the following dimensions: OC at organisation-level, PI at workgroup-level, SP at supervisor-level, MC at organisation-level (two items), PAA at organisation-level, PSP and PS (two items). Participants also discarded the WS&S dimension (4 items): concepts of work-task satisfaction and job security were considered distant from workplace safety, and the dimension was found to lack internal validity due to the association of theoretically diverse concepts of work meaningfulness, job security and organisational well-being.

As a result of the validity screenings, 71 questionnaire items were retained in the measurement scale. Safety climate dimensions' scales ranged from a minimum of 5 items (i.e. PSP) to a maximum of 11 items (i.e. MC), while on average most scales had 5 – 10 items, which is considered an appropriate number of observed indicators for estimating latent variables (Marsh et al., 1998).

HSE managers were then engaged in an additional 4-hour long focus group to discuss ambiguous terminology, overlapping contents and unclear syntax. Terminology was slightly adjusted to resemble the technical jargon most commonly used by frontline workers. Syntax was harmonised across all questionnaire items to avoid dissimilarities from item to item that could tire the respondent. In addition, all items in the dimension "Safety Priority" were formulated as negatively-worded statements, to maintain resemblance with the original scales and strengthen the dimension's meaning of tension between conflicting objectives of production and safety. Step 3 is summarised in Figure 4.

:::::::::::::INSERT FIGURE 4 HERE:::::::::::::

3.4 Pre-test and data collection.

After taking part in Step 3, four companies – Company 1, 2, 3 and 4 (Table 2) – pre-tested the measurement scale among a small sample of employees. These companies, which are four large enterprises operating in Italy in the electricity distribution, oilfield services, manufacturing, printing and minting sectors, were selected following the same criteria previously applied to HSE managers. All selected companies can be considered to have an advanced and homogeneous level of organisational safety culture (Lawrie et. 2006; Goncalves Filho & Waterson, 2018; Stemn et al., 2019): each company possesses a formalised HSE department, which is appointed to (i) safety procedures, (ii) safety training, (iii) audits and site inspections, (iv) root-cause analysis whenever an incident or near miss occurs, (v) corrective actions, (vi) stimulating a positive safety culture, (vii) assessing and monitoring safety performance. All companies also implement an OHS management system according to ISO 45001:2018.

Each company arranged a pre-test meeting involving a total of 22 employees. Researchers took part in a pre-test meeting, while the companies autonomously held the remaining meetings: in the latter cases, companies submitted the questionnaire, recorded respondents' feedback and reported filled-out questionnaires to the researchers. All the responses were voluntary and anonymous, and no incentive was offered for participation. The companies did not disclose the survey's topic and objective to reduce the risk of distortion in the sample and answers.

The questionnaire was arranged in a self-administrable format. An introductory text ensured anonymity and confidentiality of the research, by stating that: data will be managed and retained by the researchers; results will be presented in an aggregated form, so that responses could not be tracked back to individual respondents; disaggregated data will not be provided to the respondents' employer or to other parties. Scales for each safety climate dimension were placed on separate pages: a brief description of the content was placed at the beginning of each section; each dimension scale was introduced by the question *"Do you agree with the following statements? Please rate your level of agreement with each statement* on *a scale from 1 = "Totally disagree" to*

6 = "Totally agree". Choose the option "Don't know" only when you believe you do not have sufficient information to express an opinion about the statement.". The 1 – 6 Likert scale was utilised to avoid a neutral midpoint: neutral midpoints on disagreement/agreement scales are often used as "dumping grounds" or "opt out" options by respondents when the content of the question is considered sensitive, socially undesirable or controversial (Chyung et al., 2017).

During pre-test meetings, respondents took note of unclear terms or ambiguous questions. Specific attention was paid to the risk of acquiescence bias – i.e. the tendency of respondents to agree when confronted with agree-disagree survey questions (Billiet & McClendon, 2000) – by examining the questionnaires filled during pre-tests. Attention was also paid to *"Don't know"* answers, as an excessive tendency to provide *"Don't know"* answers to specific questionnaire items could signal flaws in item formulation. *"Don't know"* answers appeared limited, and they did not recur on specific items. Following the pre-test, the researchers ratified the final version of the questionnaire (Annex 1).

Company 1, 2, 3 and 4 proceeded in the data collection phase. In each company, the scope of the research setting was outlined in collaboration with the HSE personnel, based on two criteria. First, the selection of departments was based on the relevance of safety aspects. Consequently, operational departments (e.g. maintenance, logistics, production, etc.) were preferred over functional/business departments (e.g. sales, human resources, marketing, etc.), as workers in operational units were considered better informants for the sake of the research. Second, the research was addressed to frontline workers – i.e. workers who perform their work duties on-site – rather than office workers. Frontline workers were considered best informants regarding workplace safety management practices because they are directly exposed to safety risks.

Once defined the research scope, the company submitted the questionnaire to all workers within the research scope. The research scope is detailed in Table 2.

::::::::::::INSERT TABLE 2 HERE::::::::::::

The questionnaire was uploaded to an online survey platform. Between December 2019 and January 2020, the survey platform was made accessible on the companies' intranet, and respondents were emailed an introductory letter with detailed instructions on how to complete the questionnaire. Company 1 collected data both in Italy and abroad to test the applicability of the scale in different geographical settings. Reminder emails were sent every two weeks. A total of 1,688 respondents took part in the survey.

Several data quality checks were carried out. First, incomplete questionnaires were discarded to dodge missing data bias (Newman, 2014): all "*Don't know*" responses were treated as missing data. Second, a "straight-lining" check was carried out to detect respondents that exhibit zero variability in responses across questionnaire items (Johnson et al., 2019): standard deviations across all safety climate measurement items were computed for each respondent in the dataset; thus, respondents with standard deviation equal to zero were discarded. This same procedure was repeated after reverse-scoring all negatively worded items in the questionnaire (e.g. from SP.1 to SP.10). Third, outliers were detected based on the Tukey's fence method for nonparametric data (Zijlstra et al., 2011).

As a result, 808 questionnaires were discarded and 880 questionnaires were retained for analysis: two companies achieved the 50% response rate, while two companies exceeded a satisfactory 40% response rate. Information regarding the response rate is provided in Table 2, while details about the overall sample are provided in Table 3.

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3.5 Data analysis.

The analysis relied on three distinct phases. First, utilising data from Company 1 (i.e. 579 participants), an exploratory factor analysis (EFA) was conducted to test the dimensionality of safety climate dimensions' scales. EFA technique is suited for assessing the factor structure of novel psychometric scales (Morgan et al., 2021): by identifying relationships among observed variables, this technique discerns items that load to the same latent construct. EFA based on principal axis factoring (PAF) and direct oblimin rotation was carried out separately on each safety climate dimension. By identifying the number of factors that account for the most variance within each set of items, this process allowed to discard questionnaire items with an unsatisfactory or unclear association – e.g. low factor loading or double loading – with the scale (Iacobucci, 2010). The convergence between statistical evidence (structural, convergent and discriminant validity) and the theory-based formulation of items (content validity) confirms the validity of constructs.

Second, utilising data from Company 2, 3 and 4 (i.e. 301 participants in total), confirmatory factor analysis (CFA) based on the maximum likelihood estimation model was conducted to test the internal consistency and reproducibility via the overall goodness-of-fit of the safety climate measurement scale. All questionnaire items retained from EFA were included in the CFA, also specifying associations between observed variables (i.e. items) and the latent constructs (i.e. safety climate dimensions). The ratio of model $\chi2$ to degrees of freedom ($\chi2$/df) was computed to assess the difference between the data and fitted covariance matrices: $\chi2$/df values lower than 5 indicates a satisfactory model fit, while a value lower than 3 is considered good. Tucker-Lewis index (TLI) and comparative fit index (CFI) assessed the difference between the fit of the hypothesised model and that of a baseline or null model: TLI and CFI values between 0.90 and 0.95 are generally considered satisfactory, while values higher than 0.95 are considered good. Root mean square error of approximation (RMSEA) assessed the difference between the observed covariance matrix and the model implied covariance matrix (i.e. hypothesised model): values lower than 0.05 indicate a good fit, whereas values ranging from 0.05 to 0.08 are usually considered satisfactory (Hu and Bentler, 1999; Kline, 2005). We used the Cronbach's alpha (CRA) coefficient and composite reliability (CR) index (Bagozzi & Yi, 1988; Cortina, 1993) to provide statistical evidence of the convergent validity of each scale. We assessed the discriminant validity of each safety climate dimension scale by computing its average variance extracted (AVE), i.e. the amount of total variance explained by every single construct. Besides the accuracy of the measurement tool, we tested its consistency to ensure its reliability. To this end, we tested discrimination through Feguson's delta and scalability through Loevinger's H coefficients.

