Assessing the Mediating Roles of Safety Knowledge, Safety Culture, and Situational Awareness in the Relationship Between Risk Perception and Safety Compliance in the Chemical and Process Industries

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Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

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Abstract

The chemical and process industries have considerable risk factors due to the use of hazardous substances and the associated complex procedures used throughout the production facilities. To improve safety in the industry, there is an ongoing debate on how risk perception influences safety compliance, with limited research on mediating factors in this context. This thesis systematically investigates the relationship between risk perception and safety compliance, with a particular focus on the mediating roles of safety knowledge, safety culture, and situational awareness. A mixed-method approach was employed, integrating the analyses of a quantitative survey with qualitative interviews. Structural Equation Modelling was used to test the mediating effects, while Thematic Analysis provided contextual insights from the interviews. The quantitative findings show that safety knowledge and safety culture significantly, yet partially, mediate the relationship between risk perception and compliance, reinforcing their roles in shaping workplace safety compliance. Additionally, it was found that situational awareness did not mediate the relationship between risk perception and safety compliance, as the path coefficient is not statistically significant due to a statistically non-significant correlation between situational awareness and safety compliance. Qualitative interviews investigated the non-significant relationship between situational awareness and safety compliance, identifying several key factors which can be organised into groups. Qualitative results suggest that workplace factors identified impair situational awareness, reducing compliance. Conversely, most individual factors identified (e.g., safety knowledge) and all organisational factors identified (e.g., communication) have a positive influence on situational awareness, thereby improving safety compliance. The negative factors reduce vigilance and undermine situational awareness, while the positive factors may combat these negative factors and enhance situational awareness, which could explain the non-significant correlation between situational awareness and safety compliance. The study recommends safety training to enhance risk perception, workload management to improve situational awareness, and a leadership-driven safety culture.

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List of Abbreviations

AMOS	Analysis of Moment Structures
AVE	Average Variance Extracted
BPS	British Psychological Society
CCPS	Centre for Chemical Process Safety
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CI	Confidence Interval.
CPI	Chemical Process Industries
CR	Composite Reliability
C.R.	Critical Ratio
DCS	Distributed Control Systems
EFA	Exploratory Factor Analysis
F	F-statistic
HPD	hearing protection devices
H&S	Health and Safety
KMO	Kaiser-Meyer-Olkin
PAP	Perceived Affect Possibility
PCA	Principal Component Analysis
PCR	Perceived controllability of risks
PHTR	Perceived Health Threat of Risks
PIS	Participant Information Sheet
PLS-R	Partial Least Squares Regression software
PMT	Protection Motivation Theory
PSR	Perceived Severity of Risks
RMSEA	Root Mean Square Error of Approximation
RP	Risk Perception
SA	Situational Awareness
SC	Safety Compliance
SCR	Safety Culture
SEM	Structural Equation Modelling
SK	Safety Knowledge
SPSS	Statistical Package for the Social Sciences software
SRMR	Standardised Root Mean Square Residual
S.E	Standard Error
TA	Thematic analysis
TLI	Tucker-Lewis Index
VAF	Variance Accounted For
HPD	hearing protection devices
SMEs	small and medium enterprises
α	Cronbach’s alpha
β	Beta coefficient

df	Degree of Freedom
p	p-value (statistical significance)
r	Correlation coefficient
t	Observed t-value
χ^2	Chi-square

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

The Chemical Process Industries (CPI) have been recognised for their complexity and inherent risks, requiring effective measures that protect individuals, enhance safety, and safeguard the operational environment (Kidam *et al.*, 2010). However, as safety knowledge has increased, the complexity of production systems within the chemical and process industries has also grown, making it even more challenging to maintain high safety standards (Villa *et al.*, 2016). Advances in technology have led to the development of automation and sophisticated operational equipment, which are more challenging to understand and maintain properly (Lee and Seppelt, 2009).

Chemical processes are still crucial in industries such as oil and gas, petrochemicals, nuclear energy, pharmaceuticals, plastics, energy production, and water treatment, among others (Attwood, 2017; Neill, 2017; Pitblado, 2011). Safety in these various environments relies heavily on individuals' adherence to safety protocols and guidelines. Two critical constructs influencing safety behaviours are risk perception and safety compliance. Risk perception and safety compliance are paramount in high-hazard industries, such as the chemical and process industries, because unsafe practices often lead to catastrophic outcomes (Gürcanlı *et al.*, 2015).

