Safety Science 192 (2025) 107003

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Review

Safety culture maturity models in occupational safety and health: An updated scoping review

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1. Introduction

The term "safety culture" was first introduced by the International Nuclear Safety Advisory Group (INSAG) following the Chernobyl accident in 1986 (IAEA, 1986; IAEA, 1988).

Various definitions of safety culture have been reported (Cole, 2013). The INSAG defined safety culture as "that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (IAEA, 1991). The Confederation of the British Industry described the concept of safety culture as "the ideas and beliefs that all members of the organisation share about risk, accidents and ill health" (CBI, 1991). In 1993 the Advisory Committee for Safety in Nuclear Installations provided the following definition of safety culture: "the product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organisation's health & safety programs" (ACSNI, 1993).

Several attempts have been made to assess the safety culture of an organisation (Cole, 2013; Guldenmund, 2000; Díaz-Cabrera, 2007). However, there is still no consensus on how to define the construct of safety culture and which safety culture maturity measurements are best to use in occupational settings.

In 1993 Westrum proposed different organisational culture typologies based on how an organisation processes information. The flow of information was considered the most critical issue for organisation safety. This model identified three types of organisational cultures: (1) pathological; (2) bureaucratic; and (3) generative (Westrum, 1993; Westrum, 2004). The so-called pathological organisations are typically power-oriented and characterised by low cooperation across groups and inadequate information flow. On the other hand, in bureaucratic organisations, information circulates more easily, but within siloed departments. Bureaucratic cultures are more concerned with rules and positions with little interest for the overall mission of the organisation (i.e. rule-oriented organisations). Finally, generative organisations are usually performance-oriented and characterized by good information flow and high cooperation between teams to facilitate the best performance (Westrum, 1993; Westrum, 2004). Although Westrum did not use the term "safety culture maturity levels", the proposed classification can be considered a maturity model at an early stage (Table 1).

The DuPont Bradley Curve was developed in 1995 to describe the evolution of safety culture within organisations. It is commonly considered the first safety culture maturity model. This model defined four stages, namely: (1) reactive; (2) dependent; (3) independent; and (4) interdependent (Table 1) (DuPont, 2009; DuPont, 2012). At the first stage defined as reactive, safety is delegated to the safety manager with a focus on compliance. At the second stage (i.e. dependent), emphasis is pointed towards discipline, rules, and procedures. At the third stage defined as independent, focus is on personal commitment and the safety management is internalized. At the fourth stage (i.e. interdependent), team is committed to safety and coordination is valued (DuPont, 2009; DuPont, 2012).

In 2001 Hudson proposed a new safety culture maturity model based on the Westrum model, by adding two additional levels (i.e., reactive and proactive) and replacing the bureaucratic label with the term calculative (Hudson, 2001). Overall, the Hudson's safety culture maturity

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https://doi.org/10.1016/j.ssci.2025.107003
Received 18 February 2025; Received in revised form 30 July 2025; Accepted 11 September 2025
Available online 24 September 2025

Table 1
Safety culture maturity models (adapted by the authors).

	Westrum model (Westrum, 1993; Westrum, 2004)	DuPont Bradley Curve (DuPont, 2009; DuPont 2012)	Hudson model (Hudson, 2001)	Fleming model (Fleming, 2001)
First level	*Pathological* Information is hoarded, blame is common, and personal power is prioritized over organisational success	*Reactive* Safety practices are minimal, focusing mainly on responding to incidents	*Pathological* Safety culture is characterized by a lack of concern for safety	*Emerging* Safety is neglected, with minimal concern for processes and outcomes
Second level	*Bureaucratic* Emphasis on rules and procedures, with controlled information flow and a focus on formal processes	*Dependent* Safety systems are in place but rely heavily on external compliance	*Reactive* Safety practices are reactionary, focusing on incidents after they occur	*Managing* Basic safety management systems are in place, but there is room for improvement
Third level	*Generative* Information is shared openly, failures are used for learning, and there is a strong focus on collaboration and trust	*Independent* Safety practices are established and managed internally with some autonomy	*Calculative* Safety processes are documented, and safety procedures are in place	*Involving* Safety practices are more inclusive, involving employees in safety processes
Fourth level		*Interdependent* Safety culture is integrated throughout the organisation with shared responsibility and collaboration	*Proactive* The organisation anticipates potential safety issues and integrates safety measures into organisational practices	*Cooperating* Safety culture is collaborative, with high levels of cooperation between all levels of the organisation
Fifth level			*Generative* Safety culture is deeply embedded, with continuous improvement and proactive practices	*Continually improving* Safety practices are continuously improved, focusing on achieving excellence and optimizing safety performance

model provided five levels: (1) pathological; (2) reactive; (3) calculative; (4) proactive; and (5) generative (Table 1) (Hudson, 2001). The pathological level represents the least developed safety culture with minimal investment in safety systems and limited or no safety communication. At the reactive level, organisations tend to make safety improvements only in response to incidents. At the calculative level, formal management systems are put in place including audits and incident reporting is encouraged. At the proactive level, organisations start to anticipate and prevent problems by increasing workers' safety awareness and implementing safety improvements. The generative level represents the most mature safety culture: safety is fully integrated into the operational processes of the organisation and workers are fully engaged in safety activities (Hudson, 2001).

At the same time, Fleming developed a safety culture maturity model adopted by the United Kingdom Health and Safety Executive (also known as HSE model) (Fleming, 2001). This model identified five levels of maturity: (1) emerging; (2) managing; (3) involving; (4) cooperating; and (5) continually improving (Table 1) (Fleming, 2001). At the emerging level, safety is not considered as a key business and many accidents are perceived as unavoidable and as part of the job. At the managing level, organisations start to put effort into accident prevention; however, safety is exclusively defined in terms of adherence to rules and procedures. At the involving level, workers are willing to actively cooperate with management to increase health and safety and safety performance is monitored. At the cooperating level, workers take full responsibility for their own and others health and safety and organisations put effort into proactive measures to prevent accidents. At the continually improving level, safety is perceived as core value and organisations are working to find better ways to improve hazard control procedures (Fleming, 2001). The main safety culture maturity models are outlined in Table 1.

To our knowledge, two reviews investigated the use of these safety culture maturity models in organisations (Ayob, 2022; Gonçalves Filho and Waterson, 2018). Both reviews reported an increased use of maturity models across a wide range of occupational sectors over the period 2000–2020, especially in oil and gas, construction and healthcare sector (Ayob, 2022; Gonçalves Filho and Waterson, 2018). However, the vast majority of the included studies were more focused on maturity model development rather than maturity model application and/or validation. On the other hand, data on validity/reliability of these tools are necessary to guide organisations to assess their current level of maturity. One of main gap of these models is the lack of validity and reliability measures. A validated set of indicators would help organisations to easily assess their safety culture maturity level and to identify which aspects an organisation needs to enhance.

