SENSE OF VULNERABILITY in Industrial Settings: An Empirical Framework for Incident Prevention

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MANY BUSINESSES TODAY STRIVE for an injury-free workplace, ensuring that every employee returns home from work without injury every day. Nonetheless, Sanders (2013) notes that long periods without significant incidents may create an unwarranted sense of complacency and a relaxation of discipline. Complacency is frequently cited as a major contributor to industrial incidents and disasters (Årstad & Aven, 2017; Hyten & Ludwig, 2017; Innes-Jones & Scandpower, 2012). The opposite of complacency is "chronic unease," a term first coined by Reason (1997). Chronic unease might result from the absence of negative events and lead people not to "forget to be afraid." Often associated with high-reliability organizations, chronic unease is a healthy skepticism about what people see and how they react.

KEY TAKEAWAYS

- **Operating a business for long periods without major incidents may create a culture of ease, which can cause organizations and individuals to drop their guard and lose their sense of vulnerability.**
- **Failing to maintain a sense of vulnerability has led to major disasters in industrial settings. While scholars and practitioners have emphasized the importance of instilling and maintaining a sense of vulnerability in organizations, information on how to maintain such vulnerability has been found to be limited.**
- **Involving four oil refining organizations, this qualitative research study proposes an empirical framework for organizations and individuals to adopt to maintain a sense of vulnerability in a quest to prevent incidents.**
- **This study signifies the influence of on-the-job and personal factors on the sense of vulnerability through perception patterns. Furthermore, this study developed a tool to assess the vulnerability in industrial settings based on the critical factors and components that are integral parts of the proposed framework.**

It is about inquiry and probing deeper, really understanding the risks and exposures, and not assuming that just because systems are in place everything will be fine (Risktec, 2014).

Currently, no universally accepted definition exists for a sense of vulnerability. Complacency and chronic unease are the terms closely related to the concept of sense of vulnerability. With limited studies conducted on the concept, few scholars framed sense of vulnerability within the context of their research work. Sanders (2015) argues that combating complacency can be achieved by instilling and maintaining a sense of vulnerability. Sense of vulnerability in the workplace is often associated with the idea that one will be susceptible to getting hurt. It has been noted that a slight sense of susceptibility can lead to better compliance with safety practices and fewer oversights of established guidelines (Sanders, 2015). Further, maintaining a sense of vulnerability is an essential element of an organization's safety culture (Arendt & Manton, 2015; Smith et al., 2015). In recent years, the concept of building a positive safety culture has gained momentum, particularly in higher-risk industries, as the link between workers' attitudes and workplace incidents becomes ever clearer. In fact, it is suggested that 95% of workplace incidents have an element of unsafe behavior attached to them and that a poor safety culture can be just as influential on safety outcomes as an organization's safety management system (Williams, 2021). Table 1 notes some of the catastrophic disasters that have been linked to organizations or individuals failing to maintain a sense of vulnerability.

Few scholars have attempted to further the understanding of the sense of vulnerability and its implications for workplace safety and health (e.g., Arendt & Manton, 2015; Yanar et al., 2019).

An empirical study positioned employees' sense of vulnerability as an integral and important part of organizational safety

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culture (Arendt & Manton, 2015). This study found that a low sense of vulnerability among operating staff resulted in an increasing trend of process safety incidents. Mckay and Lacoursière (2008) argue that learnings from disasters such as those outlined in Table 1 necessitate the labeling of a sense of vulnerability as a critical pillar for any organization's safety culture.

Yanar et al. (2019) support Arendt and Manton's (2015) findings in their study, which examined the interplay between supervisor safety support and OSH vulnerability with respect to workplace incidents and injuries. Their study concluded that OSH vulnerability (or lack of vulnerability among team members) and lack of supervisory support independently increased the likelihood of physical injuries at work.

A case study by Dee et al. (2019) examines an incident that occurred when a fail-open valve failed to close. By analyzing the sequence of events, the researchers found that losing a sense of vulnerability was the root cause, which had the potential to lead to catastrophic consequences.

The focus on the implications of losing a sense of vulnerability by scholars or practitioners is scattered in the literature or limited to case studies, as seen from the few studies identified and summarized in Table 2 (p. 24). Further, limited empirical research exists that could provide a framework to guide organizations on how a sense of vulnerability is maintained in industrial settings.

Therefore, the aim of this research study is to develop a sense of vulnerability framework that can be adopted in the industry as a guide to help employees at all levels maintain a sense of vulnerability to prevent workplace incidents and injuries.

Methodology

The Setting

The present study is set in high-risk, high-reliability organizations located in Bahrain, Singapore and South Korea that showed a willingness to participate in the study. The identities of these organizations were protected by pseudonyms outlined in Table 3 (p. 25). With an average of 3,200 employees, these organizations are engaged in process operation, maintenance and engineering activities around the clock.

Methodological Approach

To meet the aims of the current study, a qualitative research case study design is adopted. This approach facilitates the exploration of sense of vulnerability within high-risk, high-reliability organizations using a variety of data sources. This ensures that the issue is not explored through just one lens, but rather a variety of lenses, which allows for multiple facets of the phenomenon to be revealed and understood (Yin, 2013).

In addition to the fact that the case study approach allows for in-depth, multifaceted explorations of complex issues in their real-life settings, it is the preferred approach because the focus of the current study is to answer how and why questions (Yin, 2013).