The CPI encompasses numerous large-scale industrial processes, including oil and gas production, refining and petrochemicals, as well as the manufacturing of plastics and chemicals. A common thread among these industries is the storage, handling, and management of extensive inventories of materials and chemicals that may be highly flammable, unstable, or toxic (Council, 2011; King, 2013). Additionally, numerous work systems involve materials undergoing physical changes and chemical reactions to produce various products (Seider *et al.*, 2017). The increased complexity of these processes heightens the potential for undesirable occurrences and makes managing human contributions more vital and challenging (Edmonds and Wilkinson, 2016).

Despite technological advancements and stringent regulatory measures, incidents continue to occur in the CPI, often with severe consequences. An incident is typically an unplanned or undesired event that results in negative outcomes such as personal injuries, fatalities, property damage, environmental impacts, and loss of business opportunities (Zakaria *et al.*, 2012). Notable industrial disasters like the Bhopal Gas Plant incident (1984), the Chornobyl Nuclear Power Plant disaster (1986), the Piper Alpha oil platform explosion 1988, Enschede (2000), AZF Toulouse (2001), Texas City refinery (2005) and the BP Deepwater Horizon oil spill 2010 serve as stark reminders of the potential risks inherent in these industries. These incidents have had immense consequences for personnel, the environment, businesses, and society (Deegan *et al.*, 2000; Zakaria *et al.*, 2012).

In recent years, technological advancements have resulted in a decrease in accidents caused by technical malfunctions (Petrillo and Zomparelli, 2018). While the number of incident occurrences per year may have reduced, the undesirable outcomes and consequences per incident have increased (Dakkoune *et al.*, 2018). For instance, the Piper Alpha disaster resulted in losses exceeding £2 billion, along with indirect insurance payments of about £76 million and the tragic loss of 167 lives (Executive, 1999). In contrast, the Texas City Refinery explosion in 2005 killed 15 people, 180 others were injured, and led to a financial loss of more than $1.5 billion (Ingersoll *et al.*, 2012). Moreover, in the Deepwater Horizon oil spill in 2010, 11 workers were killed, 17 were injured, and the financial cost was estimated at $144 billion (Ingersoll *et al.*, 2012). This suggests that while technological advancements have reduced mechanical failures, more focus should be placed on human factors.

These persistent incidents have been shown to highlight a critical disconnect between risk perception and safety compliance within the CPI. Employees and management may recognise the inherent risks in their operations, yet this awareness does not always translate into compliant behaviour (Hopkins, 2011; Jahangiri and Motovagheh, 2011; Meel *et al.*, 2008; Reniers and Zamparini, 2010). Several factors contribute to this disconnect between risk perception and safety compliance, including human, organisational and situational factors (Bhattacharjee and Das, 2020; Chen, 2016; Copelli, 2016; Jahangiri *et al.*, 2008; Ramtiyal *et al.*, 2022; Vesta, 2012). Human factors such as inadequate safety knowledge and training may leave employees unprepared to handle complex systems safely (Blair and Seo, 2007; Dekker *et al.*, 2008; Gajek, 2019; Leveson, 2012; Ojedokun and Ajala, 2017). Poor safety culture and insufficient organisational support can undermine safety initiatives (Clarke, 2006; Hocking, 2007; Jin and Chen, 2013; Neal and Griffin, 2006; Pidgeon, 2001; Reason, 2016). Lack of situational awareness impairs hazard recognition and decision-making and undermines safety practices (Chauvin *et al.*, 2008; Endsley, 1995; Flin *et al.*, 2008; Hollnagel, 2014; Krausmann *et al.*, 2011; Prautzsch, 2007). While employees and management might be aware of workplace hazards, this awareness does not always translate into consistent safety-compliant behaviour due to cognitive, cultural, and environmental factors.

1.2 Impact of human error and human factors on workplace incidents

Workplace incidents have multifaceted causes, with human error consistently emerging as a leading cause of industrial accidents (Garrett and Teizer, 2009; Holla, 2016; Wiegmann *et al.*, 2005). Engineering systems depend on human involvement, which is a significant vulnerability, as people are prone to errors (Kariuki and Löwe, 2007).