Third, based on the CFA results, this step aimed at extracting short versions of the safety climate measurement scale and test its goodness-of-fit *vis-à-vis* the long version of the scale. This process meets a twofold objective. First, it aims at validating a concise, less time-consuming yet complete and balanced version of the safety climate scale, with an equally satisfying measurement quality. Cross-sample comparisons were conducted to test the short-scale goodness-of-fit. Second, it aims at validating level-specific versions of the safety climate scale, i.e. organisation-level and group-level scales.

4. Results

4.1 Exploratory factor analysis results.

Company 1's sample was utilised to conduct EFAs on each safety climate dimension to detect meaningful relations between observed variables and latent constructs. Factor loadings were considered satisfactory when above the threshold of 0.40 (Jung and Lee, 2011). When items cross-loaded onto more than one latent factor (i.e. double-loading effect), a threshold of 0.60 was considered (Morris et al., 2021).

EFAs results are displayed in Table 4. Columns with heading *"EFA factor loadings"* report the factor loadings for each dimension's items. The column with the heading "*Decision on the item*" provides information regarding the decision made on each item (i.e. retained or discarded), based on the value of factor loadings and double-loading effects. When items load on more than one latent factor, the factor loading related to the second factor is reported in brackets.

When applied to multi-level safety climate dimensions (i.e. OC, PI, SP, MC, PAA, Tr), EFAs highlighted the partition of questionnaire items across the three levels of analysis – i.e. organisation-level, workgroup-level (supervisor) and workgroup-level (co-workers) – thus supporting a multi-level conceptualisation of safety climate dimensions (Zohar & Luria, 2005). When applied to single-level dimensions (i.e. PSP and PS), items loaded onto a unique major latent factor. As a result of EFAs, eleven questionnaire items were discarded due to unsatisfactory factor loadings from the following dimensions: OC (two items), SP, MC, PAA (two items), Tr, PSP, and PS (three items). 60 items were retained for subsequent analysis.

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4.2 Confirmatory factor analysis results, internal reliability and discriminant validity indices.

The CFA was conducted on 60 items retained from the previous analysis. Companies 2, 3 and 4's samples were utilised. First, items' loadings onto the latent constructs were assessed to detect unsatisfactory factor loadings. The analysis yielded factor loadings greater than 0.60 for all questionnaire items (Iacobucci, 2010), so all items were retained in the measurement model. The model presented satisfactory fit indices: the $\chi 2/df$ ratio amounts to 2.13 ($\chi 2(3200.19) = 1502$, $p < 0.001$) against a < 5 acceptability threshold; second, TLI and CFI are 0.92 and 0.93, respectively, above the threshold value of 0.90; RMSEA is 0.051, against a < 0.08 acceptability threshold (Hu and Bentler, 1999; Kline, 2005).

Safety climate dimension scales also presented good internal reliability indices: Cronbach's alpha coefficients are higher than the threshold value of 0.70 in all dimensions; composite reliability (CR) is higher than 0.70 for all dimensions (Bagozzi & Yi, 1988). Regarding discriminant validity, AVE is higher than 0.5 for all dimensions (Hair, Anderson, Tatham, & Black, 1998). CFA factor loadings, internal reliability and discriminant validity indices are displayed in Table 5.

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4.3 Short and level-specific versions of the safety climate measurement scale.

This phase aimed at extracting and validating short versions of the safety climate scale while ensuring a homogeneous measurement quality.

4.3.1 Short safety climate measurement scale.

The research aimed at devising a complete and balanced safety climate measurement tool that is easily applicable in work settings where time availability is limited. Filling a questionnaire requires workers to interrupt their work activities, hampering the completion of their work tasks and affecting their work schedules. Therefore, time is a critical constraint when it comes to devising a questionnaire that workers may have to fill in while at work. The short version of the scale constitues a safety climate measurement tool that workers can complete in considerable less time compared to the long version, while preserving the quality of information.

This phase focused on reducing the number of questionnaire items while preserving the overall structure of the questionnaire, i.e. maintaining all dimensions and levels of analysis as in the extended version of the scale. For each level of analysis, two items with the highest factor loadings resulting from the CFA were selected. Six items were retained for each multi-level safety climate dimension and two items for single-level dimensions. The items included in the short version of the scale are marked with a tick symbol in Table 5. The resulting model with 40 items was tested on data from Company 2, 3 and 4. The short version of the safety climate scale presented equally satisfactory fit indices as the extended version: the $\chi 2/df$ ratio is 2.32 ($\chi 2(1608.5) = 693$, $p < 0.001$); TLI and CFI are 0.92 and 0.93, respectively; RMSEA is 0.056. A cross-sample comparison was performed across two companies participating in the research. Company 1 and Company 2 samples were utilised separately, being the two samples with the largest number of participants (Table 3). The analysis yielded equally satisfactory goodness-of-fit statistics. With reference to the Company 1 sample, the model presents a $\chi 2/df$ ratio of 2.02 ($\chi 2(1510.60) = 747$, $p < 0.001$), TLI and CFI of 0.91 and 0.92, respectively, and RMSEA of 0.07. When applied to Company 2 sample, model fit indices are: $\chi2$/df ratio is 2.75 ($\chi2(2058.82) = 747$, $p < 0.001$); TLI and CFI are 0.90 and 0.92, respectively; RMSEA is 0.07. The results are summarised in Table 6.

::::::::::::INSERT TABLE 6 HERE::::::::::::

4.3.2 Level-specific safety climate measurement scales.

The research aimed at validating two distinct level-specific safety climate measurement scales: organisation-level and workgroup-level scales. Organisation-level and workgroup-level items (referring both to supervisors and co-workers) were extracted from the extended version of the scale. The organisation-level safety climate scale comprises 24 items referring to 8 safety climate dimensions, namely OC, PI, SP, MC, PAA, Tr, PSP and PS. This analysis was conducted on the entire sample of observations (all companies). This model presented good statistical fit indices: the $\chi2$/df ratio is 3.02 ($\chi2(676.60) = 224$, $p < 0.001$), TLI and CFI are 0.97 and 0.97, respectively; RMSEA is 0.047. The workgroup-level scale comprises 36 items, referring to 6 safety climate dimensions, namely OC, PI, SP, MC, PAA, and Tr. The model presented good statistical fit indices: the $\chi2$/df ratio is 3.09 ($\chi2(2228.48) = 720$, $p < 0.001$), TLI and CFI are 0.96 and 0.95, respectively; RMSEA is 0.055. Table 7 summarises the goodness-of-fit statistics for all safety climate measurement scales: extended, short, and level-specific scales.

::::::::::::INSERT TABLE 7 HERE::::::::::::

5. Discussion and conclusion

Safety climate has been investigated since the early ‘80s (Zohar, 1980) and has attracted attention in several contexts, from health services (Singer et al., 2009) to building and construction (Choudry et al., 2009), from oil and gas (Mearns et al., 2003) to transportation (Huang et al., 2013). Our literature review revealed that there is still no convergence on how to measure it. Based on a scale development exercise, our work provides manufacturing and service companies with high safety maturity with guidance on comprehensively measuring safety climate. Before our contribution, available metrics could only grasp early signals of successful or unsuccessful safety policy implementation, resulting in a gap between research and practice on safety climate (Sharma & Bansal, 2000). Together with the measurement tool, our work also advances the conceptualisation of safety climate as the combination of eight elemental components of workers' perceptions, namely: Open Communication, Personal Involvement, Safety Priority, Managerial Commitment, Post-Accident Administration, Training, Perceptions about System Performance, and Procedural System.

