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Decoding stakeholder priorities of safety culture preferences in the oil and gas industry

Hafiz Rahim[1,5], Rahmat Dapari[2]✉, Nazri Che Dom[1,4] & Mohd Iqbal Mohd Noor[3]

Safety culture is a critical determinant of organisational performance, particularly in high-risk industries especially in oil and gas. Understanding stakeholder preferences is essential for developing effective strategies that enhance safety culture. This study utilised the Analytic Hierarchy Process (AHP) to prioritise stakeholder preferences, identifying key elements of safety culture in Malaysia's oil and gas sector. This study employed a structured methodology to evaluate safety culture within the oil and gas industry, focusing on 18 sub-elements across three key domains: psychological, behavioural, and situational factors. A diverse sample of industry experts was recruited using purposeful and snowball sampling to ensure a comprehensive representation of stakeholder views. The AHP framework was applied to analyse the data, utilizing structured questionnaires and multicriteria decision-making techniques to prioritize the identified safety culture elements. The AHP analysis identified distinct priorities among different professional groups within the oil and gas sector. Safety and Health Practitioners emphasized practical elements such as safety rules and management commitment, while academicians prioritized knowledge and training. Management personnel highlighted the importance of safety ownership and communication, whereas policymakers focused on broader, policy-oriented aspects. The findings suggest that safety culture improvement initiatives should be tailored to address the specific needs and priorities of each professional group. A nuanced understanding of stakeholder preferences is crucial for developing comprehensive strategies that integrate observable behaviours, situational conditions, and psychological factors, ultimately fostering a robust safety culture in the oil and gas industry.

Keywords Safety culture, Elements, Analytical hierarchy process (AHP), Oil and gas, Stakeholder, Prioritization

Safety culture in the oil and gas industry is paramount to ensure operational safety as well as to safeguard human lives and the environment[1–3]. Safety culture refers to the shared attitudes, beliefs, perceptions, and values that employees hold regarding safety within an organisation[4–6]. It encompasses the commitment to safety at all levels of the organisation, influencing behaviour and decision-making processes aimed at preventing accidents and promoting a safe working environment[7]. Comprehensive integration of safety culture into the workplace environment is crucial as it forms one of the cornerstones of the holistic Health, Safety, and Environment (HSE) culture[8]. Without a comprehensive safety culture, the repercussions can be profound, directly causing accidents and injuries among oil and gas workers. Hence, robust accident prevention measures are vital in this sector[9–11].

In Malaysia, the oil and gas sector is a major contributor to the nation's economy[12]. As one of the largest contributors to the nation's GDP, the oil and gas sector significantly impacts Malaysia's economic stability and growth[13]. However, it is also associated with inherent risks stemming from suboptimal safety management practices[14–16]. Diverse regulatory practices, cultural influences on safety perceptions, and varied organisational safety practices further complicate the establishment of a unified safety culture across the industry[17,18]. Moreover, the safety landscape is highly dynamic as shaped by continuous technological advancements and evolving regulatory frameworks. Hence, an adaptable and responsive approach to safety culture development plays an important role in this industry[19,20]. In Malaysia, the oil and gas industry has been the subject of numerous

[1]Faculty of Health Sciences, Universiti Teknologi MARA, 42300 Bandar Puncak Alam, Malaysia. [2]Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Malaysia. [3]Faculty of Business Management, Universiti Teknologi Mara (UiTM), 27600 Raub, Pahang, Malaysia. [4]Institute of Biodiversity and Sustainable Development, Universiti Teknologi Mara (UiTM), 40450 Shah Alam, Selangor, Malaysia. [5]Department of Corporate Governance and HSE, Flowco Malaysia Sdn Bhd, 10, Jalan Tago 11, Sri Damansara, Kuala Lumpur, Malaysia. ✉email: drrahmat@upm.edu.my

studies, focusing on various aspects such as operational efficiency, environmental impact, and safety management practices[21]. Earlier studies have highlighted several major concerns regarding safety in the industry, including leadership, lack of effective communication, and insufficient safety training[17,22]. These issues have been identified as contributing factors to workplace accidents, which can have devastating consequences in terms of both human life and economic loss. As the industry continues to evolve with technological advancements and shifting regulatory frameworks, these safety concerns remain pertinent, requiring ongoing attention and improvement.

The development of a robust safety culture within the oil and gas industry is a critical component of organisational success, particularly in high-risk environments where the stakes are exceedingly high. Central to this endeavour is the understanding and integration of stakeholder preferences, which play a pivotal role in shaping safety practices that are both effective and sustainable. Sustainability initiatives, as highlighted in recent reviews of the petroleum industry, underscore the need for industry-specific strategies that align with environmental and social priorities, further emphasizing the importance of tailoring safety culture practices to local contexts[23]. Drawing on the principles of stakeholder theory, it is evident that aligning safety culture initiatives with the interests and expectations of key stakeholders—such as employees, management, and regulators—is essential for ensuring their successful implementation and long-term viability. Similarly, the role of ergonomic factors in industries such as leather garment manufacturing highlights the importance of considering worker well-being and social sustainability in the development of safety practices, pointing to the broader implications of safety culture beyond mere compliance[24]. However, existing research often fails to account for the nuanced preferences of local stakeholders, leading to potential misalignments between global safety norms and the specific cultural, economic, and regulatory contexts in which these practices are deployed. This gap underscores the necessity of a tailored approach to safety culture development, one that is informed by the unique characteristics of the local environment. By embedding stakeholder theory into the foundation of safety culture strategies, organisations within the oil and gas sector can create more resonant and contextually appropriate safety practices, thereby enhancing overall safety performance and organisational resilience.

The components of safety culture chosen for this study were carefully selected based on a thorough review of existing literature and their demonstrated significance in the context of the oil and gas industry. The decision to focus on specific elements such as management commitment, safety communication, safety training, and safety ownership; was influenced by their recurrent identification as foundational elements of an effective safety culture in the literature. For instance, Reason (2016) emphasizes management commitment as a cornerstone of safety culture, highlighting that leadership plays a crucial role in establishing and maintaining safety norms within an organisation[5]. Similarly, Guldenmund (2000) identifies safety communication as essential for fostering a transparent and informed safety environment, where workers are encouraged to voice concerns and share safety-related information freely[6]. Furthermore, Hopkins (2006) underscores the importance of safety training and competency in ensuring that workers are adequately prepared to handle the complexities and hazards of the oil and gas industry[25]. Safety ownership is another critical element, as described by Cooper (2000), which involves employees taking personal responsibility for safety and proactively contributing to a safer workplace[26]. By comprehensively understanding stakeholder preferences, organisations can develop targeted safety culture strategies that resonate with the diverse needs of stakeholders. Besides enhancing safety outcomes, it will also foster greater engagement and buy-in from those involved in the implementation process. Therefore, bridging the gap between overarching safety culture frameworks and localised stakeholder preferences is essential for cultivating a robust safety culture within the oil and gas industry.