Human error is a critical vulnerability in industrial systems, with studies consistently identifying it as the leading cause of accidents across sectors. Globally, approximately 80% of all industrial accidents are attributable to human error (Pouya and Habibi, 2015), with financial repercussions often reaching billions of dollars (Isiadinso, 2015). This trend is evident across various sectors: aviation (70-80%) (Shappell and Wiegmann, 2001), maritime (80-85%) (Baker and McCafferty, 2005), nuclear power (50-70%) (Kanagalakshmi, 2023) cited Trager Jr (1985), and automobile (65%) (Dhillon, 2007). In the chemical process industries, human errors account for over 80% of accidents (Kariuki and Löwe, 2007; Zarei *et al.*, 2019), resulting in severe consequences such as fatalities, injuries, financial losses, and environmental damage (Shokria *et al.*, 2016). Such statistics underscore the significant impact of human error on safety and economic outcomes in the chemical process industries industrial systems, where humans play critical roles in the design, construction, operation, and maintenance of systems (Edmonds and Wilkinson, 2016; Omidi *et al.*, 2018).

Human factors and human error are closely related yet distinct concepts within the contexts of safety and engineering. Human factors refer to the study of how humans interact with various system elements, including machines, environments, and processes. This encompasses understanding human capabilities, limitations, behaviours, and cognitive processes to improve system design and performance (Petrillo and Zomparelli, 2018; Sharit, 2006). On the other hand, human error explicitly denotes mistakes or failures made by individuals during tasks or processes that can lead to undesirable outcomes, such as accidents or incidents (Hollnagel, 1993; Shokria *et al.*, 2016). While human factors aim to understand and mitigate the conditions that lead to human error, human error represents the direct consequences of these underlying factors.

The inherent interactions between humans and industrial systems are susceptible to errors that can trigger incidents. Accidents often stem from deficiencies in knowledge or inadequate understanding (Palazzi *et al.*, 2015). Thus, understanding human factors and the contexts in which actions occur is crucial and central to designing effective safety interventions (Sharit, 2006). Contextual elements such as environmental conditions, organisational culture, workload, and situational awareness significantly influence how human factors manifest and contribute to errors (Dhillon, 2007; Edmonds and Wilkinson, 2016).

1.3 Research aim, objectives, and questions

This research aims to understand the human factors that affect risk perception and safety compliance in CPI. To achieve the aim of this research, the corresponding objectives are specified as follows:

Objective 1: Conduct a thorough literature review to identify and define the key constructs by critically evaluating existing theories and empirical studies on those constructs within the chemical and process industries, identifying significant gaps and opportunities for further research.

Objective 2: Develop a conceptual model that explores the mediating roles of safety knowledge, situational awareness, and safety culture in the relationship between risk perception and safety compliance, to guide the measurement and testing of hypothesised relationships.

Objective 3: Design a mixed-method methodology to test models developed in Objective 2.

Objective 4: Implement the designed methodology and collect data from employees in the chemical and process industries to test the hypothesised pathways and mediating effects.

Objective 5: Systematically analyse the collected data to identify critical points for safety management improvements and propose practical recommendations to enhance safety compliance within the chemical and process industries.

In alignment with the research objectives, this study seeks to answer the following research questions:

RQ1: How does risk perception influence safety compliance in the chemical and process industries?

RQ2: To what extent do safety knowledge, safety culture, and situational awareness mediate the relationship between risk perception and safety compliance?

1.4 Structure of thesis

The thesis is organised into seven chapters, each building on the previous to address the research aims. Chapter 2 presents the relevant literature on risk perception, safety knowledge, safety culture, situational awareness, and safety compliance. Chapter 3 outlines the research design, methodology, and measurement instruments used for data collection and analysis. Chapter 4 reports the quantitative findings, including survey analyses, validation of data reliability, descriptive insights, and an assessment of the mediating roles of safety knowledge, safety culture, and situational awareness. Chapter 5 reports the qualitative findings, focusing on workplace, individual, and organisational factors that shape the relationship between situational awareness and safety compliance. Chapter 6 provides the discussion, integrating the quantitative findings (Section 6.1) and qualitative findings (Section 6.2) to address the research questions. Finally, Chapter 7 presents the study’s conclusions and outlines directions for future research.

Chapter 2: Literature Review

This chapter reviews the relevant literature on the relationships among five constructs: risk perception, safety compliance, safety knowledge, safety culture, and situational awareness. The chapter is organised into seven sections. Section 2.1 provides an overview of the definitions, measurements, and factors affecting the study's constructs. Section 2.2 introduces models illustrating the relationships between constructs in research and literature. Section 2.3 discusses the relationship between risk perception and safety compliance, addressing direct, indirect, and mediating factors. Section 2.4 examines the relationship between safety knowledge and each of risk perception and safety compliance. Section 2.5 explores the relationship between safety culture and each of risk perception and safety compliance. Section 2.6 examines the relationship between situational awareness and both risk perception and safety compliance. Section 2.7 provides a summary of the literature review and the research hypothesis.