The results from an in-field validation of the resulting scale provide solid empirical support to the capability of such an integrative model to describe complementary yet independent facets of employees' perceptions of safety climate at different organisational levels. Additionally, by introducing top management, direct supervisors and co-workers as three distinct units of analysis, our results prove the possibility to reflectively measure the eight elemental components of safety climate and to highlight their systemic nature. In fact, insights into safety climate's components reveal a strong rationale for cascading interventions throughout the organisation regardless of their intention to change the status quo through top-down or bottom-up manifestation routes. Initiatives on these dimensions that are confined at a single organisational level – e.g. supervisors administrating accidents but having no influence on organisational procedures, or teams being strongly committed towards safety despite supervisors' unconditioned orientation towards business performance – are thus destined to generate little impact in terms of the overall safety climate (Brondino et al., 2012; Wu et al., 2015; Casey et al., 2019).

The adaptation of existing metrics to companies with mature safety management systems also resulted in discarding some dimensions from previous works. For example, we discarded Work Satisfaction & Security dimension after the consultation with HSE experts and safety consultants because task-specific facets of the person-job fit and meaningfulness emerged as unsatisfactory proxies for the organisational safety climate. In fact, initiatives that improve individual conditions might contribute to increased perceptions that do not reflect the realm at the organisational level. On the contrary, insights from companies that are high in safety management maturity revealed the presence of factors that respondents observe from a purely unitary perspective, i.e. denoting the alignment between individual and organisational perceptions and aspirations without losing objectivity. In line with the items developed in the reviewed studies, possible initiatives at the team or supervisor levels do not undermine the possibility of forming coherent but independent perceptions regarding, for example, the management system performance and the procedural system. As a result, our findings contribute to the current literature by proving that, in measuring safety climate in organisations with a mature safety management system, the proposed dimensions and levels are effective in balancing between scale compositions, which is key to preventing respondents' abandonment and acquiescence biases, and to providing a comprehensive representation of the potential determinants of safety performance (Zohar & Luria, 2005).

The introduction of our multi-dimensional and multi-level scale comes with policy implications concerning the systemic nature of safety culture. This study provides evidence that it is possible to design task-specific safety policies and regulations to engage companies that are still juvenile in safety management, which should become holistic when targeting organisations with high safety management maturity.

5.1 Theoretical contribution

The contribution of the research to the academic debate is manifold. First, the study addresses the call from Hofmann and colleagues (2017) to define the dimensions of safety climate, accounting for the perspectives of both academics and practitioners. In detail, the research provides a strong qualitative and statistical evidence of the multi-dimensional and multi-level nature of safety climate (Chen et., 2018). Based on an extensive review of the existing safety climate measurements, discussions with stakeholders and in-field data collection, our multi-staged work offers empirical and statistical support for considering safety climate as a score made of eight components describing facets at organisational, supervisors and team levels. These components are the mechanisms that, being involved in the causal relations that explain employees' fitness with the job and the organisation, allow opening the black box that links safety policies to safety performance.

Second, the study provides further evidence that a co-creation approach between academics and practitioners is an effective way to, on the one hand, provide a comprehensive instrument for an organization to measure a key factor of OHS performance and, on the other hand, fill an existing gap in safety climate literature regarding the lack of a safety climate measurement tool for organizations with high safety maturity. According to the recent literature on linking research and practice in management studies (Bansal, & Sharma, 2021), the study shows the effectiveness of performing research with managers starting from common needs and merging the rigour of research methodologies and the practical experience of managers.

Third, the article contributes to the ample literature on OHS management systems (Fernández-Muñiz et al., 2009; Ghahramania & Salminen, 2019; Heras-Saizarbitoria et al., 2019) by providing an operational instrument for measuring soft and intangible factors that help integrating the management system requirements into an organization's routines.

Fourth, the validation contribution: our results also demonstrate that the exposure to the same work environment makes individual perceptions of safety culture converge towards a homogeneous representation among groups of employees (Neal & Griffin, 2006; Huang et al., 2017). This fact helps clarify the distinction between safety culture, which is the situational aspect concerning what an organisation does in terms of safety management, and safety climate, which is a psychological characteristic, shared by employees, that describe how they feel about safety issues in their organisation (Huang et al., 2017). Despite being based on individual values and perceptions, we proved that the proposed components of safety climate are suited for grasping the prevailing reactions towards the work environment. Interestingly, these reactions do not tend to be fragmented among individuals, even though they reflect the peculiarities at different organisational levels (i.e. teams, supervisors and the whole organisation). Consequently, safety climate can be considered as the result of organisational characteristics that vary with the unit of analysis and that can be observed by means of a data collection among employees, which is particularly helpful to investigate safety performance at the organisational level and not just at the individual one.

It is worth noting that, even though our data collection referred only to health and safety issues, it is reasonable that similar conclusions might also be drawn for environmental issues, thus allowing for the investigation of cultural integration as a driver of HSE performance.

5.2 Managerial implications

The managerial implications of our results are fourfold. First, safety managers can use the proposed scale to evaluate safety policies and monitor their influence on relevant organisational safety outcomes, such as compliance and accident and injury rates. The cross-validation of the scale based on the literature review, discussions with stakeholders and empirical observations ensure that the scale is relevant and comprehensive. As a consequence, improving its scoring over time might be a reasonable target for organisations that pursue employees' engagement in safety issues.

Second, health and safety managers can pursue score improvements through actions targeted to specific safety climate dimensions. Our results, in fact, show that these dimensions are independent and, thus, do not necessarily require strategies oriented to their integration. This aspect is particularly relevant from a continuous improvement perspective, where interventions and resources are managed to ensure the more significant marginal effects by acting on the weaker dimensions of performance.

Third, health and safety managers are encouraged to plan for the data collection on safety climate in the broader number of employees possible, instead of relying just on a few key informants, e.g. through a limited number of interviews. On the one hand, the proposed scale mediates between comprehensiveness and ease of use, which is particularly helpful in preventing respondents' fatigue and reducing biases that are pretty common in organizational climate surveys. On the other hand, the scale is capable of representing the cascading safety climate perceptions from the organisational to the team, which reflects a conceptualization of safety climate that emphasises the salience of collective instead of individual perspectives.

To facilitate a wider involvement of employees in safety climate surveys, the study also validates a short version of the safety climate scale: as evinced by the validation analysis, the short scale preserves the measurement quality of the long scale, while reducing the time needed for completing the questionnaire. By improving ease of use, the short scale is most suited for work settings where tight work schedules or heavy workloads constraint the time that workers can devote to filling the questionnaire while at work. On the other hand, the long scale provides a slightly more comprehensive assessment of safety aspects, as a result of a wider spectrum of measurement items. Accordingly, while planning the data collection, health and safety managers may opt for the long or short version of the survey based on estimates of the time that workers may allocate to completing the questionnaire during work hours.

Fourth, referring to low safety maturity organisations, our results do not just offer directions for setting mid- and long-term ambitions but also offer the possibility to extract single dimensions from the measurement tool to start its implementation from single areas of investment in safety management.

5.3 Limitations and further research

As for any study, the findings of the research are not conclusive. Avenues for future research stem from both our results and their limitations. First, testing the relationship between safety climate and performance was beyond the scope of our study. Nevertheless, our results encourage scholars to include the proposed safety climate measure into research models aimed at disentangling the mechanisms that govern the complex nexus between safety policies and performance. Doing this would help understand which components of safety climate are more conducive to the desired safety performance in different organisational contexts, which is an issue of great interest in the pursuit of efficacy and efficiency (Pandit et al., 2019).