The Analytic Hierarchy Process (AHP) is a powerful decision-making tool that has not been widely applied in the context of safety culture, especially within the Malaysian oil and gas sector. AHP was chosen for this study due to its ability to systematically decompose complex decisions into a hierarchy of more manageable subproblems, each of which can be analysed independently[27,28]. This makes AHP particularly suitable for prioritizing elements of safety culture, where multiple criteria need to be evaluated based on the preferences of diverse stakeholders. The AHP method has been successfully used in other high-risk industries, such as construction and manufacturing, demonstrating its applicability and effectiveness in contexts similar to the oil and gas industry[29,30]. Moreover, AHP method has been widely applied in international context in safety management[31,32]. One of the key advantages of AHP is its ability to incorporate both quantitative and qualitative data, allowing for a comprehensive evaluation of stakeholder preferences. Additionally, AHP facilitates consensus-building among stakeholders by providing a clear, transparent framework for decision-making, which is crucial for ensuring the successful implementation of safety culture initiatives. This structured methodology provides a systematic approach for organising and analysing complex decisions, as well as offering quantifiable insights into stakeholders' priorities. By leveraging the AHP method, researchers can gain a clearer understanding of the elements deemed most crucial by stakeholders directly impacted by safety culture decisions. By identifying and understanding the stakeholder preferences and priorities in the Malaysian oil and gas industry, more tailored and effective safety culture strategies can be developed to fulfil the specific needs and expectations of stakeholders. This targeted approach enhances the likelihood of successful implementation and acceptance of safety initiatives among the end users.

The oil and gas industry in Malaysia, a critical contributor to the national economy, faces significant challenges in establishing a unified safety culture due to diverse regulatory practices, cultural influences, and varied organisational safety protocols[17,33]. Despite the importance of safety culture in preventing accidents and safeguarding human lives, existing research often overlooks the nuanced preferences and priorities of local stakeholders, which are shaped by specific cultural, economic, and regulatory contexts[34,35]. This gap in the literature raises concerns about the effectiveness of general safety culture initiatives that fail to resonate with the local workforce and other key stakeholders. To address this issue, this study seeks to answer the research question: "What are the key elements of safety culture as perceived by various stakeholders in the Malaysian oil and gas sector, and how can these elements be prioritized to develop more tailored and effective safety strategies?" Therefore, this study aimed to identify and prioritize key elements of safety culture as perceived by various stakeholders in the

Malaysian oil and gas sector. By establishing a safety culture framework grounded in evidence from a systematic literature review, the study delineated crucial factors for fostering a comprehensive HSE culture. Prioritizing these elements facilitates the strategic allocation of resources and efforts towards areas with the greatest potential for impact, thereby maximizing safety performance in the oil and gas sector. Additionally, the study employed the Analytic Hierarchy Process (AHP) methodology to integrate stakeholder perspectives into the decision-making process, ensuring that the safety culture established within organisations is both effective and resonates with the diverse needs of all those involved in or affected by oil and gas industry operations in Malaysia.

However, it is important to acknowledge the limitations of this study. The non-randomness of the sample limits the generalizability of the findings, and the participation of respondents from four different groups, while providing diverse perspectives, also presents certain drawbacks. These include potential biases in how different groups perceive safety culture, which may influence the prioritization of safety elements. These limitations should be considered when interpreting the results and applying them to broader contexts. Despite these limitations, this study makes several original contributions to science, practice, and society. Scientifically, it advances the understanding of safety culture within the oil and gas sector by identifying and prioritizing key elements based on stakeholder preferences, a relatively underexplored area in existing literature. Practically, the study provides a framework that organisations can use to tailor their safety culture initiatives to better align with the specific needs of their workforce, enhancing the effectiveness of safety programs. Societally, by promoting a stronger safety culture, the study contributes to reducing the risk of accidents and improving the overall well-being of workers in the Malaysian oil and gas industry, with potential implications for similar industries globally.

Methods

Study design, framework and participants

A cross-sectional study design was conducted in Malaysia. Data collection was performed gradually from April to May 2024 until the required sample size was obtained. The respondents were approached physically or virtually. In addition, informed consent was obtained from all subjects. The objective of this study was explained to each of the respondent prior data collection. This research employed a structured safety culture framework to analyse three essential aspects of safety culture in the oil and gas industry, namely psychological, behavioural, and situational factors (Fig. 1). A total of 18 sub-elements within these categories were assessed to evaluate their impact on overall safety practices. Table 1 summarised 18 sub-elements with reference of sources. Psychological elements include personal attitudes towards safety, understanding of safety practices, perceptions of risks,