2.1 Selection and theoretical grounding of mediators

The selection of safety knowledge, safety culture, and situational awareness as mediators of the risk perception–safety compliance relationship in chemical and process industries is theoretically and conceptually warranted because each represents a distinct mechanism through which perceived risk is translated into safety compliance. This position echoes Mearns and Flin (1995), who call for further investigations of knowledge, safety culture, and situational awareness in relation to risk perception and safety.

Safety knowledge, defined as workers' comprehension of hazards, rules, and safe procedures (Griffin and Neal, 2000), operates as a cognitive mediator grounded in Griffin and Neal's (2000) model of safety performance, which positions knowledge as a proximal determinant of compliance. In chemical processing contexts, where hazards are frequently latent (e.g., toxic exposure, runaway reactions), risk perception alone is insufficient; workers must possess both declarative and procedural knowledge to translate awareness into appropriate action (Zhao *et al.*, 2021).

Extending beyond individual cognition, safety culture, the shared values, attitudes, and practices prioritising safety (ACSNI, 1993), functions as a contextual mediator through mechanisms articulated in Zohar's (2003) safety climate theory and the theory of planned behaviour (Ajzen, 1991). It shapes subjective norms and perceived behavioural control, ensuring that individual risk perceptions are reinforced by organisational expectations and managerial commitment, a condition essential in major hazard facilities where compliance must remain stable despite production pressures (Vinodkumar and Bhasi, 2010).

Building on both cognitive and contextual foundations, situational awareness, defined as perceiving environmental elements, comprehending their meaning, and projecting future states (Endsley, 1995), mediates through a dynamic perceptual pathway. According to Endsley's three-level model, risk perception must be integrated into comprehension and projection to guide real-time compliance decisions in complex, automated chemical processes where conditions evolve rapidly (Sneddon *et al.*, 2013).

Conceptually, these mediators' pathways explain how risk perception is cognitively processed, organisationally reinforced, and dynamically enacted to produce safety compliance in chemical and process industries.

2.2 Study constructs overview

2.2.1 Risk perception

Risk perception refers to individuals' subjective evaluation or understanding of risks. It is the subjective assessment of the probability of a particular event transpiring and our level of concern regarding its repercussions (Renn and Rohrmann, 2000; Sjöberg *et al.*, 2004). Risk perception encompasses individuals' psychological evaluation of the probability and consequences of a negative outcome stemming from hazardous exposures. It pertains to our cognition and emotions regarding an unfavourable outcome (Burcu Bayram, 2015; Renn and Rohrmann, 2000; Slovic, 1987; Slovic *et al.*, 2004).

Risk perception is grounded in several theoretical frameworks, including the Psychometric Paradigm, Cultural Theory, and Protective Motivation Theory (PMT). The Psychometric Paradigm pioneered by Slovic (1987) emphasises that risk perception is a cognitive process. Laypeople's risk perception is influenced by dread, controllability, and familiarity with risk (Balžekienė, 2019; Cano and Salzberger, 2017). Contrastingly, experts assess risk through quantitative methods, such as statistical probabilities (severity & likelihood), historical incident rates, and scientific models. The Cultural Theory of risk perception was developed by Douglas and Wildavsky (1982), posits that risk perceptions are shaped by social and cultural values, leading to variations across groups and societies (Cano and Salzberger, 2017; Kieu and Senanayake, 2023). The Protective Motivation Theory (PMT) is a psychological theory designed to elucidate individuals' motivations for engaging in protective behaviours. The PMT claims that individuals' motivation to adopt protective behaviours is determined by four primary factors: threat assessment, coping appraisal, fear control, and risk control (Rogers, 1975). The Health Belief Model by Becker (1974) is a foundational tool for understanding risk perception and decision-making in health and safety contexts. It posits that individuals are more likely to adopt protective behaviours if they perceive a significant threat and believe the benefits of action outweigh the barriers (Becker, 1974). These theoretical frameworks provide a multidimensional lens to dissect risk perception, emphasising its complexity in shaping behaviours and informing tailored safety interventions across diverse industrial and societal contexts.