Second, our scale development and validation processes were grounded on a review of existing metrics, which ensures that it covers previous prominent conceptualizations of safety climate. This approach allowed isolating eight elemental and independent components of safety climate that allow for a detailed operationalization of this concept at different organisational levels. The resulting level of detail answers the need for holistic investigations on the relationships between safety practices and climate, as well as between safety climate and performance (Chen et al., 2018). However, scholars might find it useful to develop simplified safety climate scales to build structural models where the overall dimension of safety climate plays only a more limited and specific role. To this end, our results suggest that a simplification based on a theory-based selection of safety climate components at the proper organisational level should be preferred to a reduction of items per dimension.

Third, our validation process involved companies that are representative of the western business environment. To add further empirical evidence in support of our conclusions, it would be useful to investigate their invariance to different socio-cultural contexts.

Fourth, although the questionnaire was designed with an extensive involvement of HSE managers and tested in different work settings by frontline workers, in order to reduce complex words and keep the sentence simple and clear, a minimum level of education is required to understand the questions. In addition, the involvement of large companies with high safety maturity, also operating in industries where a certain level of technical education is required, did not allow for the involvement of workers with very low or low levels of education. Therefore, future research could focus on revising our measurement tool, adapting it to very low-skilled workers.

Finally, we have developed and validated the safety climate scale to answer the needs of organisations with high safety maturity. Future research might usefully investigate the possibility of extending the application of this scale to organisations that are less involved in safety management to both prove the relevance and accuracy of the scale in broader organisational contexts and disentangle early-stage safety strategies by revealing the most frequent investment paths among the different safety climate dimensions.