The aim of this scoping review is to provide an update on safety culture maturity models in occupational safety and health (OSH) in terms of main characteristics (e.g., dimensions, levels) by mapping potential applications of existing/new models along with data on validity and reliability of these tools. Specifically, we investigated the extent to which these models have been developed, assessed, and applied in occupational sectors.

2. Methods

This scoping review was conducted following the latest guidelines by the Joanna Briggs Institute (JBI) (Aromataris, 2024) and the reporting process adhered to the PRISMA Extension for Scoping Reviews (PRISMA-ScR) (Tricco, 2018).

2.1. Eligibility criteria

The "Population-Concept-Context" (PCC) framework was adopted. Firstly, the 'Population' referred to any organisation, company, or factory in which safety culture maturity models have been used. The 'Concept' was related to the development, application, and assessment of safety culture maturity models (either new or existing) in OSH. Lastly, the 'Context' referred to any occupational sector in which safety culture maturity models were applied. All countries were considered. Studies reporting new safety culture maturity models were included as well as the application of already existing safety culture maturity models in occupational setting. Studies referring to maturity models related to 'patient safety', 'food safety', 'cyber security' and 'technology performance' were not eligible for inclusion. We included studies published in academic journals as well as conference proceedings published in extenso. No language restrictions were applied.

2.2. Literature search

A comprehensive literature search was carried out across MEDLINE (through PubMed), Scopus, and Web of Science. The search strategy for

PubMed combined Medical Subject Headings (MeSH) and non-MeSH terms related to "safety culture" and "maturity models" along with the revised 'specific' filter developed by Mattioli et al that enabled us to restrict the search to the occupational context (Mattioli, 2010) (Supplementary Table A.1). The search strategy was adapted to Scopus and Web of Science accordingly. Considering that the last published review on the subject was performed up to 2020 (Ayob, 2022), for the present update searches were restricted to studies published from January 1, 2021, to March 31, 2024. The full search strategy was validated against the reference set of 26 citations related to OSH included in two previously published reviews (Ayob, 2022; Gonçalves Filho and Waterson, 2018). The last search was launched on April 24, 2025. The reference lists of included studies were checked for additional citations.

2.3. Study selection and data extraction

Following a pilot test, titles and abstracts were screened by three independent pairs of authors for assessment against the inclusion criteria. Potentially eligible citations were retrieved in full. The same pairs of authors assessed whether each full-text article met the inclusion criteria. Reasons for exclusion were recorded (Fig. 1, see also Supplementary Table A.2). Any disagreements between pairs of authors at each stage of the selection process were resolved through discussion. If disagreement persisted, another author made the final decision. An explicit decision rule for disagreements was defined a priori: (1) in case of oversight on the part of one of the authors, the disagreement was resolved via discussion; (2) in case of difference in interpretation, both authors attempted to resolve disagreements via discussion; (3) if this failed, the disagreement was solved by a third author. Of note, the inter-rater reliability (Cohen's kappa coefficient) calculated from the title/abstract screening stage was 0.62 indicating substantial agreement according to Landis and Koch (Landis and Koch, 1977).

A standardized data extraction form was developed and tested by the authors on a sample of articles. Authors were trained and coding instructions for the data collection form were developed. The following key variables were collected from each included study, namely: (i) study characteristics (i.e. first author, date of publication, country in which the study was undertaken, occupational sector); and (ii) maturity model characteristics (i.e. development/application of new/existing maturity model, dimensions, methods for identifying/assessing dimensions, levels, methods for defining levels, reliability/validity tests (if any)). Data extraction of included studies was carried out by one author and independently coded by two other authors. In case of disagreement, another author was consulted and discussions were held until a consensus was reached. The presence and resolution of disagreements were carefully recorded allowing assessment of reliability of coding.

The main characteristics of included studies were summarised in descriptive tables and a qualitative synthesis of the findings was reported.

2.4. Methodological quality assessment

A quality assessment of the included studies was carried out using an adapted version of the Critical Appraisal Skills Programme (CASP) checklist for qualitative research (CASP, 2025). The items reported in the original checklist were revised considering the unique