Measuring risk perception is challenging due to its subjective and multidimensional nature (Weber *et al.*, 2002). Risk perception can be categorised into two different elements: cognitive and emotional risk perceptions (Gerrard *et al.*, 2008; Loewenstein *et al.*, 2001; Slovic *et al.*, 2004). Many researchers have developed different approaches to measuring risk perception in different contexts. Common approaches to measuring risk perception include self-report surveys, such as the one developed by Flin *et al.* (1996) in offshore installations, Qin *et al.* (2021) developed a survey to measure risk perception of medical college students. Additionally, psychometric scales are used to quantify risk perception across dimensions like severity, likelihood, and emotional response (Vasvári, 2015).

Various factors influencing risk perception have been examined in other industrial sectors. Factors influencing risk perception, such as safety culture in a furniture manufacturing company (Colim *et al.*, 2021), in construction (O'Toole, 2002), safety training and distraction in the construction industry (Namian *et al.*, 2018), safety climate, safety leadership, workload, and accident experiences in manufacturing organisations (Oah *et al.*, 2018), safety attitude, safety knowledge and safety leadership in the chemical industry (Zhao *et al.*, 2021).

A key aspect of human factors is risk perception. Research indicates that humans possess limited cognitive capacities, allowing them to process only a limited amount of information at any given time (Bohnenblust and Slovic, 1998). This cognitive limitation can adversely affect workers' risk perception, leading to inappropriate decisions and unsafe behaviours, thereby increasing the likelihood of human errors (Rundmo, 2001). Higher perceived risks correlate with a greater desire to modify behaviours to mitigate hazards (Leonard and Karnes, 2000; Namian *et al.*, 2018). However, contextual factors such as safety knowledge, safety culture, and situational awareness can boost the impact of risk perception on safety behaviour (Mearns and Flin, 1999; Oah *et al.*, 2018; Pandit *et al.*, 2019). For example, managing complex processes in a high-risk work environment can lead to physical fatigue and cognitive overload. This directly impairs workers' already limited cognitive capacities (Bohnenblust and Slovic, 1998), diminishes risk perception and increases the likelihood of incidents (Ferrer and Klein, 2015; Rundmo and Nordfjærn, 2017).

2.2.2 Safety compliance

Safe behaviours, as defined by Neal and Griffin (2006) and recently corroborated by (Kalteh *et al.*, 2021; Kapp, 2012; Seo *et al.*, 2015), encompass work performance characterised by two dimensions: safety compliance (adherence to rules and procedures pertinent to the task) and safety participation (actively advocating for safety as a core value). Safety compliance, often known as compliance with safety regulations (Marchand *et al.*, 1998), encompasses the essential actions required by individuals to maintain a secure work environment. These behaviours pertain to personnel adhering to prescribed working procedures and utilising the requisite protective equipment. Safety compliance is related to the following of rules and procedures established by the organisation and regulatory authorities (Martínez-Córcoles *et al.*, 2014). Furthermore, it includes intra-role behaviours (Katz and Kahn, 2015) linked to safety, identified as behaviours required or expected within the duties and responsibilities of the designated role.

Safety compliance encompasses core activities that employees must undertake to ensure workplace safety Neal and Griffin (2006). The integrated model of workplace safety by Christian *et al.* (2009) stated that adherence to procedures, utilisation of protective equipment, and implementation of risk reduction strategies were inversely connected with workplace injuries. This is a crucial behavioural strategy in various settings to proactively reduce adverse safety outcomes (Clarke, 2012; Liu *et al.*, 2015). Consequently, adherence to safety protocols by employees is advantageous for attaining workplace safety.

Safety compliance is a critical factor in ensuring workplace safety and is extensively examined in research studies across various industries. Researchers typically measure safety compliance using a combination of self-reported surveys, direct observations, and incident records. Self-reported surveys, often based on Likert-scale questionnaires, assess employees' adherence to safety protocols and perceptions of compliance (Neal *et al.*, 2000). Direct observations provide objective data by monitoring workplace behaviour, while incident records and safety audits quantify compliance levels based on past violations, near-misses, and adherence to standard operating procedures (Neal and Griffin, 2006). Some studies also incorporate structured interviews and focus groups to gain qualitative insights into compliance behaviours and challenges.