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Figures

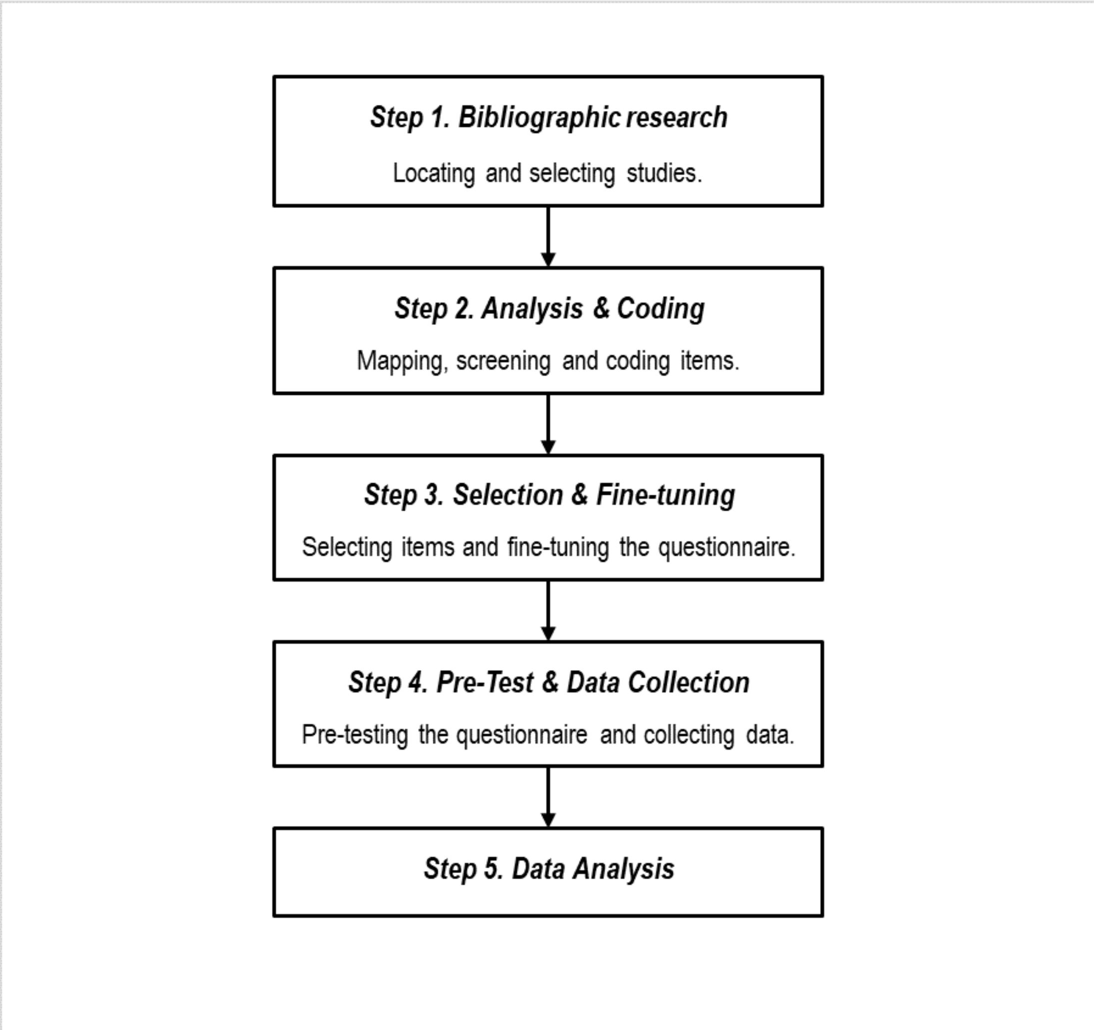

Figure 1 – Research protocol

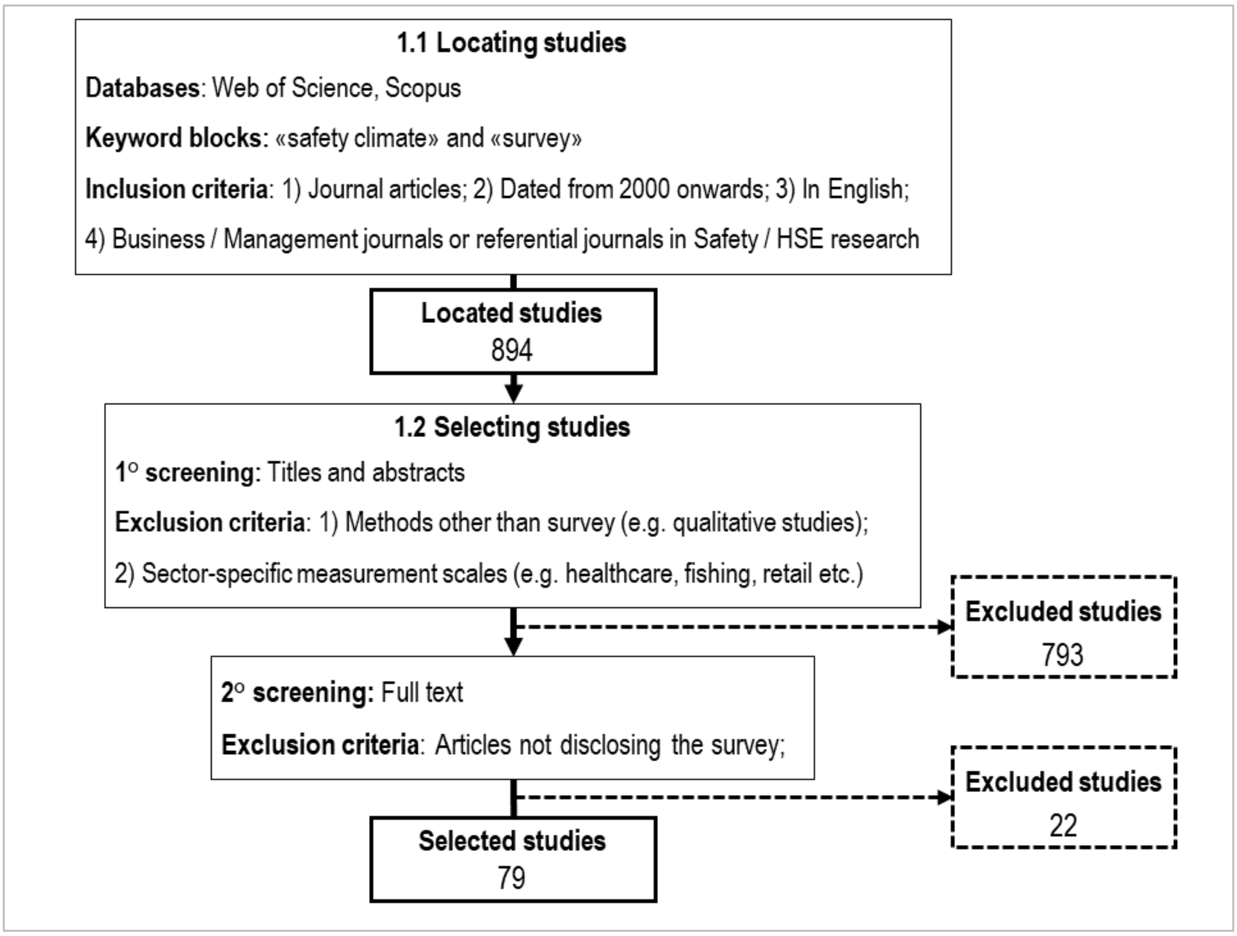

Figure 2 – Step 1. Bibliographic research

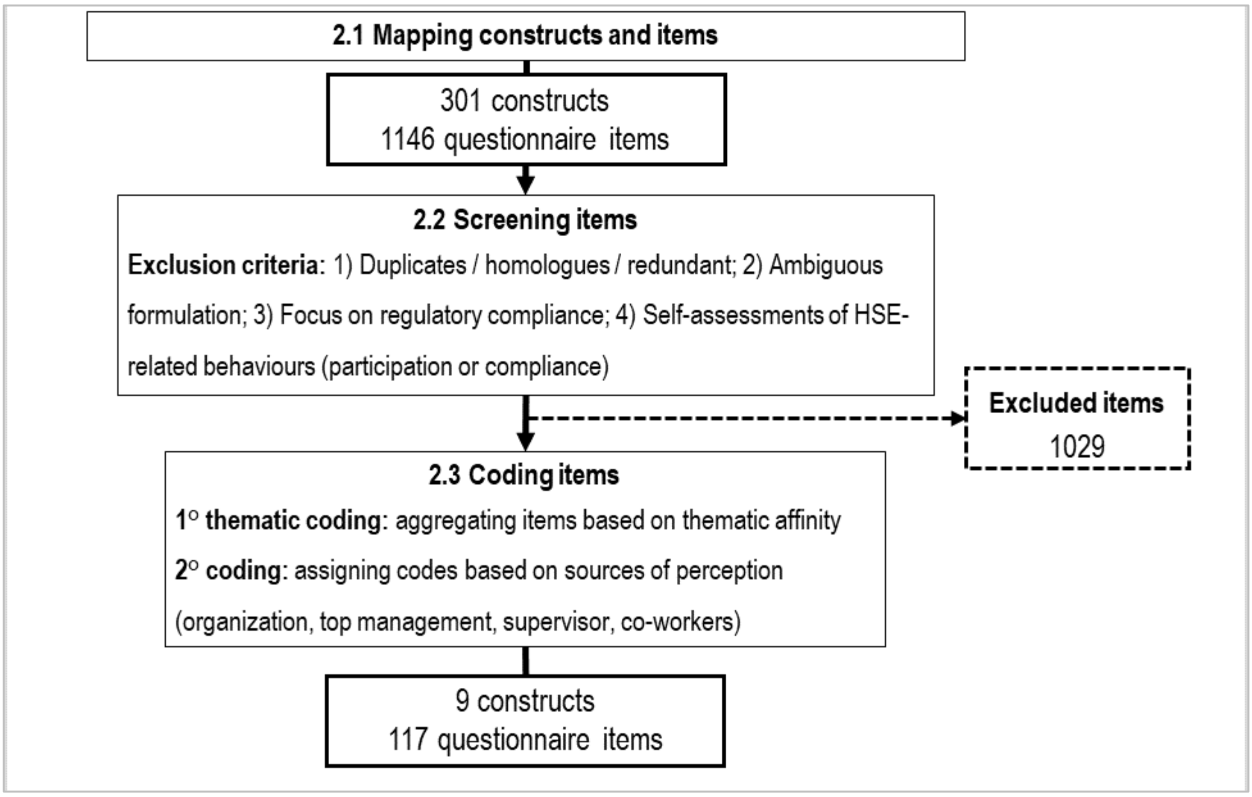

Figure 3 – Step 2. Analysis and coding

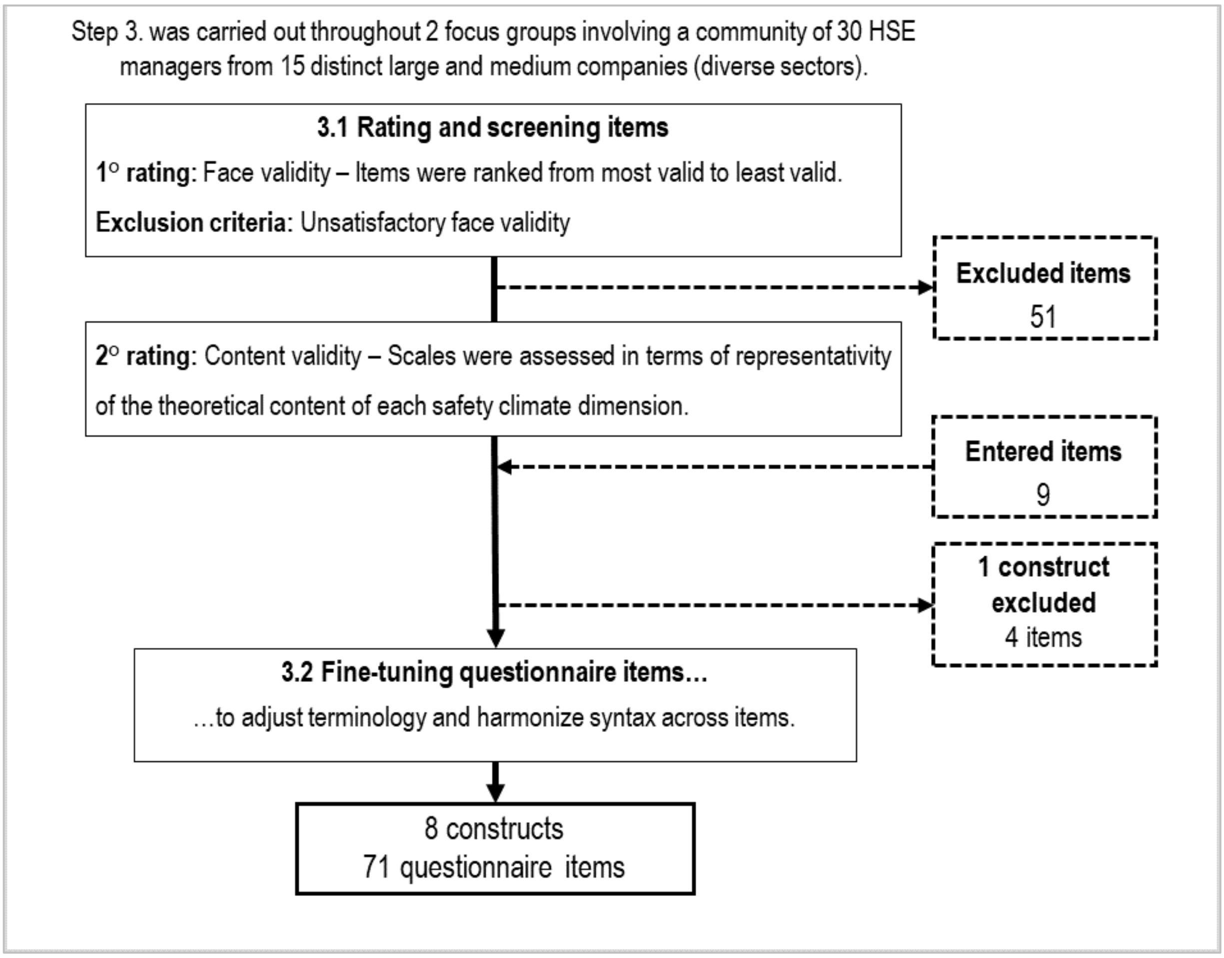

Figure 4 – Step 3. Selection and fine-tuning

Tables

Table 1 – Safety climate dimensions: definitions, exemplary measurement items and key references.