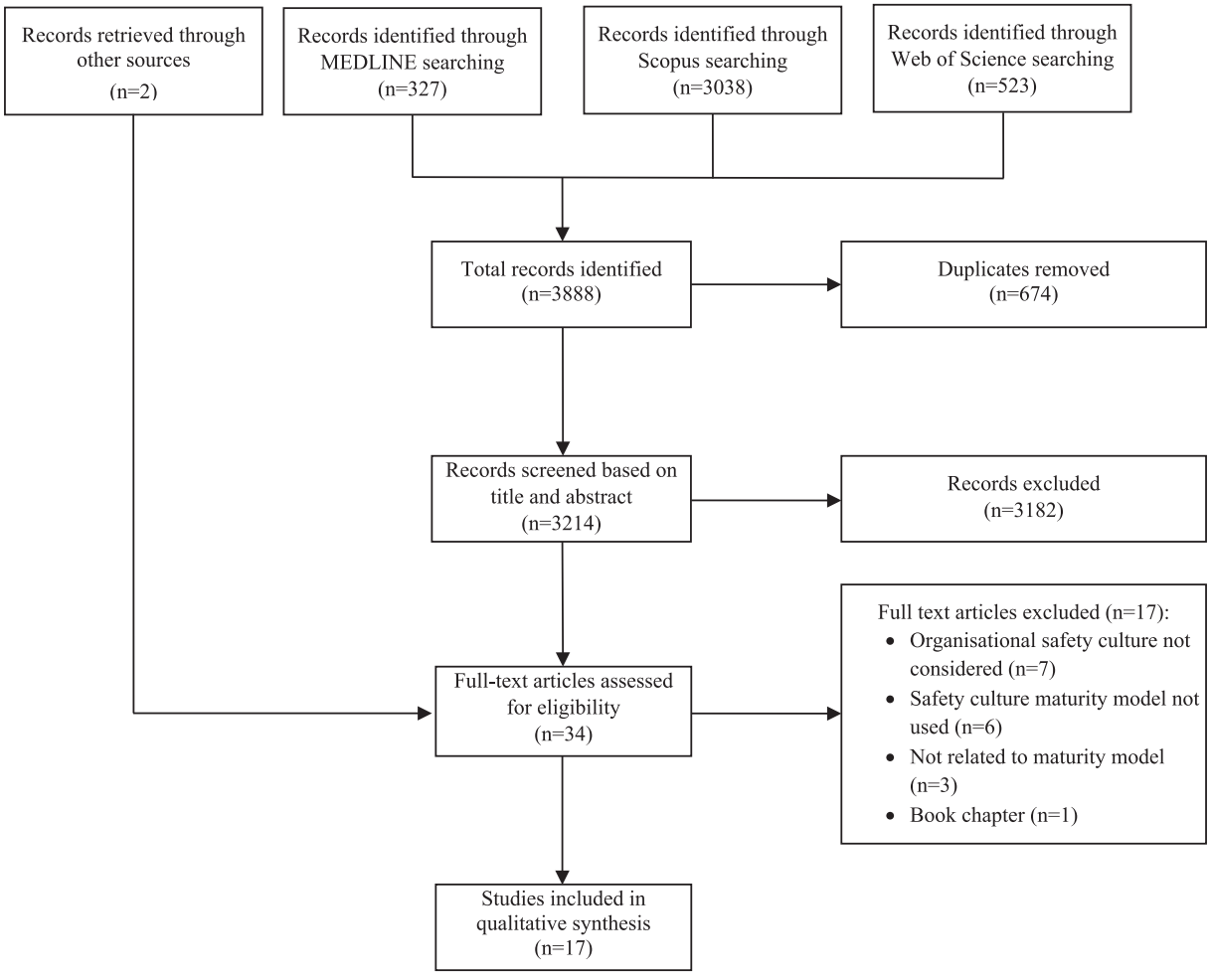

Fig. 1. Flow diagram of the study selection.

characteristics of the topic under study (Supplementary Table A.3). The number of items in the revised checklist were reduced from 10 to 8 (response options: yes/no/unclear). The methodological quality assessment form was tested by the authors on a sample of articles. The quality of the included studies was independently assessed by two authors. Disagreements were solved by the decision of a third author. All the disagreements along with their resolution were carefully recorded. We rated the included studies as methodologically sound in case of 6 out of 8 positive responses. In the case one item was found not applicable (i.e. item n. 7), high quality studies were defined as those with 5 out of 7 positive responses. The remaining studies were rated as low/moderate quality.

3. Results

3.1. Study selection

A total of 3888 potentially relevant citations were retrieved from the selected databases. After removing duplicates, 3214 citations were screened based on title and abstract. Of these, 32 were assessed in full-text against the inclusion criteria. Two additional studies were identified through handsearching and assessed for eligibility. Overall, 17 studies were included in qualitative synthesis. Of note, four out of 15 included studies were conference proceedings published *in extenso* (Mapanta, 2024; Ye, 2023; Kusumawati, 2021; Sudiarno, 2021). The flow diagram of the study selection is reported in Fig. 1.

3.2. Study characteristics

Table 2 summarizes the main characteristics of included studies. Out of 17, six studies were conducted in Indonesia (Mapanta, 2024; Putri, 2023; Sahri, 2023; Liana, 2022; Kusumawati, 2021; Sudiarno, 2021), three in China (Chan, 2023; Pei, 2023; Ye, 2023), three in Brazil (de Paula Garcia, 2022; Moreira, 2021; Rocha, 2024), and one in USA (Mc Sweeney, 2023), Poland (Siuta, 2022), Finland (Tappura, 2022), Australia (Trinh, 2022), and Iran (Jahangiri, 2021). A wide range of occupational sectors were evaluated encompassing industries from oil and gas (Mc Sweeney, 2023; Rocha, 2024; Kusumawati, 2021) to shipping (Sahri, 2023). Other settings such as health and logistic services and construction industries were reported as well (Liana, 2022; Putri, 2023; Chan, 2023; Trinh, 2022).

The vast majority of included studies (59 %, n = 10) referred to the development and application of a new (or adapted) safety culture maturity model (Chan, 2023; de Paula Garcia, 2022; Liana, 2022; Mapanta, 2024; Pei, 2023; Rocha, 2024; Siuta, 2022; Tappura, 2022; Sudiarno, 2021; Ye and Luo, 2023). Only two studies developed a new safety culture maturity model without field application (Mc Sweeney, 2023; Trinh, 2022). Out of 12, six studies were related to a new safety culture maturity model based on the Hudson model (Chan, 2023; de Paula Garcia, 2022; Liana, 2022; Mapanta, 2024; Trinh and Feng, 2022; Ye and Luo, 2023), two were based on multiple safety culture maturity models (Mc Sweeney, 2023; Tappura, 2022), one was developed starting from the Fleming model (Pei, 2023), one from the Parker model (Rocha, 2024), one from the Bradley curve (Siuta, 2022), and another one was based on the adapted version of the Anglo American Plc maturity model (Sudiarno, 2021). On the other hand, five studies applied already established safety culture maturity models: four used the Hudson model (Putri, 2023; Jahangiri, 2021; Kusumawati, 2021; Moreira, 2021), and one the Fleming model (Sahri, 2023).

Reviewing the literature was the most applied method for identifying dimensions of safety culture maturity models (Chan, 2023; Mc Sweeney, 2023; Pei, 2023; Ye, 2023; Tappura, 2022; Trinh, 2022; Sudiarno, 2021), followed by consultation with experts (Liana, 2022; Siuta, 2022; Trinh, 2022). To assess safety culture maturity model, questionnaires along with interviews were frequently used (Chan, 2023; de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Mapanta, 2024; McSweeney, 2023; Moreira, 2021; Putri, 2023; Rocha, 2024; Sahri, 2023; Siuta, 2022; Tappura, 2022; Kusumawati, 2021; Sudiarno, 2021; Ye and Luo, 2023), while only two studies applied a mathematical model based on indicators (Pei, 2023, Siuta, 2022).

The list of dimensions used to evaluate safety culture maturity models is reported in Table 3. Leadership and commitment (de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Moreira, 2021; Pei, 2023; Putri, 2023; Sahri, 2023; Siuta, 2022; Tappura, 2022; Kusumawati, 2021; Sudiarno, 2021; Ye and Luo, 2023), communication and information flow (Chan, 2023; de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Moreira, 2021; Putri, 2023; Sahri, 2023; Siuta, 2022; Tappura, 2022; Trinh and Feng, 2022; Sudiarno, 2021; Ye and Luo, 2023), participation and involvement (de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Mapanta, 2024; Moreira, 2021; Sahri, 2023; Sudiarno, 2021) along with training and competence (Sahri, 2023; Liana, 2022; Siuta, 2022; Tappura, 2022; Trinh, 2022; Kusumawati, 2021; Sudiarno, 2021) were the most frequently reported.

Out of twelve studies developing a new safety culture maturity model, five carried out a reliability test such as Cronbach's alpha and structural equation model (Chan, 2023; Liana, 2022; Siuta, 2022; Tappura, 2022; Sudiarno, 2021). Of these, only two new safety culture maturity models were validated (Liana, 2022; Sudiarno, 2021) (see Table 4).