Study Participants

Participants for the focus group discussion and semi-structured interviews were carefully selected based on their willingness to participate, their working experience in high-risk, high-reliability organizations, and the fact that they represent the organizations that participated in the current study. Nine individuals participated in the focus group discussion. Special attention was paid to the optimal size of the group, which should not be too large to hinder good discussion (Krueger & Casey, 2000). The participants' working experience was in operations, maintenance and OSH ranging from 15 to 21 years (Table 3, p. 25). Table 4 (p. 25) shows a total of 87 participants in the semi-structured interview and their average years of working experience in high-risk, high-reliability organizations.

With a minimum of 10 years of working experience, the participants in the semi-structured interviews were senior operators, supervisors, engineers and managers. Although many of the participants did not speak English as their first language, it was the official language at all the study sites. In addition, this work followed the ethical principles of second language research (Dörnyei & Taguchi, 2009), where an interpreter was assigned to each site to clarify any possible issues with the interview questions during the data collection stage.

It is important to note that unlike quantitative research, sample sizes of qualitative research inquiries are generally small (Baker & Edwards, 2012; Braun & Clarke, 2019). This is because qualitative research such as this work seeks to obtain insight into a phenomenon (i.e., a sense of vulnerability). The intention is to reach data saturation or the point in the research process when no new information is discovered in the data analysis, which was achieved with 87 participants in this research work.

Data Collection

Figure 1 (p. 25) shows the two stages of the data collection approach adopted in the current study to develop and validate a sense of vulnerability framework. The first method of data collection was focus group discussion, which is a method of collecting data from several participants at the same time (Rosenthal, 2016). Focus groups involve a relatively unstructured but guided or moderated group discussion on a predefined topic for research purposes (Krueger & Casey, 2000). The researcher only moderates the discussion because the aim is to foster a natural and free-flowing conversation about the discussed topics (Carey, 1994). Lasting for 3 hours, a face-to-face focus group discussion was facilitated that aimed to

TABLE 1

CATASTROPHIC DISASTERS LINKED TO LACK OF SENSE OF VULNERABILITY

Disaster	Nature	Fatalities	Lack of sense of vulnerability
Flixborough chemical plant, 1974	Vapor cloud explosion	28	• inadequate design and testing of bypass line and support for jumper • lack of qualified person (subject matter expert), as it was not considered critical
Space Shuttle *Challenger*, 1986	Liquid hydrogen tank explosion	7	• safety concerns were discounted by NASA • overconfidence from past success
Piper Alpha oil platform, 1988	Vapor cloud explosion	167	• no follow up actions on highlighted issues and recommendations from earlier safety studies

TABLE 2

SUMMARY OF THE LITERATURE REVIEW

Authors	Context	Source type	Summary points
Sanders, 2013	Suggestions on raising the awareness by sharing focused examples of past mistakes and some catastrophic blunders	Peer-reviewed article	The author concludes that long periods without significant incidents may create an unwarranted sense of complacency and relaxation of discipline. This directly supports the study's central theme, which is the importance of maintaining a sense of vulnerability in industrial settings.
Reason, 1997	Introduction to safety and systems theory	Book	Opposite to complacency is "chronic unease," which might result from the absence of negative events and lead people to "forget to be afraid." The concept of chronic unease is synonymous with the concept of vulnerability.
Risktec, 2014	Explaining the concept of chronic unease	Newsletter	Chronic unease is defined as an inquiry and probing deeper, truly understanding the risks and exposures, and not assuming that just because systems are in place everything will be fine. Further, it also stresses the importance of personal attributes that are closely linked with this study.
Sanders, 2015	Explaining the steps to combat complacency that can compromise process safety	Peer-reviewed article	The author argues that combating complacency can be achieved by instilling and maintaining a sense of vulnerability. The study of the author on complacency, which stresses the importance of instilling and maintaining a sense of vulnerability to combat complacency, could be signified through this study, as job-related triggers help combat complacency by triggering the sense of vulnerability.
Arendt and Manton, 2015	Discussing how to nurture process safety culture	Symposium series	The outcome identified by the author is that the low sense of vulnerability among operating staff could result in an increasing trend of process safety incidents. As the perception of risk triggers a sense of vulnerability, the findings of the study could be positively related to the author's findings.
Smith et al., 2015	Development of a conceptual model and self-reported measure of OSH vulnerability	Peer-reviewed article	The most closely related research was conducted in the area of vulnerability. The concept of a framework developed by this study is in line with the study of the author, which developed a multidimensional measure of OSH vulnerability with several factors that influence a sense of vulnerability. However, the result of the study differs significantly, owing to the different methodologies adopted for the study.
Mckay and Lacoursière, 2008	Development of a process safety culture of chemical engineers	Peer-reviewed article	The authors explain that learnings from the disasters referred to in this study necessitate the labeling of a sense of vulnerability as a critical pillar for any organization's safety culture. Thus, it stresses the overall importance of this study.
Yanar et al., 2019	Examining the interplay between supervisor safety support and OSH vulnerability on workplace incidents and injuries	Peer-reviewed article	The authors support Arendt and Manton's (2015) findings in their study, which examines the interplay between supervisor safety support and OSH vulnerability with respect to workplace incidents and injuries. Their study concluded that OSH vulnerability (or lack of vulnerability among team members) and lack of supervisory support independently increased the likelihood of physical injuries at work.
Dee et al., 2019		Peer-reviewed article	This case study examines an incident that occurred when a fail-open valve failed to close. By analyzing the sequence of events, the researchers found that losing a sense of vulnerability was the root cause, which had the potential to lead to catastrophic consequences. This signifies the importance of having this study for greater benefit.
Brewer et al., 2007	Meta-analysis of the relationship between risk perception and health behavior	Peer-reviewed article	According to the author, a higher perceived risk can increase an individual's adherence to preventive measures. This view supports a finding of this study related to critical activities.
Fishbein et al., 1975	An introduction to theory and research: Belief, attitude, intention and behavior	Book	The authors argue that the probability and magnitude of a potential hazard (risk perception) are crucial factors in shaping risk behavior. However, the employees who participated in this study demonstrated a focus on severity rather than likelihood as their reference to the hazards related to severe impact inflicting hazards.
Ajzen, 1991	Review of research on the theory of planned behavior and discussion of unresolved issues. In broad terms, the theory is found to be well supported by empirical evidence.	Peer-reviewed article	Ajzen postulated in his theory of planned behavior—the most widely researched behavioral model—that actual behavior is driven by the intention to perform an action. Attitude, which is formed by knowledge and beliefs about the behavior in question, is identified as a critical factor, which is in line with the outcome of this study.