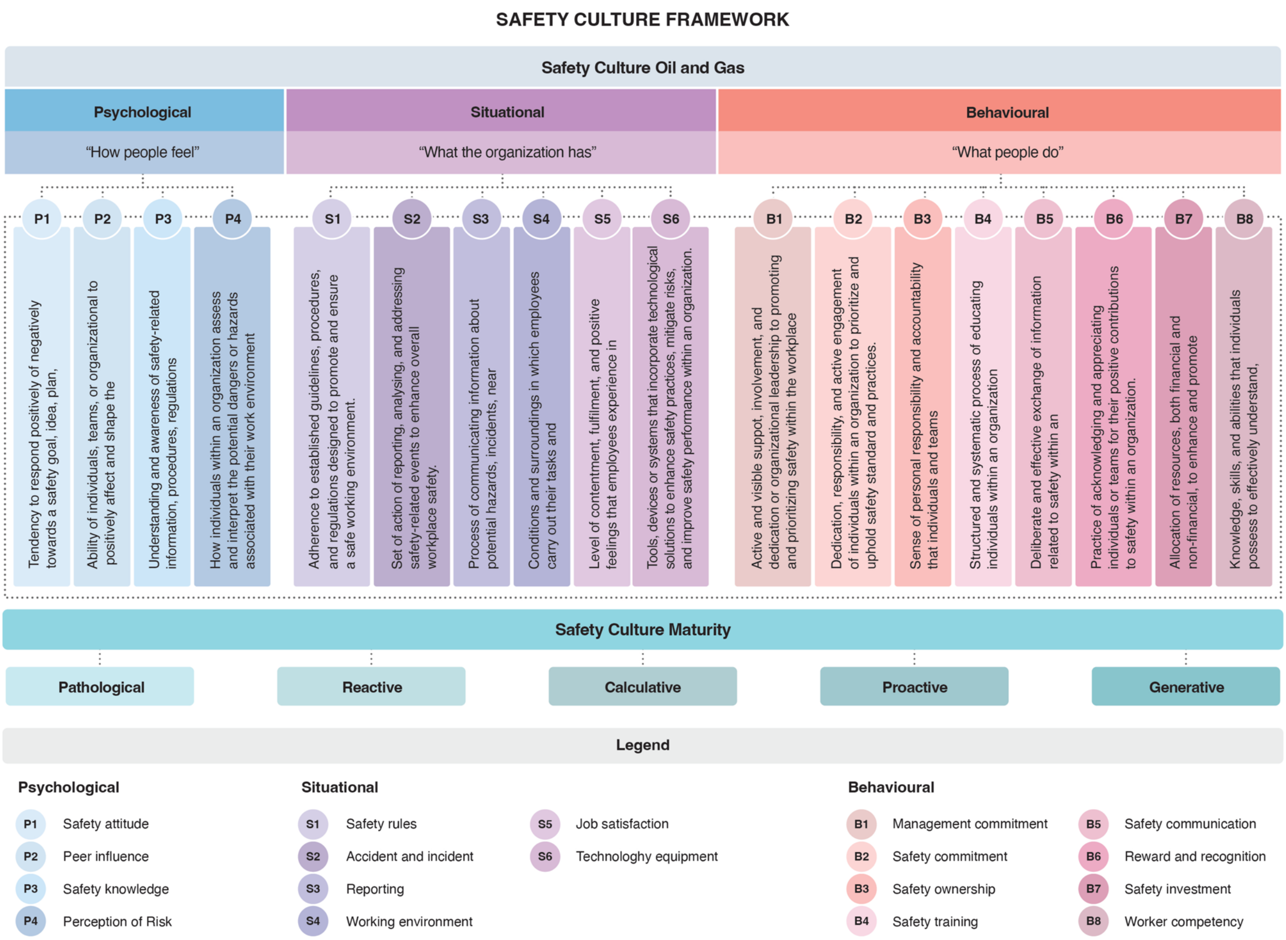

Fig. 1. Safety culture elements of the oil and gas industry.

Elements	Sub-elements	References
Psychological	Safety attitude	[36,37]
	Peer influence	[36]
	Safety knowledge	[38]
	Perception of risk	[39]
Situational	Safety rules	[11]
	Accident and incident	[2,3]
	Reporting	[40]
	Working environment	[1]
	Job satisfaction	[41]
	Technology equipment	[42]
Behavioural	Management commitment	[43]
	Safety commitment	[1,43]
	Safety ownership	[41]
	Safety training	[41,43]
	Safety communication	[44,45]
	Reward recognition	[40]
	Safety investment	[46]
	Worker competency	[11,38]

Table 1. Safety culture elements reference of sources.

and the influence of peers on safety compliance. Behavioural elements are assessed through visible actions and encompass eight sub-components such as management's safety commitment, employee safety commitment, safety ownership, safety communication, safety investment, safety training, and the recognition of safety-oriented behaviours. Next, situational factors address external conditions impacting safety, including clear safety rules, incident reporting systems, the working environment, employee satisfaction, and the quality of technology and equipment used. This comprehensive analysis can guide the identification of the most influential factors affecting safety culture and the design of targeted improvements in the oil and gas sector.

As for study participants, a diverse group of participants spanning a broad age range with varied educational qualifications, ranging from PhDs to professional certificates, was recruited from various organisational types, with nearly equal distribution between government or statutory bodies and private or multinational companies. These participants were drawn among those actively involved in occupational safety and health (OSH) from multiple sectors related to the oil and gas industry, including those from governmental and regulatory bodies and those with educational roles specific to OSH. Professionally, their roles spanned from safety and health practitioners, government regulators, lecturers, researchers, and trainers, to managers. This demographic makeup of participants who were directly engaged with safety practices in their respective fields ensured a comprehensive insight from various professional perspectives and areas of expertise that would generate a thorough understanding of safety practices and culture across the industry.

Identification of stakeholders

The sampling method of stakeholders was performed via purposeful and snowball sampling techniques[47]. Under purposeful sampling, participants with direct involvement or influence in safety culture within the Malaysian oil and gas sector were recruited to ensure representation from key stakeholders. Additionally, snowball sampling was utilised whereby additional participants were referred by those already included in the study via their industry contacts. This approach led to the inclusion of individuals with diverse perspectives and experiences, thus enhancing the comprehensiveness of the stakeholder sample in this study. The required sample size was determined based on the guidelines for qualitative research in similar studies, which suggest that a sample size of 30–50 participants is sufficient to reach saturation, where no new information is being discovered[29,48,49]. A total of 40 subject matter experts (SMEs) participated in this study.

The eligibility criteria were properly designed to ensure a comprehensive and representative sample of study participants. Firstly, only individuals with direct involvement or responsibility in safety management or decision-making within the industry were included to guarantee first-hand insights of safety culture practices. Secondly, they were recruited from diverse sectors within the industry, including government/statutory bodies and private or multinational companies, to capture a broad spectrum of perspectives. Additionally, they could be holding varied professional roles, such as Safety & Health Practitioners, Government/Regulator Officers, academic professionals, and managerial positions to ensure a multidimensional understanding of safety culture dynamics. Lastly, active engagement in OSH activities is a key criterion as participants must demonstrate a tangible commitment to safety issues through their professional involvement or responsibilities. These selection criteria enabled comprehensive insights from stakeholders with the relevant expertise and experiences to enrich the depth and breadth of the study's findings.

For the study recruitment, potential participants were contacted through industry associations, professional networks, and relevant organisations. Existing connections were leveraged to identify suitable individuals with direct involvement in safety culture within the sector. Personalised invitations were then sent out, detailing the purpose and significance of the research. Various channels including online platforms, email, and phone calls were utilised to facilitate communication. To provide a clear overview of the participants, the profile of the experts has been summarised in Table 2. This table includes key details such as the professional roles of the experts, their years of experience, the sectors they represent, and their specific involvement in safety management within the oil and gas industry.

Surveys and questionnaire design

A structured questionnaire was designed based on the AHP methodology[27]. The questionnaire comprised 49 questions organised into three sections; i.e. psychological, situational, and behavioural, with each section containing 6, 15, and 28 questions, respectively. Within each section, experts were asked to indicate their preferences between pairs of variables representing different combinations of the three criteria. Definitions of each variable were provided to ensure clarity and consistency in responses. To quantify preferences, a Likert scale ranging from 1 to 9 was utilised, where 1 denoted equal importance and 9 denoted absolute importance, with intermediate values representing varying degrees of preference. The questionnaire was administered using Google Forms (https://forms.gle/ccwt3Ytd9XNt8qP18), an accessible and user-friendly platform for data collection. Through this structured approach, stakeholder preferences on safety culture criteria were systematically elicited and analysed. The AHP methodology was utilised to prioritise these criteria effectively.