Safety climate dimension	Definition and description	Exemplary measurement items	Key references
Open Communication (OC)	Perceptions about the quality and frequency of communication and information exchange about safety of work, such as updates concerning safety procedures and safety risks, as well as feedback, advice or suggestions. Scholars have emphasised the open and free-flowing exchange of information about safety issues (both formal and informal) as a key feature of a non-punitive and committed approach to safety, and as a determinant of a positive safety climate. Items in this dimension investigate both communication initiatives and the perceived state of communication and information sharing about safety on the job.	*"My organisation promotes sharing of experiences regarding safety issues among workers"*	Grote, 2008 Mearns et al., 1997 Hofmann & Stetzer, 1998 Tholén et al., 2013 Vanderberg et al., 1999
Personal Involvement (PI)	Perceptions about workers' involvement in decision-making concerning work organisation and management of safety aspects of work, as well as perceptions about the effectiveness of organisational efforts to enact such involvement (e.g. consultations, feedback, reporting systems etc.). Workers' involvement in safety management is often associated with a good reporting and learning culture, and with safety-oriented decision-making.	*"Management regularly consults with workers about safety issues in the workplace"*	Flin et al., 2000 Chen et al., 2018 Wiegmann et al., 2004 Keren et al., 2009

Safety Priority (SP)	Perceptions about the priority that is assigned to safety vis-à-vis production objectives and other potentially conflicting objectives (e.g. efficiency, profit, and the pace of operations), as well as perceived pressure to meet production objectives irrespective of safety. Work pressure is often stressed as a major hurdle to safe behaviour. Items in this dimension emphasise time and workload constraints as causes of negligence towards safety. Unlike the other safety climate dimensions, the vast majority of items ascribed to this dimension are negatively worded, i.e. they depict an organisational context where production objectives are given priority over safety.	*"Sometimes work schedules are too tight for us to follow safety procedures"*	Lee et al., 2016 Lingard et al., 2019 Kouabenan et al., 2015 Håvold et al., 2009
Managerial Commitment (MC)	Perceptions about organisational efforts to improve safety in the workplace. Commitment at all organisational levels is a crucial leverage to continuous safety improvement, which is achieved by aligning strategic priorities with safety objectives. In safety literature, commitment is also found to affect numerous safety-related behaviours, from hazard recognition to compliance and safety citizenship behaviour, through social-exchange or rewarding mechanisms.	*My organisation is committed to continuously improve the safety performance of each individual department"*	Keren et al., 2009 Wu et al., 2015 Flin et al., 2000 Curcuruto & Griffin, 2018 Pandit et al., 2019
Post-Accident Administration (PAA)	Perceptions about the effectiveness and timeliness of organisational responses to safety accidents and near misses: accidents investigations and analysis, corrective actions and the implementation of "lessons learned". Although this dimension is rarely examined as a construct per se in safety climate studies, questions regarding the quality and effectiveness of corrective actions and follow-up measures are very frequent in safety climate questionnaires.	*"In my organisation, corrective actions resulting from safety accident investigations are implemented promptly"*	Vinodkumar & Bhasi, 2009 Cigularov et al., 2013

Training (Tr)	Perceptions about the effectiveness, completeness and pertinence of safety training programs and organisational efforts to ensure that workers possess the necessary skills to perform work operations safely. Items in this dimension elicit perceptions about safety training, as well as perceptions about the competence, awareness and knowledge that organisational members possess about workplace safety.	*"Training activities are effective in promoting safe behaviours"*	Huang et al., 2013 Grote, 2008
Perceptions about System Performance (PSP)	Perceptions about the effectiveness of organisational structures, procedures and management systems in maintaining safety while facing organisational and operational changes (both expected and unexpected). This dimension emerges from studies that advance a resilience perspective to safety climate research. Items in this dimension focus on unprecedented or uncertain conditions (such as emergency situations) or serious safety accidents.	*"In my organisation, potential impacts on safety performance resulting from organisational and operational changes are always evaluated"*	Håvold et al., 2009 Shirali et al., 2018 Chen et al., 2018
Procedural System (PS)	Perceptions about the effectiveness, clarity, accessibility and completeness of safety rules and procedures in the workplace.	*"Safety procedures contain all the information I need for managing safety risks associated with my work duties"*	Zhou et al., 2008
Work Satisfaction & Security (WS&S)	Perceptions of workplace well-being, occupational stability, and job satisfaction. Despite being rarely considered in safety climate studies, this dimension adds a psychosocial health perspective to safety climate. Tthis dimension accounts for common sources of psychosocial risks on the workplace, such as work-life balance and work meaningfulness.	*"My colleagues find it difficult to balance their personal and working life"*	Håvold et al., 2009 Jafari et al., 2017 Dahler-Larsen et al., 2020

Table 2 – Surveyed companies: general information, research scope and response rate.

General information				Research scope		Data collected & Response rate		
ID	**Sector**	**Number of employees**	**Sites**	**Organisational units**	**Workers**	**Total participants**	**Completed questionnaires**	**Response rate**
Company 1	Oilfield services: drilling and assembly	~32,000	5	2 operating units: - *Offshore drilling* - *Onshore drilling* 2 staff units: - *Engineering* - *Construction*	1,218	1,152	579	47%
Company 2	Generation & distribution of electric power	433	6	1 operating unit: - *Production* 3 staff units: - *Technical services* - *Industrial assets* - *Quality & Control*	406	354	208	51%
Company 3	Manufacturing of building materials	254	1	4 operating units: - *Quarrying* - *Production* - *Processing 1* - *Processing 2* 2 staff units: - *Logistics* - *Maintenance*	97	82	41	42%
Company 4	Minting and printing	1,736	1	1 operating unit: - *Production* 3 staff units:	101	100	52	51%

- *Technical services*
- *Logistics*
- *HSE*

Table 3 – Sample characteristics.

	Company ID									
Sector	***Company 1***		***Company 2***		***Company 3***		***Company 4***		***Total sample***	
Number of observations	579		208		41		52		880	
Gender	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
Male	Not available		Not available		37	89%	42	80%	N/A	
Female					4	11%	10	20%		
Age	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
< 30	157	27%	23	11%	11	26%	11	22%	202	23%
30 – 50	319	55%	98	47%	26	64%	20	38%	463	53%
> 50	103	18%	87	42%	4	10%	21	40%	215	24%
Seniority (years in the company)	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
< 10	100	17%	Not available		18	45%	19	37%	N/A	
10 – 20	267	46%			9	21%	13	23%		
> 20	212	37%			14	34%	20	38%		

Table 4 – EFA results. Company 1 - number of participants = 579

			EFA factor loadings			
Construct	**Level of analysis**	**Item ID**	*Org*	*Sup*	*Cow*	**Decision on the item**
Open Communication (OC)	*Org*	OC.1	0.75			Retained
		OC.2	0.84			Retained
		OC.3	0.64			Retained
		OC.4	0.26			Discarded for low factor loading

	Sup	OC.5		0.63		Retained
		OC.6		0.67		Retained
		OC.7		0.76		Retained
	Cow	OC.8			0.67	Retained
		OC.9			0.83	Retained
		OC.10			0.35	Discarded for low factor loading
Personal Involvement (PI)	*Org*	PI.1	0.81			Retained
		PI.2	0.67			Retained
		PI.3	0.82			Retained
	Sup	PI.4		0.85		Retained
		PI.5		0.70		Retained
		PI.6		0.74		Retained
		PI.7		0.79		Retained
	Cow	PI.8			0.78	Retained
		PI.9			0.63	Retained
		PI.10			0.85	Retained
Safety Priority (SP)	*Org*	SP.1	0.80			Retained
		SP.2	0.86			Retained
		SP.3	0.78			Retained
	Sup	SP.4		0.42		Discarded for double loading (0.51)
		SP.5		0.63		Retained
		SP.6		0.75		Retained
		SP.7		0.54		Retained
	Cow	SP.8			0.65	Retained
		SP.9			0.75	Retained
		SP.10			0.82	Retained
Managerial Commitment (MC)	*Org*	MC.1	0.68			Retained
		MC.2	0.98			Retained
		MC.3	0.10			Discarded for low factor loading
		MC.4	0.52			Retained
	Sup	MC.5		0.83		Retained
		MC.6		0.82		Retained
		MC.7		0.59		Retained