develop an initial sense of vulnerability framework that would, in turn, be further validated in the second stage of data collection. To facilitate the development of such a model, all participants were given the opportunity during the discussions to participate or ask open questions related to the following:

1. Think of instances at your organization where you should feel vulnerable.
2. Who do you think is most affected by these vulnerabilities?
3. Think of three control measures that can address these vulnerabilities.

Participants' responses were displayed on a flip chart for visual representation during the discussion, audio-recorded and transcribed to provide accurate records to perform the analysis (Kvale, 2007).

The second method of data collection consisted of semi-structured interviews, which is an appropriate approach to adopt when something about a topic is known (e.g., sense of vulnerability initial framework), but it is needed to explore it further, deepen the understanding, and validate the data (Given, 2008). Semi-structured interviews include a short list of guiding questions that are supplemented by follow-up and probing questions that are dependent on the interviewee's responses (Adams, 2015). A total of 87 semi-structured interviews from four sites were conducted by phone (Table 4). All interviews were conducted in English, and the average time was 50 minutes.

Data Analysis

A thematic data analysis was used to analyze the data generated from focus group discussions and semi-structured interviews. Braun and Clarke's (2006) six-step process to conduct thematic analysis was followed: familiarization, coding, generating themes, reviewing themes, defining and naming themes, and writing up.

Results

Result of Focus Group Workshop

The overall intent of the focus group was to create a unified definition that would be applicable to all participating organizations and to develop a high-level framework to help organizations and individuals instill and maintain a sense of vulnerability in order to prevent incidents. More than 80 keywords provided by the focus group were refined to develop the following definition:

> Maintaining a sense of vulnerability is about having a knowledgeable workforce with vigilant behaviors in order to overcome complacency and achieve a safety-reliant culture.

While complacency refers to the negative mindset that is contributory to incidents, sense of vulnerability refers to the proactive positive mindset that prevents the incidents. In the context of this study, sense of vulnerability denotes a state of mind with required knowledge and awareness that makes employees stay vigilant during their work to prevent any harm.

This definition plays a pivotal role in structuring the framework proposed by this work. Not only the questions to develop the high-level framework were derived from this definition but also the questions adopted to validate the framework. Further, the team considered more than 20 symptoms as triggers of a sense of vulnerability, which were identified and grouped into the following five main themes:

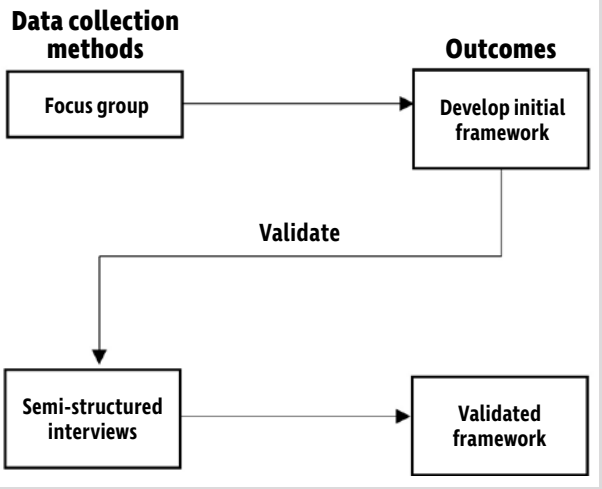
TABLE 3
FOCUS GROUP DETAILS

Site	No. of participants	Average years of experience	Nationality
A-1 Bahrain	3	19	Bahrainis (2), British (1)
B-1-1 Singapore	2	18	Singaporean
B-1-2 Singapore	2	17	Singaporean (1), Indian (1)
D-1 South Korea	2	20	South Korean
Total	**9**		

TABLE 4
SEMI-STRUCTURED INTERVIEWS

Site	No. of interviewees	Average years of experience
A-1 Bahrain	25	20
B-1-1 Singapore	20	15
B-1-2 Singapore	18	16
D-1 South Korea	24	19
Total	**87**	

FIGURE 1
RESEARCH METHOD



1. routine activities
2. critical activities
3. outstanding safety, health and environmental performance was achieved
4. resources constraint
5. inclusion culture

Five themes were developed to identify who in the organization should raise their sense of vulnerability whenever required. The focus on raising a sense of vulnerability is split by company or contractor, and the workforce is sliced into three levels, namely management, supervisors and employees. The team is of the opinion that all levels of the workforce are impacted; however, the supervisor level is clearly the most at stake to maintain their sense of vulnerability during all five identified symptoms.