Multicriteria decision-making methodology selection

The chosen methodology of AHP represents a robust framework for capturing stakeholder preferences in the context of safety culture within the Malaysian oil and gas industry. Developed by Thomas Saaty, AHP provides a structured approach to convert qualitative evaluations into numerical values for each element in the hierarchy, thus enabling precise comparisons of diverse and potentially incommensurable factors across the entire range of safety culture criteria in a rational and consistent manner.

The methodology involves several systematic steps, from criteria identification, pairwise comparison, and consistency check, to priority calculation. In this study, psychological, behavioural, and situational factors were identified as criteria and weighted through pairwise comparisons by SMEs. The consistency of judgments was rigorously verified using the consistency ratio, ensuring the reliability of the results. Ultimately, priority scores were calculated for each safety culture influencing factor as a valuable guide for decision-making and resource allocation within the industry.

Data analysis plan

Initially, the survey responses comprising ratings or rankings of various safety and health criteria as assessed across distinct professional roles were collected and compiled. Data cleaning was performed. Missing data management was conducted to maintain consistency across responses before data analysis AHP. The responses were organised into a matrix format to allow a direct comparison of each criterion across different roles, hence facilitating an efficient evaluation process in the subsequent stages of the AHP analysis.

The preparation of the pairwise comparison matrix involved comparing each criterion against every other criterion within the context of the specific professional roles. Each matrix element a_{ij} represents the relative importance of criterion i compared to criterion j, as perceived by the respondents. This critical phase involved constructing pairwise comparison matrices for each criterion against each professional role. These matrices served to capture and quantify the respondents' assessments regarding the relative importance of one factor compared to another within the context of their professional roles. To calculate the priority vector, the average of the normalized values was used. Specifically, each matrix was normalized by dividing each element by the sum of its respective column. The average of these normalized values across each row was then calculated to determine the priority vector. For each of these matrices, the priority vector was calculated by normalising the sum of each column in the matrix and then averaging the normalised values across each row. This process can be mathematically represented as follows:

$$a'_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$

where a_{ij} is the element of the matrix at the ith row and jth column, and n is the number of elements in the column.

Expert ID	Professional role	Experience (year)	Safety involvement
1	Safety & health practitioner	5*	Direct responsibility managing safety and health
2	Government/ Regulator	5*	Policy formulation, oversight
3	Academic Professional (Lecturer/Researcher/Trainer	5*	Research, teaching and training in safety and health
4	Managerial	5*	Strategic planning, decision maker

Table 2. Experts profile. *5 years and above.

The calculation of the priority vector is represented as follows:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} a'_{ij}$$

where w_i is the weight for the ith criterion, and a'_{ij} is the normalised value from the first step.

This step transformed qualitative judgments provided by the survey responses into quantifiable weights. It was an essential step to facilitate a more objective analysis. To enhance the reliability and accuracy of these calculated priorities, the eigenvalue method was then employed. This method was particularly effective in addressing and adjusting for potential inconsistencies in human judgment that often arise during the survey process:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(Aw)_i}{w_i}$$

where $\lambda_{\max}$ is the largest eigenvalue of the matrix A, Aw is the matrix–vector product of A and w, and w_i is the ith component of the priority vector w.

By utilising the eigenvalue method, the AHP model ensured that the derived weights would not only be a mathematical reflection of the survey responses but would also be robust against subjective biases, thereby strengthening the overall decision-making framework within the study.

Following the determination of priority vectors in the AHP model, the next crucial step was to calculate the Consistency Index (CI) for each comparison matrix. The CI was instrumental in assessing the reliability of the judgments made during the pairwise comparisons. CI was used to evaluate whether the preferences and priorities derived from the survey responses were logically coherent. The calculation of the CI was performed using the formula:

$$CI = \frac{\lambda_{\max^2} - n}{n - 1}$$

where λ_{max} represents the largest eigenvalue of the matrix, and n is the number of criteria or elements within the matrix. This formula measures the deviation of λ_{max} from n, normalised by $n - 1$ to scale the index appropriately for matrices of different sizes.

A standard threshold for the CI is 0.1. A CI value exceeding this threshold indicates potential inconsistencies within the judgments, suggesting a need to revisit and possibly revise the pairwise comparisons to reduce bias or inconsistency. To further validate the consistency of the matrix, the Consistency Ratio (CR) is computed by comparing the CI to the Random Index (RI), which is a predefined value based on the matrix size. The CR is given by:

$$CR = \frac{CI}{RI}$$

A CR value less than or equal to 0.1 is generally acceptable, indicating a reasonable level of consistency in the judgments. If the CR exceeds 0.1, it is advisable to re-evaluate the pairwise comparisons to enhance the decision-making process's accuracy and reliability. In this study, this step was fundamental to ensure the robustness of the AHP analysis as it would be used to confirm that the derived priorities were based on coherent and reliable judgments.

To further ensure the robustness of the final rankings, a sensitivity analysis was applied. This analysis involved systematically varying the input parameters to assess how changes in these parameters affected the final rankings. The sensitivity analysis provided additional confidence in the stability of the results, ensuring that the rankings derived from the AHP model remained consistent under different scenarios. This step was critical in validating the robustness and reliability of the conclusions drawn from the study.

Ethics statement

The study was approved by the Research Ethics Committee (REC) of UiTM under the reference number: REC/07/2023 (PG/MR/251) dated 21st July 2023. all methods were carried out in accordance with relevant guidelines and regulations as stated in the research ethics approval. Consent was obtained from each participant using an online consent form, following their verbal agreement to participate in this study before administering the questionnaire. No minors were involved in this study and participants were allowed to withdraw at any point without any penalty.

Results

Characteristics of study participants

The characteristics of study participants are shown in Table 3. The study participants were predominantly male (n = 70%) with an average age of 38 years. They exhibited a diverse educational background, with most of them holding a Bachelor's Degree (n = 47.5%), followed by a Master's Degree (n = 27.5%) or Ph.D. (n = 10%), while the rest possessed diplomas or professional certificates. There was an equal distribution between those employed by government/statutory bodies (n = 55.0%) and those in private or multinational companies (n = 45.0%). Their professional roles varied, including Safety & Health Practitioners (n = 40%), Government/Regulator Officers (n = 35%), and others in academic or managerial positions. The majority (n = 92.5%) of them were actively involved in OSH.

Characteristic	*n* = 40 (%)
Age (Average year)	38 (SD = 7.5)
Gender	
Male	28 (70.0)
Female	12 (30.0)
Education Background	
Ph.D	4 (10.0)
Master's Degree	11 (27.5)
Bachelor's Degree	19 (47.5)
Diploma	3 (7.5)
Professional Certificate	3 (7.5)
Type of Organisation	
Government/Statutory Body	22 (55.0)
Private/Multinational/GLC	18 (45.0)
Sector	
Oil and gas	7 (17.5)
Education	6 (15.0)
Government & Regulatory Body	19 (47.5)
Other Industries	8 (20.0)
Stakeholder	
Safety & Health Practitioner	16 (40.0)
Government//Regulator Officer	14 (35.0)
Lecturer/Researcher/Trainer	5 (12.5)
Management/Manager	5 (12.5)

Table 3. Characteristics of study participants.