The quality assessment of the included studies is reported in Table 5. The quality score ranged from 1 to 7 positive responses (out of 8). Eleven out of 17 studies (Chan, 2023; de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Moreira, 2021; Rocha, 2024; Siuta, 2022; Tappura, 2022; Trinh and Feng, 2022; Kusumawati, 2021; Sudiarno, 2021) were classified as high quality studies. The other six studies were of poor methodological quality (Mapanta, 2024; Mc Sweeney, 2023; Pei, 2023; Putri, 2023; Sahri, 2023; Ye, 2023). The most frequently missing items were those related to the evaluation of the effectiveness of interventions along with the application of validity/reliability test.

4. Discussion

This scoping review aimed at updating the existing knowledge on safety culture maturity models in OSH and investigating the extent to which these models have been developed, assessed, and applied in occupational sectors.

4.1. Summary of findings

We provided a summary of the main characteristics of safety culture maturity models that can be applied to any process (within an organisation), occupational sector, or enterprise (small, medium, and large). These findings underlined that these models could act as a roadmap for organisations to assess their current level of maturity by spotting aspects/dimensions to be tackled to reach a higher level of maturity. However, there is no consensus on which safety culture maturity assessment tool is the best to put into practice considering that it may depend on organisational goals, type of industry, and socio-economic context.

The vast majority of included studies applied a qualitative method to assess dimensions of safety culture maturity models; this is likely to be biased due to subjective assessment mainly based on questionnaires and interviews. Only two studies applied quantitative methods (i.e. mathematical models based on indicators) (Pei, 2023; Siuta, 2022). As a matter of fact, the most frequently reported dimensions were more likely to encompass aspects related to leadership, commitment, communication, participation, and training rather than statistics of accidents, injuries, and occupational diseases.

In contrast to two previously published reviews (Ayob, 2022; Gonçalves Filho and Waterson, 2018), we found that most included studies developed and applied new (or adapted) safety culture maturity models (Chan, 2023; de Paula Garcia, 2022; Liana, 2022; Mapanta, 2024; Pei,

Table 2
Characteristics of included studies (in chronological order).

Study ID	Study characteristics		Maturity model structure					
	Country	Sector	Development and/or application of maturity model	Dimensions	Methods for identifying dimensions	Methods for assessing dimensions	Levels name	Methods for defining levels
Mapanta 2024	Indonesia	Mining Service	Development and application of a new model based on the Hudson model	– Worker Participation – Responsibilities of the head of the work unit – Analysis and statistics of accidents, occupational diseases, occupational diseases and hazardous events – Control efforts that have been carried out	– Not reported	– Observation – Interview – Recording analysis – Documentary analysis	1. Basic 2. Reactive 3. Planned 4. Proactive 5. Resilient	– Assignment based on qualitative description
Rocha 2024	Brazil	Oil and gas industry	Development and application of a new model based on the Parker model (Parker, 2006)	– Benchmarking, trends, and statistics – Audits and incident and accident investigation and analysis – Hazard and unsafe acts reporting – Work planning – Contractor management	– Dimensions based on the Parker model	– Questionnaire – Focus group with expert – Interview	1. Pathological 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on qualitative and quantitative evaluation
Chan 2023	China	Construction building	Development and application of a multi-level (client, main contractor and subcontractor) version of the Hudson model	– Informed culture: Information flow, incident response; safety statistics Management – Just culture: response to sabotage; response to honest Mistake; response to reckless violation – Reporting culture: reaction to near miss outside designated area; reaction to critical unsafe situation in own area; reaction to noncompliance by fellow staff member – –Learning culture: response to minor incident; response to serious accident and investigation; response to near miss – Flexible culture: hazard management, crisis preparedness; approach to innovation	– Literature review	– Questionnaire	1. Pathogenic 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on specific intervals of overall response score average
Mc Sweeney 2023	USA	Offshore oil and gas industry	Development of a new model based on the Fleming model, Hudson model, and Bradley curve	– Safety culture perceptions surveys – Worker Interviews – Site safety inspections – Review of previous incident investigations	– Literature review	– Survey – Interviews – Collection and review of incident reports	1. Reactive 2. Rulebased 3. Management driven 4. Workforce involvement 5. Continual improvement	– Assignment based on qualitative description

(*continued on next page*)

Table 2 (*continued*)

Study ID	Study characteristics		Maturity model structure					
	Country	Sector	Development and/or application of maturity model	Dimensions	Methods for identifying dimensions	Methods for assessing dimensions	Levels name	Methods for defining levels
				– Review of potential leading indicators (accident precursors) – Safety and Environmental Management System (SEMS) review				
Pei 2023	China	Not reported	Development and application of a new model based on the Fleming model	– Safety concept culture: commitment, attitude, concept – Safety system culture: management, system – Safety behaviour culture: decision layer behaviour, management behaviour, employee behaviour – Safety physical culture: device, visualization on site, tools and protective equipment, promotional display, business environment	– Literature review – Expert scoring	– Mathematical model using indicators – Evaluation matrix	1. Original 2. Starting 3. Developing 4. Completion 5. Leading	– Assignment based on qualitative description and score ranking
Putri 2023	Indonesia	Logistics service	Hudson model	– Commitment – Information – Awareness – Behaviour	– Dimensions based on the Hudson model	– Qualitative interviews – Field observation – Company records	1. Pathological 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on qualitative description and interview interpretation
Sahri 2023	Indonesia	Shipping industry	Fleming model	– Management commitment and visibility – Communication – Productivity versus safety – Learning organisation – Safety resources – Participation – Shared perceptions about safety – Trust – Industrial relations and job satisfaction – Training	– Dimensions based on the Fleming model	– Questionnaire – In-depth interview – Mean of considered indicators	1. Emerging 2. Managing 3. Involving 4. Cooperating 5. Continually improving	– Assignment based on score ranking
Ye 2023	China	Civil aviation industry	Development and application of a new model based on the Hudson model	– Awareness – Justness – Adaptability – Information – Behaviour – Commitment	– Literature review	– Questionnaire	1. Pathological 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on specific intervals of overall response average score
de Paula Garcia 2022	Brazil	Food Industry	Adapted from the Hudson model (Gonçalves Filho, 2011)	– Information – Organisational learning – Involvement – Communication – Commitment	– Dimensions based on the Hudson model	– Questionnaire	1. Pathologic 2. Reactive 3. Bureaucratic 4. Proactive 5. Sustainable	– Assignment based on the average frequency
Liana 2022	Indonesia	Health service	Development and application of a new model based	– Management commitment	– Consultation with experts	– Questionnaire	1. Pathologic 2. Reactive 3. Bureaucratic	– Assignment based on specific

(*continued on next page*)

Table 2 (*continued*)