The members of the focus group suggested more than 50 control measures, which were aligned with the identified symptoms, resulting in the proposal of a model represented by Figure 2.

Result of Semi-Structured Interview

The objective of the interview was to identify and analyze the employees' perceptions of the factors that trigger their sense of vulnerability. And the participants were asked to specify their concerns related to the identified triggers and the actions they would take to address those concerns.

From the interviews conducted, it was evident that the perception of the sense of vulnerability is influenced by various factors. As shown Table 5, the top three triggers (i.e., attitude, hazards at the workplace, criticality of the task) contribute to 73% of the employees' perception of a sense of vulnerability. Based on the interviews, 30% of the total responses recognized the presence of hazards at the workplace as a major factor that triggers their sense of vulnerability. Of the respondents, 20% stated that the criticality of the activities performed makes them feel vulnerable. The varying degree of risk posed by the activity had an impact on the criticality of the responses. Hence, it is appropriate to group them as on-the-job factors that trigger their sense of vulnerability at the workplace. On-the-job factors are the most recognized trigger, as perceived by 50% of the responses.

The attitude of the employees was perceived as a trigger that stimulates a sense of vulnerability in about 23% of the responses. The responses that related to self-discipline, duty of care toward family and coworkers, and safe behaviors were attributed to "attitude." Several other factors were identified as triggers by the employees participating in the survey. However, those factors' total contribution to their perception is 27%. Out of this, a significant percentage was made up of "resource constraints" and "safe systems of work." As the sample respondents consist of various attributes regarding their position, experience, type of organization they represent and demography, it is of significance to analyze their response pattern that triggers their sense of vulnerability. The result of the study based on various attributes of the respondents is presented in Table 6.

The result of the study indicates a minor shift in the pattern of perception of the employees with respect to their role in the organizational hierarchy. Figure 3 (p. 28) represents the pattern of triggers across the range of respondents in the perception survey. Hazards have a greater impact on all roles within the organization. Employees weigh job and personal factors almost equally, but supervisors and managers perceive higher triggers from hazards than the rest. Supervisors also recognized safe systems of work and resource constraints as significant triggers.

The contractor employees' participation is 30% in the survey. The perception follows a similar overall pattern as presented in Figure 4 (p. 28), except that the contractor's sense of vulnerability is significantly impacted by resource constraints.

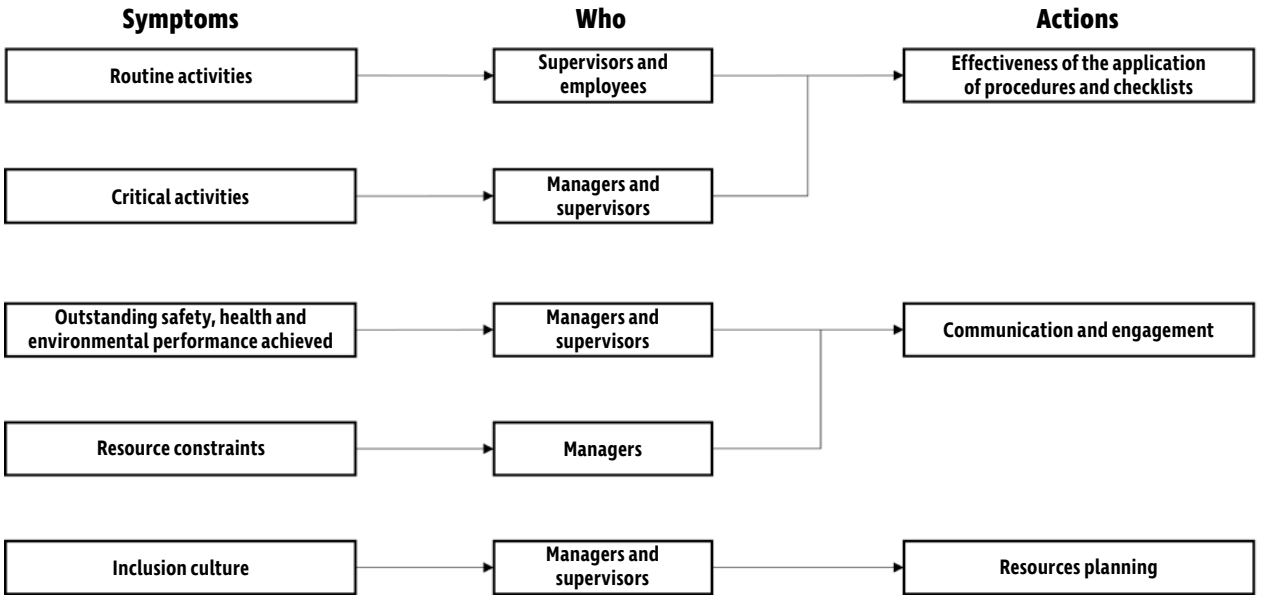
With respect to "who," the respondents believe that "management" should raise their sense of vulnerability for all the identified factors, followed by supervisors for four of them except resource constraints. This implies that employees believe that resource constraints in the workplace can only be resolved by management, not their supervisors.

The participants identified concerns related to the triggers and actions to address those concerns. The responses were analyzed and grouped into the following actions: effective application of procedures and checklists; awareness and employee engagement; and resource planning. As shown in Table 7 (p. 28), with 42%, awareness and employee engagement

FIGURE 2

MODEL FOR MAINTAINING A SENSE OF VULNERABILITY

Model for maintaining a sense of vulnerability in industrial settings.



were identified as major actions, followed by effective procedure application (37%) and resource planning (21%).