		MC.8		0.53		Retained
	Cow	MC.9			0.78	Retained
		MC.10			0.84	Retained
		MC.11			0.49	Retained
Post-Accident Administration (PAA)	*Org*	PAA.1	0.70			Retained
		PAA.2	0.82			Retained
		PAA.3	0.53			Retained
		PAA.4	0.31			Discarded for low factor loading
	Sup	PAA.5		0.40		Discarded for double loading (0.41)
		PAA.6		0.74		Retained
		PAA.7		0.71		Retained
	Cow	PAA.8			0.45	Retained
		PAA.9			0.80	Retained
		PAA.10			0.73	Retained
Training (Tr)	*Org*	TR.1	0.85			Retained
		TR.2	0.75			Retained
		TR.3	0.38			Discarded for low factor loading
	Sup	TR.4		0.66		Retained
		TR.5		0.85		Retained
		TR.6		0.76		Retained
	Cow	TR.7			0.87	Retained
		TR.8			0.90	Retained
		TR.9			0.68	Retained
Perceptions about System Performance (PSP)	*Org*	PSP.1	0.15			Discarded for low factor loading
		PSP.2	0.61			Retained
		PSP.3	0.86			Retained
		PSP.4	0.86			Retained
		PSP.5	0.80			Retained
Procedural System (PS)	*Org*	PS.1	0.85			Retained
		PS.2	0.83			Retained
		PS.3	0.05			Discarded for low factor loading
		PS.4	0.03			Discarded for low factor loading
		PS.5	0.14			Discarded for low factor loading

		PS.6	0.63				Retained

Table 5 – CFA results. Items marked with ✓ are included in the short version of the scale. *Companies 2, 3 and 4 = 301 participants*

Construct	**Level of analysis**	**Item ID**	**Factor loading**	**CRA**	**AVE**	**CR**	**Items in the short scale**
Internal	*Org*	OC.1	0.74	0.94	0.67	0,94	
Communication		OC.2	0.77				✓
(IC)		OC.3	0.76				✓
	Sup	OC.5	0.89				✓
		OC.6	0.85				✓
		OC.7	0.82				
	Cow	OC.8	0.78				✓
		OC.9	0.88				✓
Personal	*Org*	PI.1	0.82	0.95	0.68	0.95	
Involvement		PI.2	0.86				✓
(PI)		PI.3	0.84				✓
	Sup	PI.4	0.90				
		PI.5	0.90				
		PI.6	0.91				✓
		PI.7	0.91				✓
	Cow	PI.8	0.62				
		PI.9	0.70				✓
		PI.10	0.70				✓
Safety Priority	*Org*	SP.1	0.63	0.96	0.54	0.95	
(SP)		SP.2	0.68				✓
		SP.3	0.74				✓

	Sup	SP.5	0.74				✓
		SP.6	0.74				✓
		SP.7	0.73				
	Cow	SP.8	0.68				
		SP.9	0.81				✓
		SP.10	0.76				✓
Managerial	*Org*	MC.1	0.70	0.94	0.59	0.93	
Commitment		MC.2	0.81				✓
(MC)		MC.4	0.82				✓
	Sup	MC.5	0.87				✓
		MC.6	0.84				
		MC.7	0.75				
		MC.8	0.87				✓
	Cow	MC.9	0.73				
		MC.10	0.75				✓
		MC.11	0.80				✓
Post-Accident	*Org*	PAA.1	0.74	0.94	0.63	0.94	
Administration		PAA.2	0.77				✓
(PAA)		PAA.3	0.79				✓
	Sup	PAA.6	0.83				✓
		PAA.7	0.89				✓
	Cow	PAA.8	0.67				
		PAA.9	0.72				✓
		PAA.10	0.76				✓
Training (Tr)	*Org*	TR.1	0.83	0.95	0.69	0.94	✓
		TR.2	0.84				✓
	Sup	TR.4	0.86				✓
		TR.5	0.88				✓
		TR.6	0.85				
	Cow	TR.7	0.78				
		TR.8	0.82				✓

		TR.9	0.81				✓
Perceptions about System Performance (PSP)	*Org*	PSP.2	0.79	0.95	0.71	0.95	
		PSP.3	0.79				
		PSP.4	0.86				✓
		PSP.5	0.91				✓
Procedural System (PS)	*Org*	PS.1	0.88	0.84	0.67	0.84	✓
		PS.2	0.87				✓
		PS.6	0.67				

CRA = Cronbach's alpha. AVE = Average variance extracted. CR = Composite reliability.

*Table 6 – Cross-sample comparison based on the short scale (number of items = 40): goodness of fit statistics. ***p < 0.001*

Goodness-of-fit indexes	***Company 1***	***Company 2***
Model Chi-Square (χ^2)	1510.60***	2058.82***
Degrees of freedom	747	747
Chi-square to degrees of freedom ratio ($\chi 2/df$)	2,02	2.75
Tucker Lewis Index (TLI)	0.91	0.90
Comparative Fit Index (CFI)	0.92	0.92
Root Mean Square Error of Approximation (RMSEA)	0.07	0.07

*Table 7 – Goodness of fit statistics: long scale, short scale, and level-specific scales (organisation-level, group-level). ***p < 0.001*

			Level-specific scales	
	Extended scale	**Short scale**	*Organisation-level*	*Workgroup-level (Supervisor & Co-workers)*
Dimensions of HSE climate	8	8	8	6
Number of items	60	40	24	36
Model Chi-Square (χ^2)	3200.19***	1608.50***	676.60***	2228.48***
Degrees of freedom	1502	693	224	720
Chi-square to degrees of freedom ratio ($\chi2/df$)	2.13	2.32	3.02	3.09
Tucker Lewis Index (TLI)	0.92	0.92	0.97	0.96
Comparative Fit Index (CFI)	0.93	0.93	0.97	0.95
Root Mean Square Error of Approximation (RMSEA)	0.051	0.056	0.047	0.055

Annexes

Annex 1 – Questionnaire items. (R) = reverse-scored item.

Questionnaire

Do you agree with the following statements?

Please rate your level of agreement with each statement on a scale from 1 = "Totally disagree" to 6 = "Totally agree".

Choose the option "Don't know" only when you believe you do not have sufficient information to express an opinion about the statement.

Item ID	Operationalisation	Key references
OC.1	When a change of activities, operations, or processes is implemented, decisions that are taken regarding safety aspects are immediately communicated in a clear and comprehensive manner	Grote, 2008 Shirali et al., 2018
OC.2	In my organisation, workers who report safety issues are provided with timely feedback	Jiang et al., 2010 Chen et al., 2018
OC.3	My organisation promotes sharing of experiences regarding safety issues among workers	Lin et al., 2008
OC.4	In my organisation, there is free and open talk about safety issues	Tholén et al., 2013
OC.5	Our supervisor discusses how to improve safety performance with us	Rodrigues et al., 2015 Lee et al., 2016
OC.6	Our supervisor uses examples and provides explanations to get us to act safely	Rodrigues et al., 2015 Newaz et al., 2019
OC.7	Our supervisor is willing to listen to any news relating to safety issues, even when they negatively impact the time schedules of work activities	Shirali et al., 2018
OC.8	My co-workers often exchange advice on how to work in compliance with safety procedures	Lin et al., 2008
OC.9	My co-workers openly discuss about safety issues with supervisors and managers	Jiang et al., 2010 Jafari et al., 2017