Study ID	Study characteristics		Maturity model structure					
	Country	Sector	Development and/or application of maturity model	Dimensions	Methods for identifying dimensions	Methods for assessing dimensions	Levels name	Methods for defining levels
			on the Hudson model	– Safety communication – Rules and procedures (regulations) – Enabling environment – Personal involvement (participation) – Safety training			4. Proactive 5. Generative	intervals of mean score
Siuta 2022	Poland	Energy industry	Development and application of a new model based on the Bradley curve	– Leadership for safety – Recognition and awards – Communication and information flow – Networking – Personal knowledge and skills in the field of process technology and safety – Care for yourself – Costs of accidents – Loss of organisation image – Fatal accident rate – Loss of working time – Occupational injuries – Safety training – Inherent safety – Care for others – Cost of proactive actions – Organisational pride	– Consultation with experts	– Questionnaire – Mathematical model using indicators	1. Reactive 2. Dependent 3. Independent 4. Interdependent	– Assignment based on qualitative description and index range
Tappura 2022	Finland	Infrastructure building and chemical industry	Development and application of a new model based on the Fleming model, Hudson model, and Bradley curve	– Management commitment – Supervisor commitment – Employee commitment – Training – Communication	– Literature review	– Questionnaire	1. Level 1 2. Level 2 3. Level 3 4. Level 4	– Assignment based on specific intervals of overall response score average
Trinh 2022	Australia	Construction industry	Development of a new model based on the Hudson model	Hazard prevention: – Safety policy – Site safety organisation – Risk assessment and hazard analysis – Safety inspection Hazard control program – Personal protection program – Safety meetings – Safety training – Safety promotion – Management support Error management: – Learning from errors – Error competence – Thinking about errors	– Literature review – Consultation with experts	– Delphi method	1. Pathological 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on qualitative evaluation and index range

(*continued on next page*)

Table 2 (*continued*)

Study ID	Study characteristics		Maturity model structure					
	Country	Sector	Development and/or application of maturity model	Dimensions	Methods for identifying dimensions	Methods for assessing dimensions	Levels name	Methods for defining levels
				– Error communication Mindful organizing practices: – Preoccupation with failure – Reluctance to simplify interpretations – Sensitivity to operations – Commitment to resilience – Deference to expertise				
Jahangiri 2021	Iran	Drilling industry	Hudson model	– Commitment and leadership – Participation/ Involvement – Communication – Organisational learning	– Dimensions based on the Hudson model	– Questionnaire	1. Pathological 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on the frequency of each level chosen by participants
Kusumawati 2021	Indonesia	Oil and gas company	Hudson model	– Trend and Statistics – Audit and Review – Accident Investigation – Safety Report – Accident Causes – Accident Follow-up – Safety Meeting – Work Permit – Contractor Management – Standard Setting – Training and Competency – Hazard Management Technique – Safety Inspection – Safety Priority – Safety Socialization – Commitment – Procedure Development – Procedure Objectives – HSE Existence – Safety Reward	– Dimensions based on the Hudson model	– Observation, documentary analysis – Questionnaire – Interviews – Open-ended group discussion	1. Pathogenic 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on score ranking
Moreira 2021	Brazil	Engineering academic laboratory	Hudson model	– Information – Organisational learning – Communication – Commitment – Involvement	– Dimensions based on the Hudson model	– Questionnaire	1. Pathogenic 2. Reactive 3. Calculative 4. Proactive 5. Generative	– Assignment based on qualitative description and score ranking
Sudiarno 2021	Indonesia	Coal power industry	Adapted version of the Anglo-American Plc maturity model by Foster and Hoult (Foster and Hoult, 2013)	– Commitment – Leadership – Responsibility – Engagement and involvement – Risk identification – Competence – Information and Communication – Organisational Learning	– Literature review – Best practices report	– Questionnaire	1. Basic 2. Reactive 3. Compliant 4. Proactive 5. Resilient	– Assignment based on qualitative description

Table 3
Dimensions used to evaluate safety culture maturity in included studies.

	Mapanta 2024	Chan 2023	McSweeney 2023	Pei 2023	Putri 2023	Rocha 2024	Sahri 2023	Ye and Luo 2023	de Paula Garcia 2022	Liana 2022	Siuta 2022	Tappura 2022	Trinh 2022	Jahangiri 2021	Kusumawati 2021	Moreira 2021	Sudiarno 2021
Leadership and commitment																	
Management commitment							✓			✓		✓					
Supervisor commitment												✓					
Employee commitment												✓					
Commitment				✓	✓			✓	✓					✓	✓	✓	✓
Leadership											✓			✓			✓
Management visibility							✓										
Participation and Involvement																	
Participation	✓						✓			✓				✓			
Engagement																	✓
Involvement									✓	✓				✓		✓	✓
Communication and Information Flow																	
Communication							✓		✓	✓	✓	✓		✓		✓	✓
Information		✓			✓			✓	✓		✓					✓	✓
Networking/Industrial relations							✓				✓						
Error communication													✓				
Safety concept																	
Awareness					✓			✓									
Safety perceptions			✓				✓										
Safety attitude				✓													
Organisational pride											✓						
Training and Competence																	
Training/Safey training							✓			✓	✓	✓	✓		✓		
Competence/Personal knowledge and skills											✓				✓		✓
Mindful organizing practices																	
Preoccupation with failure													✓				
Reluctance to simplify interpretations													✓				
Sensitivity to operations													✓				
Commitment to resilience													✓				
Deference to expertise													✓				
Safety management system and practice																	
Worker Interviews			✓														
Safety and Environmental Management System (SEMS) review			✓														
Device, visualization on site, tools and protective equipment, promotional display, business environment				✓													
Audit and Review						✓									✓		
Management system				✓													
Safety Meeting													✓		✓		

(*continued on next page*)

Table 3 (*continued*)

	Mapanta 2024	Chan 2023	McSweeney 2023	Pei 2023	Putri 2023	Rocha 2024	Sahri 2023	Ye and Luo 2023	de Paula Garcia 2022	Liana 2022	Siuta 2022	Tappura 2022	Trinh 2022	Jahangiri 2021	Kusumawati 2021	Moreira 2021	Sudiarno 2021
Work Permit															✓		
Work planning						✓											
Contractor management						✓									✓		
Standard Setting															✓		
Procedure Development															✓		
Procedure Objectives															✓		
Safety Reward															✓		
Safety Inspection			✓										✓		✓		
Safety Priority															✓		
Safety Socialization															✓		
Rules and procedures										✓							
Productivity versus safety							✓										
Safety Policy													✓				
Site Safety Organisation													✓				
Safety Promotion													✓				
Management Support													✓				
Hazard management																	
Hazard management, crisis preparedness, approach to innovation		✓															
Hazard Management Technique															✓		
Health Safety Environment (HSE) Existence															✓		
Hazard control program													✓				
Personal protection program													✓				
Analysis and Evaluation																	
Analysis and statistics of accidents, occupational diseases, and hazardous events	✓					✓											
Review of previous incident investigations			✓			✓											
Review of potential leading indicators (accident precursors)			✓														
Trend and Statistics						✓									✓		
Accident Investigation															✓		
Accident Causes															✓		
Accident Follow-up															✓		
Costs of accidents											✓						
Loss of organisation image											✓						
Fatal accident rate											✓						
Loss of working time											✓						
Occupational injuries											✓						
Cost of proactive actions											✓						
Safety statistics Management		✓															
Risk identification																	✓
Risk assessment and hazard analysis													✓				