Stakeholder preferences

Figure 2 represents a detailed matrix of how different professions perceived various safety culture criteria in this study. Each cell in the matrix represents the percentage of respondents who prioritised different aspects of safety, such as attitudes, knowledge, rules, management commitment, ownership, training, and communication. The colour gradient from white to dark purple illustrated an increasing level of response.

Safety & Health Practitioners tended to focus more on practical safety rules and management commitment. Academicians appeared to emphasise more on theoretical aspects of safety, such as knowledge and training. Management personnel showed a broader range of focus, from emphasising practical approaches to safety ownership and communication. Policy makers showed lower responses across various categories, which might suggest that they hold a broader, more policy-oriented perspective on safety culture rather than prioritising specific measures. To understand these preferences better, the demographic compositions of the participants, including age, gender, professional experience, geographical location, and industry, must be further analysed to explain the biases in responses and more importantly, to determine how these preferences can be translated into actual safety practices within their respective fields.

Table 4 reveals differentiated prioritisation across four key professional groups: Safety & Health Practitioners, Policy Makers, Academicians, and Management. Based on the eigenvector values, the findings underscored distinct emphases aligned with the specific operational roles of each group. Academicians allocated the highest priority to the perception of risk, as evidenced by an eigenvector value of 0.171. This emphasis reflected the intrinsic need for heightened risk awareness in academic environments, where research activities and educational responsibilities necessitated rigorous safety measures. In addition, a significant focus on peer influence was observed among academicians, with an eigenvector value of 0.450. This high value indicated the critical role of peer interaction and collaboration in shaping safety practices within academic settings, hence suggesting that safety behaviours can be heavily influenced by collective norms and peer assessments.

As for management personnel, they exhibited the strongest valuation of safety attitude with an eigenvector value of 0.519. This prioritisation highlighted the pivotal role of organisational leaders in cultivating a proactive safety culture as management's commitment to safety attitudes plays a significant role in influencing overall safety practices across the organisation. On the other hand, policy makers demonstrated a pronounced concern for the safety of technology equipment, with an eigenvector value of 0.409. This focus likely stemmed from their regulatory responsibilities to ensure that all technological implementations adhere to established safety standards. Lastly, Safety & Health Practitioners emphasised the importance of management commitment to safety, marked by an eigenvector value of 0.173. Overall, this figure highlighted the critical expectation that safety standards and practices are not only established by leaders but must also be actively enforced and modelled by professionals in leadership roles, particularly in environments where safety is directly linked to operational success.

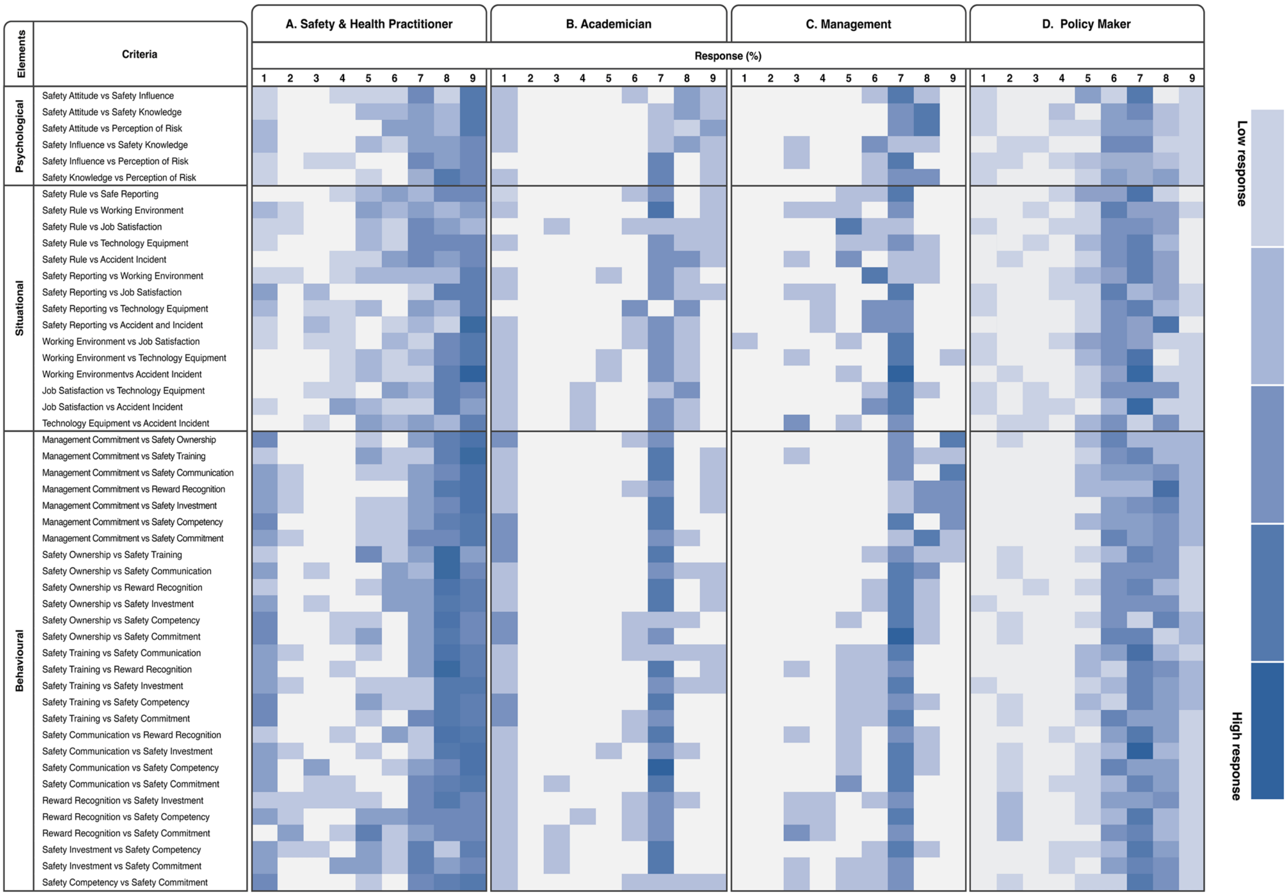

Fig. 2. Distribution of study participants' response.