Most of the participants believed that awareness and employee engagement are crucial actions that enhance the sense of vulnerability. Effective application of procedures and proper resource planning are inevitable actions that facilitate the maintenance of sense of vulnerability.

Validation of Sense of Vulnerability Framework

The responses from the survey regarding the triggers (Table 5), along with the concerns and actions to address them, led to the revision of the model to incorporate the real-time interpretation of the employees in industrial settings (Figure 5, p. 29).

Only a negligible percentage of participants perceived routine activities, outstanding safety, health and environmental performance, and inclusion culture as triggers of sense of vulnerability. These factors were considered significant during the focus group workshop. Hence, those were removed from the model (Figure 2) after the survey, as they were not significantly recognized as triggers by the respondents. In turn, during the interview, presence of hazards, a safe system of work, and the attitude of employees were incorporated into the model, as these were identified by a notable percentage of respondents. The accountabilities are also revised based on the responses. The actions proposed by the respondents remain unaltered, as their response follows the same pattern as the original model.

Vulnerability Assessment Tool

Following the revalidation of the sense of vulnerability framework, the focus group brainstormed methods for assessing workplace vulnerabilities. Table 8 (p. 30) illustrates the key factors and components of the tool proposed for the vulnerability risk assessment (Figure 6, p. 30), based on the revised sense of vulnerability framework.

The methodology proposed for the vulnerability assessment is that the user is prompted to evaluate the key components using the questionnaire that revolves around the critical factors. The action items proposed in the tool are more indicative than exhaustive, so customization might be required based on the business or organizational profile.

Discussion

The focus group workshop delivered a foundational framework for the sense of vulnerability. However, among the five factors identified through the workshop, only two (critical activities and resource constraints) were perceived as factors that influence the respondents' sense of vulnerability. The majority of participants responded that their sense of vulnerability is greatly influenced by the risk profile and resource availability. These responses altered the view of the focus group's proposal and nullified the rest of the elements of the framework. As a result, the framework for the sense of vulnerability was revised based on feedback from respondents at various levels of the organizational hierarchy, as shown in Figure 5 (p. 29). The framework demonstrates that the sense of vulnerability is influenced by multiple factors in the workplace, which is in line with the study by Smith et al. (2015), which developed a multidimensional measure of OSH vulnerability with multiple factors that influence the sense of vulnerability. However, the result of the study differs significantly, owing to the different methodologies adopted for the study.

According to the findings of the semi-structured survey, the recognized triggers for employees' feelings of vulnerability follow a consistent pattern of perception regardless of organizational roles or employee type (contractor). One exception to that pattern is the supervisor's perception of resource constraints and safe systems of work.

The job-related factors that pose an imminent threat to the employees' safety were perceived as a major trigger. The respondents specifically referred to the hazards that have the

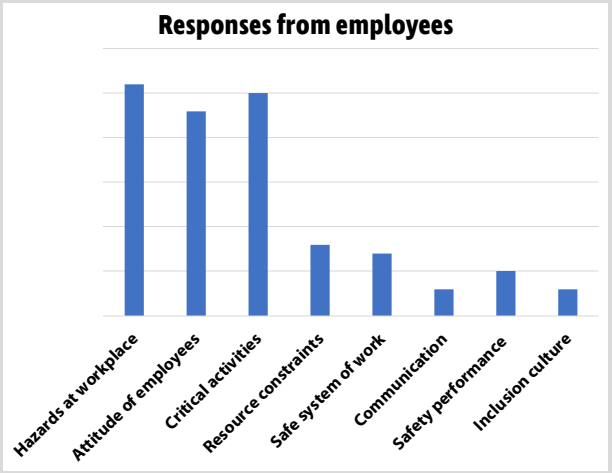
TABLE 5
EMPLOYEES' RESPONSE ON THE TRIGGERS OF SENSE OF VULNERABILITY

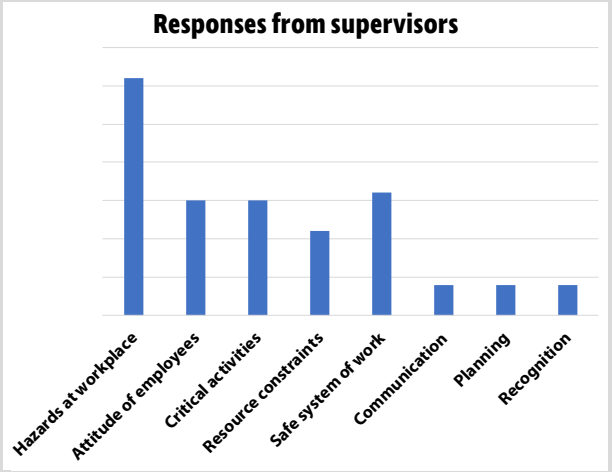
Triggers identified	Percentage
Hazards at workplace	30
Attitude of employees	23
Criticality of task	20
Resource constraints	8
Safe system of work	7
Communication	3
Safety performance of the organization	3
Inclusion culture	2
Planning	1
Recognition	1
Safety culture of the organization	1
Management support	1
Total	**100**