(*continued on next page*)

Table 3 (*continued*)

	Mapanta 2024	Chan 2023	McSweeney 2023	Pei 2023	Putri 2023	Rocha 2024	Sahri 2023	Ye and Luo 2023	de Paula Garcia 2022	Liana 2022	Siuta 2022	Tappura 2022	Trinh 2022	Jahangiri 2021	Kusumawati 2021	Moreira 2021	Sudiarno 2021
Safety Resources (human, technology, and financial)																	
Adaptability								✓									
Safety resources							✓										
Job satisfaction							✓										
Inherent safety											✓						
Recognition and rewards											✓						
Care and responsibility																	
Care for yourself											✓						
Care for others											✓						
Responsibilities of the head of the work unit	✓																
Responsibility																	✓
Enabling environment										✓							
Behavioural Aspects																	
Behaviour					✓			✓									
Decision layer behaviour, management behaviour, employee behaviour				✓													
Learning and response to safety issues																	
Organisational learning							✓		✓					✓		✓	✓
Learning from errors													✓				
Error competence													✓				
Thinking about errors													✓				
Response to minor incident, response to serious accident and investigation, response to near miss		✓															
Control efforts	✓																
Response to sabotage, response to honest mistake, response to reckless violation		✓															
Reaction to near miss outside designated area, reaction to critical unsafe situation in own area, reaction to non-compliance by fellow staff member		✓															
Reporting management																	
Safety Report						✓									✓		
Trust and Justness																	
Trust							✓										
Justness								✓									

Table 4
Validity and reliability tests for assessing new safety culture maturity models in included studies.

Study ID	Validity	Reliability test
Mapanta 2024	Not validated	Not performed
Chan 2023	Not validated	Cronbach's alpha
Mc Sweeney 2023	Not validated	Not performed
Pei 2023	Not validated	Not performed
Rocha 2024	Not validated	Not performed
Ye 2023	Not validated	Not performed
de Paula Garcia 2022	Not validated	Not performed
Liana 2022	Construct validity assessed with: −Average Variance Extracted (AVE) −Confirmatory Factor analysis (CFA)	Structural equation model (SEM)
Siuta 2022	Not validated	Cronbach's alpha
Tappura 2022	Not validated	Structural equation model (SEM)
Trinh 2022	Not validated	Not performed
Sudiarno 2021	Convergent validity assessed with: −Confirmatory Factor analysis (CFA)	Standardized loading factor

2023; Rocha, 2024; Siuta, 2022; Tappura, 2022; Sudiarno, 2021; Ye and Luo, 2023). However, only five of those studies carried out a reliability test (Chan, 2023; Liana, 2022; Siuta, 2022; Tappura, 2022; Sudiarno, 2021) and only two new safety culture maturity models were validated (Liana, 2022; Sudiarno, 2021). This lack of validation and reliability assessment precludes the generalizability of the findings related to the application of these newly proposed safety culture maturity models in OSH. Data on validity/reliability of these tools are crucial for ensuring data accuracy and trustworthiness of findings aimed at supporting organisations to properly assess their level of maturity. Specifically, validity examines whether a tool effectively measures what it is supposed to measure; on the other hand, reliability refers to whether it produces consistent results. A list of validated indicators would assist organisations to properly evaluate their safety culture maturity level by detecting issues that need to be dealt with.

In line with other reports (Ayob, 2022; Gonçalves Filho and Waterson, 2018), a variety of occupational sectors were represented; in particular, oil and gas industry was the most frequently reported (Mc Sweeney, 2023; Rocha, 2024; Kusumawati, 2021). According to the World Bank country classifications for 2023 (World Bank, 2023), 80 % (13 out of 17) of the studies evaluating safety culture maturity models were located in upper-middle-income countries (Chan, 2023; de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Mapanta, 2024; Moreira, 2021; Pei, 2023; Putri, 2023; Rocha, 2024; Sahri, 2023; Kusumawati, 2021; Sudiarno, 2021; Ye and Luo, 2023). Of these, 77 % (10 out of 13) were located in Asia (Mapanta, 2024; Putri, 2023; Sahri, 2023; Liana, 2022; Kusumawati, 2021; Sudiarno, 2021; Chan, 2023; Pei, 2023; Ye, 2023; Jahangiri, 2021). These findings highlighted that these countries are currently paying more attention to the concept of safety culture in a wide range of occupational sectors by aiming to reach a higher level of maturity. On the contrary, no study was conducted in low-income countries; this might be related to a variety of factors such as inadequate resources, economic constraints, lack of awareness about the topic, and scarcity of OSH experts. Low-income countries are likely to have poorly enforced safety regulations aimed at minimising work-related risks compared to high-income countries. The application of tailored safety culture maturity models to the specific context of low-income countries might be a first step to improve safety culture.

4.2. Strengths and limitations

The present scoping review follows the PRISMA-ScR review protocol along with the latest guidelines issued by JBI providing a framework for future expansion. All countries without any restriction to occupational sector were included, providing an overall mapping of safety culture maturity models along with field application with a global perspective. We also included studies regardless of language to minimize the risk of language/indexing bias (Jia, 2020; Egger, 1997).

We searched three databases (MEDLINE, Scopus, and Web of Science). However, considering that safety culture maturity models might be underreported in peer-reviewed journals, this scoping review aimed at including grey literature as well. It is worth noting that 24 % (four out 17) of included studies were conference proceedings published *in extenso* (Mapanta, 2024; Ye, 2023; Kusumawati, 2021; Sudiarno, 2021). Despite this, we acknowledge that this topic might be disseminated through internal reports or informal feedback rather than academic journals. Furthermore, the included studies were more likely to be published in journals addressing safety engineering and safety science rather than medical/public health journals. This highlights that this topic might not be well known among occupational health professionals (including occupational physicians) – who play a crucial role in promoting safety and health at work.

Most of the included studies were of high quality (Chan, 2023; de Paula Garcia, 2022; Jahangiri, 2021; Liana, 2022; Moreira, 2021; Rocha, 2024; Siuta, 2022; Tappura, 2022; Trinh and Feng, 2022; Kusumawati, 2021; Sudiarno, 2021). However, only five out of the eleven high quality studies performed validity/reliability tests (Chan, 2023; Liana, 2022; Siuta, 2022; Tappura, 2022; Sudiarno, 2021). In addition, it is worth noting that none of the studies applied a safety culture maturity model to evaluate the effectiveness of interventions in the workplace.