Factor group	Criteria	Entire profession rank	Safety & health practitioner	Policy maker	Academician	Management
Psychological	Safety attitude	0.300	0.494	0.479	0.260	0.519
	Peer influence	0.077	0.251	0.294	0.450	0.260
	Safety knowledge	0.064	0.136	0.094	0.120	0.124
	Perception of risk	0.559	0.119	0.133	0.171	0.097
Situational	Safety rules	0.189	0.071	0.100	0.255	0.258
	Accident incident	0.161	0.137	0.063	0.082	0.092
	Reporting	0.073	0.104	0.049	0.035	0.062
	Working environment	0.067	0.160	0.127	0.091	0.076
	Job satisfaction	0.250	0.233	0.252	0.233	0.225
	Technology equipment	0.260	0.295	0.409	0.305	0.288
Behavioural	Management commitment	0.088	0.173	0.075	0.117	0.144
	Safety commitment	0.078	0.143	0.088	0.109	0.108
	Safety ownership	0.090	0.100	0.101	0.109	0.143
	Safety training	0.068	0.116	0.120	0.109	0.143
	Safety communication	0.068	0.121	0.106	0.146	0.093
	Reward recognition	0.189	0.124	0.166	0.145	0.094
	Safety investment	0.230	0.100	0.181	0.132	0.137
	Worker competency	0.189	0.124	0.164	0.132	0.138

Table 4. Profession factor group preference elements. A higher eigenvector score signifies greater importance or significance attributed to the corresponding criterion.

Critical elements contributing to a safety culture within organisations

Table 5 delineates the relative importance of various elements spanning the psychological, behavioural, and situational domains. To ascertain the constituents that fall within the top 30% bracket in terms of significance, an analytical approach was adopted. The top 30% threshold corresponded to approximately five elements out of the aggregate of all 18 elements across the three domains. From the results, the most critical elements within the safety culture of an organisation were identified by their eigenvector scores. In the behavioural domain, the elements that stood out included safety investment, safety competency, and reward recognition, with eigenvector scores of 0.23, 0.18, and 0.18, respectively. These elements emphasised the importance of financial commitment to safety practices, as well as the need for skilful execution of these safety measures. Compliance with safety measures should be incentivised through recognition and rewards. In the situational domain, technology/equipment and job satisfaction were identified as paramount, scoring eigenvector scores of 0.26 and 0.25, respectively. The high score for technology/equipment indicated the critical need for up-to-date and safe operational tools, while job satisfaction highlighted the correlation between employees' contentment and their adherence to safety protocols. Based on this analysis, these five elements have been pinpointed as key focus areas for organisations to enhance their safety culture.

To achieve a more comprehensive understanding of complex decision-making situations or performance evaluations, the Importance-Performance Analysis (IPA) was conducted. The IPA matrix categorised 18 key safety culture elements into four distinct quadrants, each representing different strategic implications (Fig. 3). The matrix highlighted that 22% of the elements belonged in the High Importance-High Performance (Maintain) quadrant, suggesting that these are well-managed areas crucial for safety culture, such as 'Technology Equipment' and 'Safety Investment', that should continue to receive sustained attention and resources.

Variable		Normalise Matrix								Eigenvector	Rank
Behavioural		B1	B2	B3	B4	B5	B6	B7	B8		
	B1	0.06	0.06	0.25	0.06	0.06	0.03	0.05	0.10	**0.08**	**9**
	B2	0.06	0.06	0.16	0.06	0.06	0.03	0.05	0.10	**0.07**	**11**
	B3	0.02	0.03	0.08	0.06	0.06	0.14	0.10	0.20	**0.09**	**7**
	B4	0.06	0.06	0.08	0.06	0.06	0.03	0.05	0.10	**0.06**	**14**
	B5	0.06	0.06	0.08	0.06	0.06	0.03	0.05	0.10	**0.06**	**14**
	B6	0.27	0.27	0.08	0.26	0.26	0.14	0.1	0.10	**0.18**	**4**
	B7	0.27	0.27	0.16	0.26	0.26	0.28	0.20	0.10	**0.23**	**3**
	B8	0.13	0.13	0.08	0.13	0.13	0.28	0.40	0.20	**0.18**	**4**
Situational		S1	S2	S3	S4	S5	S6				
	S1	0.16	0.41	0.15	0.12	0.13	0.13			**0.18**	**4**
	S2	0.04	0.10	0.23	0.31	0.13	0.13			**0.16**	**6**
	S3	0.08	0.03	0.07	0.06	0.09	0.09			**0.07**	**11**
	S4	0.08	0.02	0.07	0.06	0.09	0.06			**0.06**	**14**
	S5	0.32	0.20	0.23	0.18	0.27	0.27			**0.25**	**2**
	S6	0.32	0.20	0.23	0.25	0.27	0.27			**0.26**	**1**
Psychological		P1	P2	P3	P4						
	P1	0.06	0.06	0.25	0.06					**0.08**	**9**
	P2	0.06	0.06	0.16	0.06					**0.07**	**11**
	P3	0.02	0.03	0.08	0.06					**0.09**	**7**
	P4	0.06	0.06	0.08	0.06					**0.06**	**14**

Psychological		Behavioural		Situational	
P1	Safety attitude	B1	Management commitment	S1	Safety rule
P2	Peer influence	B2	Safety commitment	S2	Accident incident
P3	Safety knowledge	B3	Safety ownership	S3	Reporting
P4	Risk perception	B4	Safety training	S4	Working environment
		B5	Safety communication	S5	Job satisfaction
		B6	Reward recognition	S6	Technology equipment
		B7	Safety investment		
		B8	Safety competency		

Note: A higher eigenvector score signifies greater importance or significance attributed to the corresponding criterion. Significant values are in bold.

Table 5. Calculation of psychological, behavioural, and situational preference.