TABLE 6
ATTRIBUTE-BASED RESPONSE ON THE TRIGGERS OF SENSE OF VULNERABILITY

	Triggers in %											
	Hazards at workplace	Attitude of employees	Critical activities	Resource constraints	Safe system of work	Communication	Safety performance	Inclusion culture	Planning	Recognition	Safety culture	Management support
Position in the organization												
Employee	26	23	25	8	7	3	5	3	0	0	0	0
Supervisor	31	15	15	11	16	4	0	0	4	4	0	0
Manager	50	22	12	6	0	0	0	0	0	0	5	5
Employee type												
Employee	30	22	26	7	7	3	1	2	1	1	0	0
Contractor	34	20	7	13	10	3	7	0	0	0	3	3

FIGURE 3
TRIGGERS BY ORGANIZATION ROLE





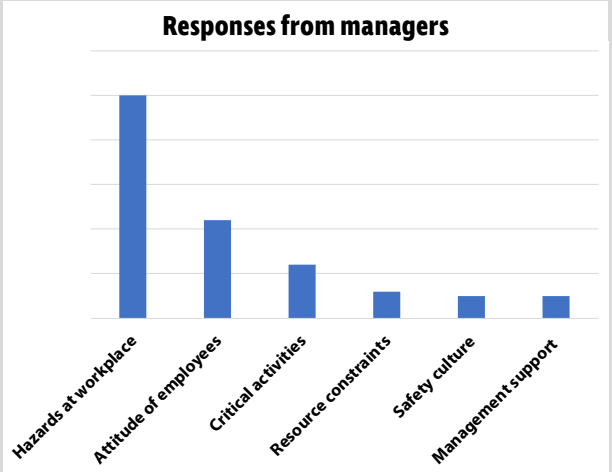
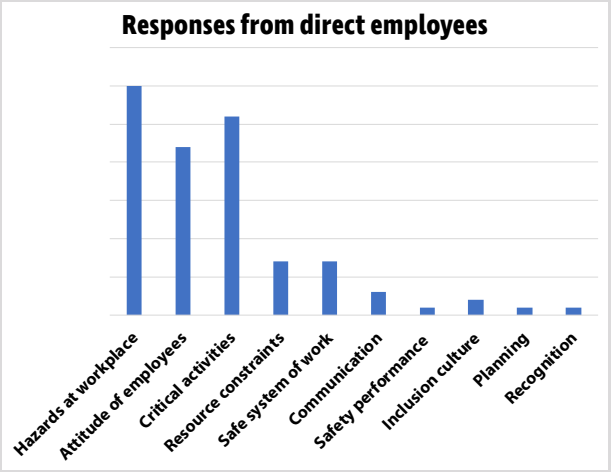


FIGURE 4
CONTRACTORS' PERCEPTION



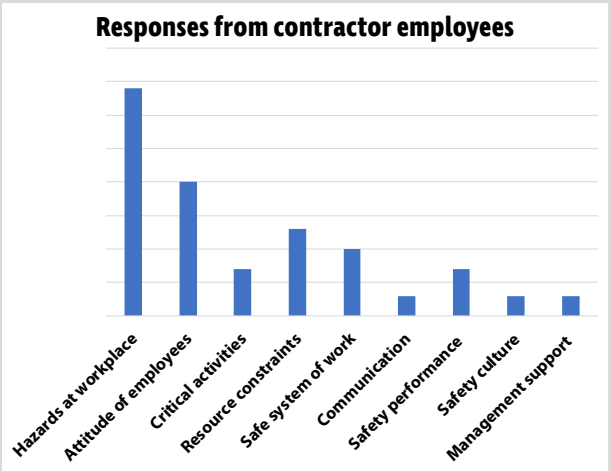


TABLE 7
ACTIONS TO CONTROL CONCERNS RELATED TO IDENTIFIED TRIGGERS

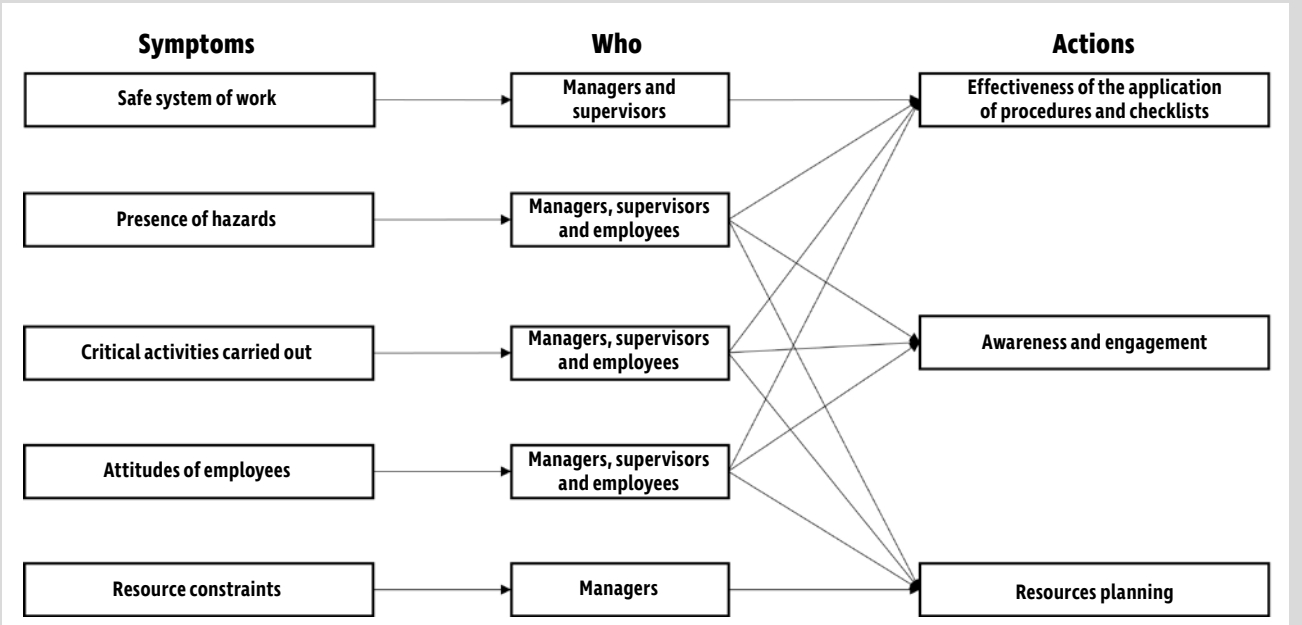
Actions	Response (%)
Effective application of procedures and checklists	37
Awareness and engagement	42
Resource planning	21