A variety of sectors and industries were investigated precluding a comparability between organisations. However, the two validated safety culture maturity models (Liana, 2022; Sudiarno, 2021) can be applied to any process within an organisation, occupational sector, and companies regardless of their size. On the other hand, the other models without validation could only be used to assess the level of maturity across time within the same production unit. The lack of cross-validation across studies is a relevant issue as well. Most safety culture maturity models were developed independently and many of them were not validated. In addition, no overlap in terms of dimensions has been investigated so far, albeit we cross-tabulated those used to evaluate the safety culture maturity level in included studies (see Table 3). This might preclude whether safety culture maturity models could be integrated into a universal framework. A geographic bias should be taken into account. To some extent, the absence of validation would limit the model's applicability in terms of regional characteristics including cultural differences and industry-specific factors.

Meta-analysis and/or qualitative synthesis of effect sizes would have strengthened the results. However, it was not applicable in the present study. Specifically, this scoping review focuses on methods/characteristics of safety culture maturity models, rather than on specific results/findings of an epidemiological study (usually expressed in terms of relative risks and/or odds ratios).

5. Conclusion

This scoping review provided an overview of the state of the art on safety culture maturity models in OSH. This may help OSH professionals as well as researchers identifying current gaps in terms of development, application, and assessment of these models in occupational setting. At the same time, it can support organisations in the selection of the appropriate tools to assess safety culture maturity levels at work. Further research is needed to validate existing and newly developed tools aimed at assessing safety culture maturity level allowing comparisons between organisations. Future studies can expand the sample scope by increasing

Table 5
Quality assessment of the included studies.

Items*	Mapanta 2024	Chan 2023	McSweeney 2023	Pei 2023	Putri 2023	Rocha 2024	Sahri 2023	Ye 2023	de Paula Garcia 2022	Liana 2022	Siuta 2022	Tappura 2022	Trinh 2022	Jahangiri 2021	Kusumawati 2021	Moreira 2021	Sudiarno 2021
1. Was there a clear statement of the aims of the research?	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y
2. Was the research design appropriate to address the aims of the research?	U	Y	U	Y	Y	Y	Y	U	Y	U	Y	Y	Y	Y	U	Y	Y
3. Was the context adequately described in terms of setting/plant/sector?	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4. Was the data collection (e.g. procedures, instruments) appropriate to address the research issue?	U	Y	U	N	N	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y
5. Were the findings adequately derived from the data?	N	Y	N	N	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
6. Was the interpretation of results sufficiently substantiated by data?	N	Y	N	U	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
7. Were validity/reliability tests performed?	N	Y	N	N	NA	N	NA	N	N	Y	Y	Y	N	NA	NA	NA	Y
8. Was the safety culture maturity model used to evaluate the effectiveness of intervention?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Appraisal summary	L/M	H	L/M	L/M	L/M	H	L/M	L/M	H	H	H	H	H	H	H	H	H

*Possible responses: Yes (Y), No (N), Unclear (U). High quality studies were defined as those with 6 out of 8 positive responses. In the case one item was found not applicable (NA) (i.e. item n. 7), high quality studies were those with 5 out of 7 positive responses. Appraisal summary: High (H) quality studies, Low/Moderate (L/M) quality studies.

the geographical area covered including countries with different economic levels (e.g. low income countries) and by covering multiple sectors and companies of different size. This would allow comparisons in terms of industrial as well as cultural differences by exploring which maturity model is adequate to evaluate safety culture in that specific context. By adapting safety culture maturity models to the local context, organisations can create a strong safety culture and improve safety performance in the workplace.

CRediT authorship contribution statement

Stefania Curti: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Data curation, Conceptualization. **Mena Gallo:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Mattia Roberto Nocilla:** Writing – review & editing, Investigation, Data curation. **Andrea Montagnani:** Writing – review & editing, Investigation, Data curation. **Stefano Mattioli:** Writing – review & editing, Methodology, Conceptualization. **Maria Grazia Gnoni:** Writing – review & editing, Funding acquisition, Conceptualization. **Diego De Merich:** Writing – review & editing, Supervision, Conceptualization.

Funding

This study was partially supported by the *Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro* (INAIL), Rome, Italy – INAIL BRIC Project 2022 (ID 01).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssci.2025.107003.

Data availability

Data will be made available on request.

References

Advisory Committee on the Safety of Nuclear Installations (ACSNI). ACSNI study group on human factors. United Kingdom: HM Stationery Office. London United Kingdom, 1993.

Aromataris, E., Lockwood, C., Porritt, K., Pilla, B., Jordan, Z. (Eds.), JBI Manual for Evidence Synthesis. JBI; 2024. Available from: https://synthesismanual.jbi.global (Accessed on February 17, 2025).

Ayob, A.N., Che Hassan, C.R., Hamid, M.D., 2022. Safety culture maturity measurement methods: a systematic literature review. J. Loss Prev. Process Ind. 80, 104910.

CBI, 1991. Developing a Safety Culture. Confederation of British Industry, London.

Chan, E., 2023. A multi-level safety culture maturity model for (new) building projects in Hong Kong. HKIE Transactions Hong Kong Institution of Engineers. 30 (1), 95–105.

Cole, K.S., Stevens-Adams, S.M., Wenner, C.A., 2013. A Literature Review of Safety Culture. Sandia Report (SAND2013-2754), Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation. pp. 1–47.

Critical Appraisal Skills Programme (2025). CASP (qualitative research checklist). Available at: https://casp-uk.net/casp-tools-checklists/ (Accessed on July 11, 2025).

de Paula Garcia, D., Polezi Munhoz, I., SilveiraStopiglia, F., Cristina Santos Akkari, A., 2022. Assessment of safety culture maturity in a food industry: a comparison between manufacturing and administration sector. Rev. Científ. Hermes 32, 182–201.

Díaz-Cabrera, D., Hernandez-Fernaud, E., Isla-Díaz, R., 2007. An evaluation of a new instrument to measure organisational safety culture values and practices. Accid. Anal. Prev. 39 (6), 1202–1211.

DuPont, 2009. Overview of DuPont' S Safety Model and Sustainability Initiatives. DOE and DuPont Safety Initiative, USA.

DuPont Sustainable Solutions. The DuPont Integrated Approach (DnA) for Safety: A Catalyst to Accelerate Performance; DuPont Sustainable Solutions: Wilmington, DE, USA, 2012.

Egger, M., Zellweger-Zähner, T., Schneider, M., Junker, C., Lengeler, C., Antes, G., 1997. Language bias in randomised controlled trials published in English and German. Lancet 350 (9074), 326–329.