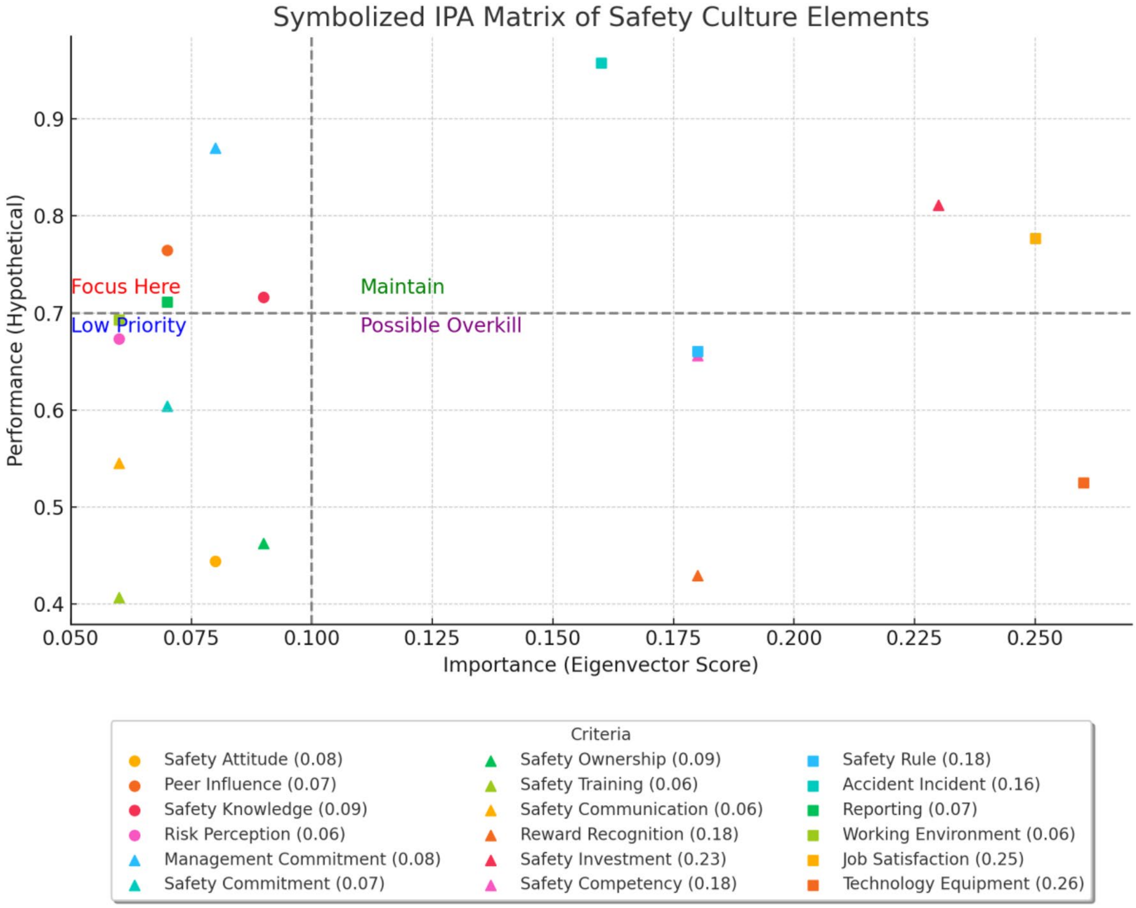

Fig. 3. The IPA Matrix of 18 safety culture elements.

Conversely, 28% of the elements were categorised under the High Importance-Low Performance (Focus Here) quadrant. This included critical but underperforming elements like 'Management Commitment' and 'Safety Rule', indicating a pressing need for targeted improvement and increased resource allocation. Interestingly, 17% of the elements were placed in the Low Importance-High Performance (Possible Overkill) quadrant, such as 'Safety Communication', suggesting that these elements might be receiving more resources than necessary given their current importance and indicating potential reallocation to more critical areas. Finally, 33% of the elements were considered under the Low Importance-Low Performance (Low Priority) quadrant, including 'Risk Perception' and 'Accident Incident'. Even though deemed as less crucial, these elements showed poor performance and required minimal investment. They should also be monitored for any significant trend changes that could alter their strategic importance.

Table 6 provides a structured analysis to show the weighting of safety culture preference elements among the psychological, behavioural, and situational factors. The importance of each element was assessed using the AHP, resulting in normalised eigenvector values that signified their respective weights in fostering a robust safety culture. Behavioural elements emerged as the most influential, with the highest eigenvector value (0.53). Behavioural factors directly influence daily operations and cast a tangible impact on the overall safety culture. Situational elements involving external and environmental conditions that affected the organisation came in next (Eigenvector = 0.29). While not as directly impactful as behavioural elements, situational elements often create a foundational context that either enables or hinders safety behaviours. Lastly, although ranked lowest, psychological factors remained vital (Eigenvector = 0.16). They encompassed attitudes, perceptions, and the

	Normalised matrix				
Variable	Psychological	Behavioural	Situational	Eigenvector	Prioritisation
Psychological	0.16	0.18	0.14	0.16	3
Behavioural	0.50	0.54	0.57	0.53	1
Situational	0.33	0.27	0.28	0.29	2

Table 6. Weighting of safety culture preference elements. The safety culture elements are categorised with: *P* psychological, *B* behavioural, *S* situational.

mental readiness of employees towards safety, such as the psychological safety of speaking up about hazards without fear of retribution. Despite their lower weights, these elements were crucial for sustaining a safety culture.

Discussion

This research set out to refine existing safety culture frameworks by analysing the preference elements for organisational improvement in the Malaysian oil and gas industry. Previous research has consistently highlighted the importance of these components in maintaining a robust safety culture across various industries[50,51]. In line with these findings, our study conducted a detailed comparative analysis of how different professionals within the oil and gas industry prioritize various aspects of safety culture. This approach is crucial for developing customized safety strategies that cater to the specific needs of diverse stakeholder groups, leading to more targeted and effective safety interventions in the sector.

The current study's findings align with earlier research that emphasizes the importance of practical safety measures and management commitment in establishing a strong safety culture. For instance, Safety & Health Practitioners in our study prioritized practical safety rules and management commitment, which mirrors the findings of[52,53], where top-down enforcement of safety standards was seen as essential in high-risk environments. This focus on practical measures is particularly vital in industries where procedural adherence directly influences safety outcomes. In contrast, academicians in our study placed greater emphasis on theoretical aspects such as safety knowledge and training, which complements existing frameworks that identify education and awareness as foundational elements of safety culture[54,55]. This finding underscores the role of a well-informed workforce in effectively integrating safety practices into daily operations. Moreover, management's emphasis on safety ownership and communication in our study is consistent with modern safety culture frameworks that stress the importance of leadership involvement in cultivating a proactive safety culture[56–59]. Additionally, policymakers in our study showed a preference for technological and equipment safety, reflecting a macro-level approach that aligns with previous studies highlighting the role of regulatory frameworks and technological advancements in enhancing industry safety standards[60–62].

As reported in previous research, behavioural elements are crucial in cultivating safety culture within oil and gas organisations[63]. Our study reinforces this perspective by emphasizing the significance of tangible actions in improving safety outcomes. This finding aligns with the reciprocal model of safety culture, which suggests that the interplay between organisational culture and individual behavioural significantly influences safety outcomes[26]. Our findings further support this model by highlighting the importance of situational factors, i.e., external and environmental conditions, as key areas for intervention. Even though psychological elements appeared to be less influential in our framework, their importance cannot be side lined. Guldenmund's research suggests that although psychological aspects are less visible, they remain fundamental to safety culture and should not be neglected in strategies aimed at cultivating a safety culture[5]. Our study echoes this sentiment, highlighting the need for an integrated approach that combines behavioural, situational, and psychological elements to create a robust safety culture in the oil and gas sector.