potential to inflict severe harm in most of their responses. Hence, the severity of the hazards has a significant influence on triggering a sense of vulnerability. Also, the criticality of the activities performed makes them feel vulnerable. Note that the varying degree of risk posed by the activity had an impact on the criticality of the responses. To eliminate and control workplace risks, organizations universally implement risk management practices. The organizations from which the employees participated in the perception survey are subscribed to an internationally accepted benchmark safety and health management system, through which risks are managed in a systematic manner. Companies that use a safe system of work ensure that the risk level is kept as low as reasonably practicable through qualitative or semiquantitative risk assessments. Though developed, accepted and acknowledged as a task with tolerable risk, the employees continue to perceive and maintain their sense of vulnerability at site level for high-risk critical tasks. According to Brewer et al. (2007), a higher perceived risk can increase an individual's adherence to preventive measures. Risk perception is central to many models that explain behaviors related to health-related choices (e.g., health belief model; Rosenstock, 1974). The study of Sanders (2015) on complacency, which

FIGURE 5

REVISED MODEL FOR MAINTAINING A SENSE OF VULNERABILITY

Revised model for maintaining a sense of vulnerability in industrial settings.



stresses the importance of instilling and maintaining a sense of vulnerability to combat complacency, could be signified through this study, as the noted job-related triggers help combat complacency by triggering the sense of vulnerability. However, the mere nature of the routine of the task was not perceived as a trigger by the respondents. Fruhen et al.'s (2014) work on chronic unease stressed the importance of personal attributes that impact chronic unease. Because chronic unease is linked to sense of vulnerability in such a way that both rely on individuals' perceptions to maintain a proactive safety culture, it is critical to shed light on specific factors that influence perception and behavior in the workplace. This study explored the factors related to the task, system and resources in addition to personal factors that trigger the sense of vulnerability.

Major behavioral models such as the theory of reasoned action (Fishbein & Ajzen, 1975), the theory of planned behavior (Ajzen, 1991), and the subjective expected utility theory (Edwards, 1954; Ronis, 1992; Sutton, 1987) argue that the probability and the magnitude of a potential hazard (risk perception) are crucial factors in shaping risk behavior. However, the employees who participated in this study demonstrated a focus on severity rather than likelihood as their reference to the hazards related to severe impact-inflicting hazards. As the perception of risk triggers the sense of vulnerability, this study could be positively related to the outcome of the study by Arendt and Manton (2015), which identifies that the low sense of vulnerability among operating staff could result in an increasing trend of process safety incidents.

Ajzen (1991) postulated in his theory of planned behavior, the most widely researched behavioral model, that actual behavior is driven by the intention to perform an action. Attitude, which is formed by knowledge and beliefs about the behavior in question, is identified as a critical factor, which is in line with the outcome of this study.

The information provided by this study is important as it reflects the real-time perceptions of employees in industrial settings. Significant actionable findings of the study are:

- Employees' sense of vulnerability is influenced by various factors, and it is important to identify those to maintain the sense of vulnerability.
- The presence of hazards is one of the most commonly perceived factors that triggers the sense of vulnerability. It means that the sense of vulnerability might not be maintained if the employee is not aware of the presence of a hazard. Awareness about the hazards in the workplace and worker engagement in risk management are important to maintain a sense of vulnerability.
- Effective procedures are another significant tool that helps employees maintain their sense of vulnerability.

The vulnerability assessment tool can be used in the industry to identify vulnerability opportunities in the workplace and apply appropriate interventions to direct individuals' attention and raise their sense of vulnerability in time to avoid incidents and injuries by incorporating it into existing safety management tools such as the risk assessment process.

Study Limitations

This research study has potential limitations, within which the findings need to be interpreted accordingly. First, the study focused on individuals' sense of vulnerability rather than the organization's sense of vulnerability, as it is assumed that individuals directly impact the organization's sense of vulnerability. Second, the proposed framework may not be generalizable primarily because the sample size is not large enough to reflect every situation encountered by the respondents and because

this study is limited to four organizations. Third, English was adopted in all data collection methods (i.e., the focus group workshop and semi-structured interview questionnaire), as it is the official language in the organizations that participated in this study. This may limit the ability of respondents who spoke different languages (e.g., Arabic, Chinese, Thai) to articulate their views.