Fleming, M., 2001. Safety Culture Maturity Model, Offshore Technology Report 2000/049. Keil Centre for HSE, UK.

Foster, P., Hoult, S., 2013. The safety journey: using a safety maturity model for safety planning and assurance in UK coal mining industry. Minerals 3 (1), 59–72.

Gonçalves Filho, A.P., Andrade, J.C.S., Marinho, M.M.D.O., 2011. Cultura e gestão da segurança no trabalho: uma proposta de modelo [Culture and safety management: the proposal of a model]. Gest Prod. 18 (1), 205–220.

Gonçalves Filho, A.P., Waterson, P., 2018. Maturity models and safety culture: a critical review. Saf. Sci. 105, 192–211.

Guldenmund, F.W., 2000. The nature of safety culture: a review of theory and research. Saf. Sci. 34 (1–3), 215–257.

Hudson, P., 2001. Safety management and safety culture the long. Hard and Winding Road. 3.

IAEA, 1986. INSAG's Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident. Safety Series No.75-INSAG-1, 1986, Vienna.

IAEA, 1988. INSAG's Basic Safety Principles for Nuclear Power Plants. Safety Series No.75-INSAG-3, Vienna, 1988.

IAEA, 1991. Safety culture. Safety Series No. 75-INSAG-4. International Atomic Energy Agency, Vienna, 1991.

Jahangiri, M., Zinat-Motlagh, K., Ghaem, H., Zinat-Motlagh, F., Kamalinia, M., Banaee, S., 2021. Safety culture maturity and resilience engineering in an oil drilling industry: a comparison study among government-owned and private companies. Work. 70 (2), 443–453.

Jia, Y., Huang, D., Wen, J., Wang, Y., Rosman, L., Chen, Q., Robinson, K.A., Gagnier, J.J., Ehrhardt, S., Celentano, D.D., 2020. Assessment of language and indexing biases among Chinese-sponsored randomized clinical trials. JAMA Netw Open. 3 (5).

Landis, J.R., Koch, G.G., 1977. The measurement of observer agreement for categorical data. Biometrics. 33 (1), 159–174.

Liana, D., Lestari, F., Sutoto, S., Modjo, R., Bachtiar, A., 2022. A self-assessment model for hospital safety culture maturity. J. Public Health Res. 11 (2), 253.

Kusumawati, D., Erwandi, D., 2021. Examining Relationship between Safety Culture Maturity and Safety Performance in Oil and Gas Company. Society of Petroleum Engineers, Abu Dhabi International Petroleum Exhibition and Conference, UAE, November 15-18, SPE-208190-MS.

Mapanta, J., Mandeli, R.S., Aminuddin, A., Handayana, R.H., Syah, N., Heldi, H., Carlo, N., Barlian, E., Dewata, I., Zainul, R., Yusoff, S.M., Rahim, R., 2024. Preliminary study of measurement of maturity level of mining work environment safety management performance. AIP Conf. Proc. 3001, 030001.

Mattioli, S., Zanardi, F., Baldasseroni, A., Schaafsma, F., Cooke, R.M., Mancini, G., Fierro, M., Santangelo, C., Farioli, A., Fucksia, S., Curti, S., Violante, F.S., Verbeek, J., 2010. Search strings for the study of putative occupational determinants of disease. Occup Environ Med. 67 (7), 436–443.

McSweeney, K., Curry, J., Curtis, R., Wari, E., Zhu, W., Craig, B., Hussain, M.M., Haces-Garcia, A., Idahosa, O.P., Zeni, E., Seshasaikrishna, G., 2023. Development of a comprehensive multi-component toolkit for offshore safety culture assessment. Process Saf. Environ. Prot. 175, 78–87.

Moreira, F.G.P., Ramos, A.L.F., Fonseca, K.R.C., 2021. Safety culture maturity in a civil engineering academic laboratory. Saf. Sci. 134, 105076.

Parker, D., Lawrie, M., Hudson, P., 2006. A framework for understanding the development of organisational safety culture. Saf. Sci. 44, 551–562.

Pei, J., Liu, L., Chi, Y., Yu, C., 2023. Research on the maturity evaluation model of enterprise safety culture. Int. J. Environ. Res. Public Health. 20 (3), 2664.

Putri, E.C., Yusvita, F., Situngkir, D., 2023. Safety maturity level assessment at logistic service company in ancol. Indones. J. Occup. Saf. Health. 12 (3), 402–412.

Rocha, R., Duarte, F., Lima, F.P.A., Mercado, M., Araújo, A., Garotti, L., Campos, M., 2024. Framework for the assessment of the safety culture in the oil and gas industry. Int. J. Occup. Saf. Ergon. 30 (1), 224–237.

Sahri, M., Arifin, M.I.R.M., Fasya, A.H.Z., Ibad, M., 2023. Assessment of health and safety culture maturity level in the shipping industry in Surabaya. Bali Med. J. 12 (3), 2886–2890.

Siuta, D., Kukfisz, B., Kuczyńska, A., Mitkowski, P.T., 2022. Methodology for the determination of a process safety culture index and safety culture maturity level in industries. Int. J. Environ. Res. Public Health. 19 (5), 2668.

Sudiarno, A., Hermawan, E., Partiwi, S.G., 2021. Conceptual modeling of safety culture in coal steam power plant operations and maintenance services in Indonesia. In: 4th Asia Pacific Conference on Research in Industrial and Systems Engineering, Depok, Indonesia, May 25, 2021:627–634.

Tappura, S., Jääskeläinen, A., Pirhonen, J., 2022. Creation of satisfactory safety culture by developing its key dimensions. Saf. Sci. 154, 105849.

Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., Hempel, S., Akl, E.A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M.G., Garritty, C., Lewin, S., Godfrey, C.M., Macdonald, M.T., Langlois, E.V., Soares-Weiser, K., Moriarty, J., Clifford, T., Tunçalp, Ö., Straus, S.E., 2018. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann. Int. Med. 169 (7), 467–473.

Trinh, M.T., Feng, Y., 2022. A maturity model for resilient safety culture development in construction companies. Buildings 12, 733.

Westrum, R., 1993. Cultures with requisite imagination. In: Wise, J.A., Hopkin, V.D., Stager, P. (Eds.), Verification and Validation of Complex Systems: Human Factor Issues. Springer-Verlag, New York, pp. 401–416.

Westrum, R., 2004. A typology of organisational cultures. Qual. Saf. Health Care. 13 (Suppl II), ii22–ii27.
World Bank country classifications by income level, 2023. Available at: https://datahelpdesk.worldbank.org/ (Accessed on February 17, 2025).
Ye, H., Luo, M., 2023. Research on China civil aviation safety culture maturity evaluation. In: The 7th International Conference on Transportation Information and Safety, Xi'an, China, Aug 4–6, 2023:100–104.