Moreover, this study also highlights the differential prioritization of these elements in cultivating a safety culture, with specific implications for enhancement strategies. Behavioural aspects, focusing on modifying employee behavioural and fostering intrinsic motivation towards safety compliance, align with safety culture frameworks that support bottom-up, behavioural-driven approaches[64,65]. Situational factors emphasize enhancing the physical and organisational environment to support safe practices, facilitating a conducive setting for safety[66]. Although psychological elements were less prioritized, they are still fundamental, with effective safety culture strategies promoting psychological safety, enabling employees to express safety concerns freely and fostering a safety-first mindset. An integrated approach that combines all three elements is necessary to address dynamic industry challenges, ensuring that safety culture enhancement remains a central organisational focus supported by continuous refinement and responsive leadership practices[67]. In other words, enhancing safety culture in the oil and gas industry should be a multifaceted endeavour, addressing direct actions (behavioural), the enabling environment (situational), and foundational attitudes (psychological). By adopting a comprehensive approach, the industry can significantly mitigate risks and enhance overall safety performance, cultivating a resilient and proactive safety culture.

Given the high-risk nature of the oil and gas industry, enhancing safety culture strategies through several key approaches is imperative. Substantial investments in industry-specific training and resources are crucial for strengthening risk management and accident prevention[68,69]. The adoption of advanced safety technologies and regular maintenance of equipment standards are essential to prevent operational failures[70]. Moreover, the strong link between job satisfaction and safety outcomes calls for management practices that promote effective communication and a supportive environment, allowing employees to raise safety concerns freely[71,72]. At the same time, stringent regulatory oversight is required to ensure compliance and maintain high safety standards across the industry[73,74]. Aligning these safety culture enhancement strategies with the specific preferences and priorities of diverse stakeholder groups is crucial. By focusing on these areas, the industry can achieve a more effective and resilient safety culture that not only meets but exceeds regulatory standards, safeguarding the well-being of its workforce.

This study utilized the Importance-Performance Analysis (IPA) matrix to assess the relevance and efficacy of 18 safety culture criteria across psychological, behavioural, and situational dimensions within organisations. This method allows for the identification of areas needing improvement and facilitates targeted budget and resource allocation to maximize safety outcomes. Our findings provide a detailed understanding of organisational safety culture, highlighting key areas where strategic interventions can significantly enhance safety performance. The IPA matrix serves as a guide for prioritizing resources towards high-impact areas while recommending reduced investment in less important and/or over-performing areas. This strategy aligns with recent research that stresses the importance of resource allocation in safety management, pointing out that optimized resource distribution can lead to substantial improvements in safety practices[75]. Particularly, this study emphasizes the need to enhance elements within the High Importance-Low Performance quadrant to mitigate risks and improve overall safety culture practices[76]. Conversely, identifying over-invested elements in the Low Importance-High Performance quadrant offers vital insights into potential cost savings, a critical measure during budget constraints[77]. Overall, the IPA matrix serves not only as a resource allocation guide but also as a reflective tool for continuous safety culture improvement, applying a dynamic approach to safety management that adapts to changing organisational needs.

Following the integration of the Analytic Hierarchy Process (AHP) with IPA, a nuanced relationship emerged between structured decision-making and performance evaluation methodologies. AHP, known for its hierarchical structuring of decision criteria, provides a robust framework for establishing the relative importance of various factors within a decision context. Conversely, IPA focuses on assessing the importance and performance of individual attributes or factors, often within the domain of customer satisfaction or organisational performance. When elements identified in AHP diverge from those in IPA, it may indicate a disparity in focus and purpose, reflecting the distinct objectives between the two methodologies. While AHP assists in decision-making processes, IPA serves as a tool for performance evaluation and improvement. The variation in identified elements between AHP and IPA sheds light on the nuanced interplay between structured decision analysis and performance assessment, highlighting their complementary roles in facilitating comprehensive decision-making and performance management initiatives.

Limitations and strengths

This research provided a comprehensive overview of strategies for enhancing safety culture in the oil and gas industry, primarily focusing on the differential prioritisation of behavioural, situational, and psychological elements based on the SMEs in the industry. However, there are several limitations of the current study that can be addressed in future research to further refine safety culture strategies. While the study discusses each element individually, the complex interdependencies between behavioural, situational, and psychological factors were not fully explored. The interactions between these elements can significantly influence the effectiveness of safety culture enhancement strategies. Therefore, future research should focus on the complex interdependencies between behavioural, situational, and psychological elements. For instance, systems thinking approaches or network analysis can be applied to map out and quantify these interactions, ultimately pinpointing key leverage points where interventions can be most effective.

Conclusion

In summary, this study provides a comprehensive analysis of the multifaceted nature of psychological, behavioural, and situational factors that significantly influence safety culture dynamics within the Malaysian oil and gas sector. By employing the Analytic Hierarchy Process (AHP), the research successfully identified and prioritized key elements of safety culture as perceived by various stakeholders. The findings highlight the complexity of safety culture, where each factor plays a critical role in shaping the overall safety environment. The study's results reveal the hierarchical structure of these factors, emphasizing the importance of addressing both individual attitudes and behavioural, as well as organisational and environmental conditions, to foster a robust safety culture. The psychological factors, including personal attitudes towards safety and risk perception, were found to be crucial in determining how safety practices are adopted and internalized by employees. Similarly, the behavioural elements, such as management commitment and employee safety ownership, were shown to have a direct impact on the effectiveness of safety interventions and the overall safety performance of the organisation. Situational factors, encompassing the physical working environment, safety rules, and reporting systems, were also identified as pivotal in sustaining a safety culture that promotes continuous improvement and adaptability to changing conditions. The study underscores the need for organisations to adopt a holistic approach to safety management, where psychological, behavioural, and situational factors are integrated into safety strategies.

The insights generated from this study provide valuable guidance for organisations in the oil and gas industry, and potentially other high-risk sectors, on how to effectively allocate resources and prioritize interventions that will yield the greatest impact on safety performance. By understanding the relative importance of these factors, organisations can tailor their safety programs to address the specific needs and preferences of their workforce, thereby enhancing the overall safety culture and reducing the likelihood of accidents and incidents. Furthermore, the application of the AHP methodology in this context demonstrates its utility as a decision-making tool that can be used to systematically evaluate complex, multi-criteria scenarios. This approach not only provides a structured framework for prioritizing safety initiatives but also ensures that the perspectives of all relevant stakeholders are considered in the decision-making process.

In conclusion, this study contributes to the broader understanding of safety culture in high-risk industries by offering a nuanced perspective on the factors that drive safety performance. The findings have practical implications for safety practitioners, managers, and policymakers who are tasked with improving workplace safety outcomes. As organisations continue to navigate the challenges of maintaining a strong safety culture, the insights provided by this research will be instrumental in guiding effective and sustainable safety interventions.

Data availability

All data generated or analysed during this study are included in this published article.

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Author contributions
Conceptualisation: M.H.R., N.C.D., R.D. Methodology: M.H.R., N.C.D., R.D., Iqbal Writing—original draft: M.H.R., N.C.D. Writing—review & editing: M.H.R., N.C.D., R.D., Iqbal.

Competing interests
The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to R.D.