Conclusion

While several studies on complacency and chronic unease shed light on personal attributes, this study is a further step that proposes a model for the sense of vulnerability based on the specific factors perceived by the respondents. This study demonstrates the possible correlation between the outcomes of studies conducted by various authors, which is evident through the literature summary (Table 2, p. 24). Moreover, most of the empirical studies conducted focused on the factors responsible for a sense of vulnerability; this study emphasizes controlling those factors in real time using the vulnerability assessment tool, which is a significant contribution of this study to the industry. The result of this study signifies the level of influence that on-the-job factors (hazards and critical activities) and personal factors (attitude) have on the sense of vulnerability. The authors consider these factors highly reliable as they were drawn out of the respondents in an open-ended, semi-structured interview instead of defined through a predetermined questionnaire. Hazards at the workplace, critical activities and the attitude of the employees all define the level of sense of vulnerability that the employee exhibits. By focusing on improvements in awareness and engagement, the application of procedures and resource planning, organizations may maintain and improve the sense of vulnerability, which is vital for the prevention of incidents and injuries. As the vulnerability assessment tool is developed based on the perceptions of respondents who are working in the industry, it is believed to have the most empirical aspects of vulnerability assessment. However, the effectiveness of the tool could be further enhanced by applying context-specific customization to components based on the business or operational profile.

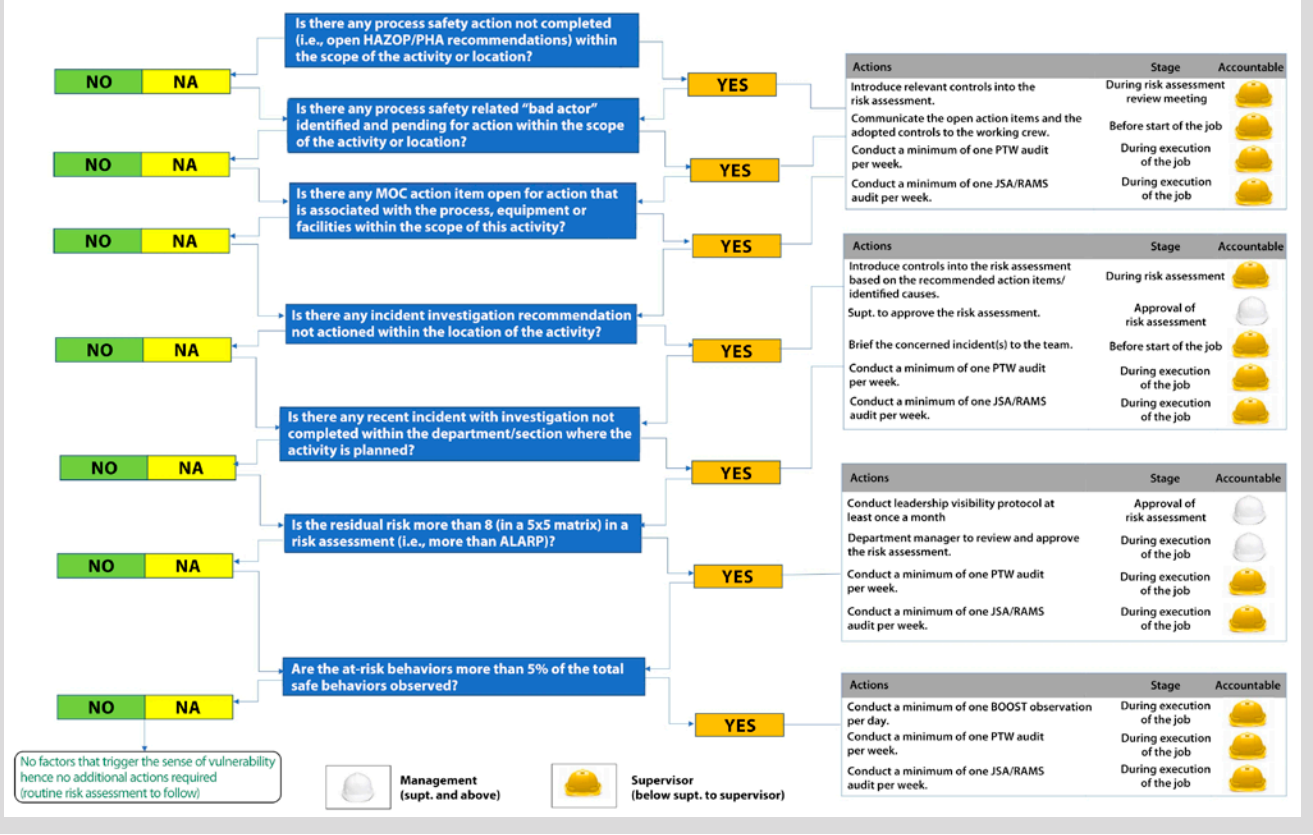
TABLE 8

KEY FACTORS & COMPONENTS OF VULNERABILITY ASSESSMENT TOOL

Key critical factor	Component
Process safety	Process hazard analysis Maintenance-related "bad actors" Management of change
Learning from incidents	Root causes identified through recent incidents
Risk assessment	Residual risk level
Behavior-based safety	Pattern of at-risk behaviors identified

FIGURE 6

THE VULNERABILITY ASSESSMENT TOOL



This study paves the way for future work on effectively and practically integrating the vulnerability assessment tool with the behavior and process safety tools in an industrial setting. There is also a potential for further research to explore the role of various levels of employees in maintaining a sense of vulnerability, with a specific focus on the proposed framework and assessment tool. Further exploration of the effectiveness of this framework across various organizations with differing risk profiles will be useful to validate its impact on eliminating incidents. **PSJ**

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