OC.10	Communication about safety issues between my colleagues and the supervisor is clear and effective	Huang et al., 2013 Kouabenan et al., 2015
PI.1	In my organisation, the management regularly looks for feedback about change processes from all employees affected	Grote, 2008 Pandit et al., 2019
PI.2	In my organisation, the management considers that workers' participation, commitment, and involvement is essential for improving safety performance	Boughaba et al., 2014 Liu et al., 2015
PI.3	In my organisation, the management regularly consults with workers about safety issues in the workplace	Vinodkumar & Bhasi, 2009 Jafari et al., 2017
PI.4	Our supervisor encourages discussion on how to improve safety issues in the workplace	Boughaba et al., 2014
PI.5	Our supervisor carefully listens and assesses employees' suggestions on how to improve safety performance	Huang et al., 2017 Saunders et al., 2017
PI.6	Our supervisor involves us in decisions related to improving safety performance	Ajslev et al., 2017 Boughaba et al., 2014
PI.7	Our supervisor considers and implements (whenever possible) my ideas on how to improve safety performance and prevent risks, even when I propose changes to working methods	Lingard et al., 2010
PI.8	My co-workers encourage others to pay attention to safety aspects	Chen et al., 2018
PI.9	My co-workers share their own experiences on safety issues with their colleagues	Shirali et al., 2018
PI.10	My co-workers are committed to identify problems and suggest solutions regarding safety issues	Jafari et al., 2017
SP.1	In my organisation, sometimes work schedules are too tight for us to follow safety procedures (R)	Lin et al., 2008 Lee et al., 2016
SP.2	In my organisation, sometimes concurrent working activities are not correctly managed and thus create dangerous situations (R)	Nielsen et al., 2013 Nielsen et al., 2016
SP.3	In my organisation, sometimes operational targets conflict with safety procedures (R)	Håvold & Nesset, 2009
SP.4	Our supervisor accepts that safety procedures are not followed "to the letter" when work falls behind schedule (R)	Lee et al., 2016 Fogarty & Shaw, 2010

SP.5	Our supervisor does not stress safety procedures when we are working with tight deadlines (R)	Ajslev et al., 2017 Newaz et al., 2019
SP.6	Our supervisor believes it is a waste of time to read safety procedures (R)	Vinodkumar & Bhasi, 2009
SP.7	Our supervisor believes productivity comes first, rather than safety (R)	Panidt et al., 2019
SP.8	My co-workers think productivity is more important than safety (R)	Cigularov et al., 2013
SP.9	Sometimes my co-workers overlook safety procedures while carrying out their working duties in order to meet deadlines (R)	Lin et al., 2018
SP.10	Sometimes my co-workers do not report dangerous situations because there is no time to stop work (R)	Lingard et al., 2019 Nielsen et al., 2013
Co.1	My organisation invests in safety training for workers, even in times of scarce resources	Rodrigues et al., 2015 Grote, 2008
Co.2	My organisation is committed to continuously improve the safety performance of each individual department	Wu et al., 2015 Sunindijo & Zou, 2012
Co.3	My organisation views workers who pay particular attention to safety issues in a positive way, and this is reflected in the company's rewarding system	Vinodkumar & Bhasi, 2009 Chen et al., 2018
Co.4	My organisation takes safety issues into account when setting long and short-term goals	Wu et al., 2015
Co.5	Our supervisor regularly checks whether we comply with safety procedures	Rodrigues et al., 2015 Huang et al., 2017
Co.6	Our supervisor ensures that I make use of protective equipment and other safety measures when performing operational activities	Newaz et al., 2019
Co.7	Our supervisor appreciates and compliments employees who pay particular attention to safety issues	Lee at al., 2016 Huang et al., 2013
Co.8	Through his/her behaviour, our supervisor displays commitment in improving safety issues in the workplace	Chen et al., 2018
Co.9	My co-workers promptly intervene when operational activities do not comply with safety procedures	Nielsen et al., 2008 Keren et al., 2009
Co.10	My co-workers step-in to stop operational activities that do not comply with safety procedures whenever a	Pandit et al., 2019

	dangerous situation occurs	
Co.11	In my working group, we strive to eliminate the risk of harm to people and prevent accidents	Kongsvik et al., 2011
PAA.1	In my organisation, the analysis of near misses and accidents is always used to design and implement safety improvement actions in the workplace	Shirali et al., 2018 Chen et al., 2018
PAA.2	In my organisation, corrective actions resulting from safety accident investigations are implemented promptly	Keren et al., 2009 Ghahramani & Khalkhali, 2015
PAA.3	When a near miss, accident or unsafe condition is reported, my organisation quickly intervene to solve the problems	Cigularov et al., 2013 Pandit et al., 2019
PAA.4	In my organisation, when safety problems occur, the management acts decisively	Sunindijo & Zou, 2012 Lu & Tsai, 2010
PAA.5	Following an accident, our supervisor focuses on improving safety conditions, instead of blaming specific individuals	Chen et al., 2018 Shirali et al., 2018
PAA.6	Our supervisor wants us to inform him/her about any safety issues, so he/she can get them fixed or reported to whom they concern	Cigularov et al., 2013 Pandit et al., 2019
PAA.7	Our supervisor acts promptly to correct problems relating to safety aspects	Lu & Tsai, 2010
PAA.8	When protective equipment wears out or becomes unavailable, my co-workers are empowered to take prompt action and, if necessary, suspend operational activities	Payne et al., 2010
PAA.9	My co-workers always report dangerous situations when they see them	Håvold & Nesset, 2009
PAA.10	When they notice a potential danger in the workplace, my co-workers know what to do and whom to report it to	Vinodkumar & Bhasi, 2009
TR.1	In my organisation, I received sufficient training to carry out my job duties properly and safely	Jiang et al., 2010 Sunindijo & Zou, 2012
TR.2	In my organisation, training activities are effective in promoting safe behaviours	Shirali et al., 2018
TR.3	When new activities and/or new equipment are introduced, my organisation ensures that adequate training and information on relevant safety aspects is provided	Jiang et al., 2010
TR.4	Our supervisor supports the workers to attend safety training	Vinodkumar & Bhasi, 2009 Boughaba et al., 2014

TR.5	Our supervisor ensures adequate training on safety issues is provided to prepare us to manage changes, unforeseen situations and emergencies	Vinodkumar & Bhasi, 2009 Jiang et al., 2010
TR.6	Our supervisor is aware of the safety risks associated with our working duties and knows how to manage them	Shirali et al., 2018
TR.7	My co-workers are fully aware of the safety risks associated with their job duties	Lingard et al., 2019
TR.8	My co-workers are familiar with the safety requirements specified in operational procedures	Keren et al., 2009
TR.9	My co-workers have the skills needed to effectively complete their work tasks, while accounting for relevant safety aspects	Shirali et al., 2018 Ghahramani & Khalkhali, 2015
PSP.1	In my organisation, during a serious emergency, important decisions (such as stopping operations because of significant safety issues) do not require manager's authorisation	Shirali et al., 2018
PSP.2	My organisation clearly and carefully defines everyone's responsibilities regarding workplace safety	Grote, 2008 Chen et al., 2018
PSP.3	In my organisation, changes to organisational structures and operational procedures are always carried out in a way to ensure sufficient resources and procedures to manage safety issues adequately	Grote, 2008
PSP.4	In my organisation, potential impacts on safety performance resulting from organisational and operational changes are always evaluated	Grote, 2008
PSP.5	The management system implemented by my organisation is effective in preventing serious accidents and managing operational risks	Shirali et al., 2018
PS.1	In my organisation, safety procedures and operational instructions are useful and effective, also during emergency situations	Shirali et al., 2018 Boughaba et al., 2014
PS.2	In my organisation, current safety procedures contain all the information I need for managing safety risks associated with my work duties	Saunders et al., 2017
PS.3	In my organisation, some safety procedures are difficult to follow (R)	Zhou et al., 2008 Håvold & Nesset, 2009
PS.4	In my organisation, some safety procedures do not reflect how job tasks are actually carried out (R)	Zhou et al., 2008 Kvalheim & Dahl, 2016
PS.5	In my organisation, safety procedures are written without involving the individuals concerned (R)	Zhou et al., 2008
PS.6	In my organisation, I can easily consult the safety procedures that apply to my work duties	Sunindijo & Zou, 2012