Companies are attempting to improve production. Employees tend to disregard safety protocols in their attempts to achieve performance goals (Masia and Pienaar, 2011; Möller, 2003; Probst and Brubaker, 2001). Due to performance challenges and time limitations, many workers might engage in risky behaviours. They encompass shortcuts that undermine safety compliance and may result in accidents (Reason, 2016). Companies must strike a balance between productivity demands and rigorous safety measures to mitigate risks associated with non-compliance and prevent workplace accidents.

Factors affecting safety compliance, such as risk perception in construction industry (Xia *et al.*, 2016), safety culture in academic laboratories (Ayi and Hon, 2018), safety knowledge in the petroleum industry (Dahl, 2013), knowledge management in the petroleum industry (Gressgård, 2014), work stress, job insecurity, satisfaction and commitment in the mining industry (Masia and Pienaar, 2011), knowledge and safety climate in Mechanical Companies (Ricci *et al.*, 2022), situational awareness (Endsley, 1995), workload and time pressure (Nahrgang *et al.*, 2011). Understanding what drives or hinders safety compliance across various industries is crucial for developing targeted interventions that enhance adherence to safety protocols and mitigate workplace hazards.

2.2.3 Safety knowledge

Dong *et al.* (2018, p. 113) defined safety knowledge as "*a justified belief that increases an organisation's ability to effectively manage the documented hazards to attain an acceptable level of risk*". Safety knowledge encompasses a worker's comprehension of safety-related information, including safety facts, regulations, and operational procedures (Nykänen *et al.*, 2020). It also involves an understanding of how to execute job tasks safely (Burke *et al.*, 2006; Burke and Signal, 2010; Griffin and Neal, 2000). This knowledge arises from experience, habits, and learning (Okoye *et al.*, 2016) and enhances workers' abilities to detect hazards, prevent accidents, and mitigate risks (Hasanzadeh *et al.*, 2017; Huang and Yang, 2019). Teo *et al.* (2005) demonstrated that employees' safety-related knowledge strongly impacts site safety. The study confirms that safety information is essential for achieving safety success and that employees must retain this knowledge.

Knowledge is manifested through the cognition and behaviours of individuals (Argote and Miron-Spektor, 2011) and is classified into two categories: tacit and explicit knowledge (Zhang and He, 2016). Tacit safety knowledge can be obtained through hands-on learning, accumulation of experience, and exposure to injuries (Hallowell, 2012; Koskinen *et al.*, 2003; Podgórski, 2010). Previous experiences and exposures will be encoded as knowledge patterns in the brain, enabling a worker to draw upon memory-based intuition to respond appropriately when encountering similar situations (Zhang and He, 2016). Conversely, explicit knowledge can be imparted by safety training (Aboagye-Nimo *et al.*, 2012) or established theories in the literature, safety records, procedures and guidelines (Hadikusumo and Rowlinson, 2004). Irrespective of the category of safety knowledge, scholarly consensus indicates that such knowledge can be obtained by training, practical experience, and exposure (Aboagye-Nimo *et al.*, 2012; Argote and Miron-Spektor, 2011; Podgórski, 2010). Safety training provides employees with the competencies necessary to identify and manage hazards (Jeelani *et al.*, 2017). Consequently, it will probably influence worker focus and underpin employees' hazard identification and responsiveness. Enhancing workers' safety knowledge mitigates the probability of accidents (Li *et al.*, 2019).

Safety knowledge is crucial for effectively managing workplace safety (Hallowell, 2012). Numerous researchers have emphasised the significance of safety knowledge (Ding *et al.*, 2016; Hadikusumo and Rowlinson, 2004; Hallowell, 2012; Zhang *et al.*, 2015) for improving safety. Therefore, an organisational supportive safety culture encourages knowledge sharing and continuous learning. Organisations prioritising safety provide training resources and foster open communication about risks (Zohar, 2002).

Safety knowledge is an important element in the workplace. Zhao *et al.* (2021) revealed a positive impact of safety knowledge on risk perception severity. Additionally, safety knowledge improves safety compliance (Amponsah-Tawaih and Adu, 2016; Ansori and Widyanti, 2021; Gressgård, 2014; Okoye *et al.*, 2016).

The quantitative approach of Self-reported surveys and questionnaires is prevalent in measuring safety knowledge. It has been used to quantify participants' understanding of safety protocols and practice of safety knowledge in studies such as Zhao *et al.* (2021), Vinodkumar and Bhasi (2010), Rajabi *et al.* (2022), and Okoye *et al.* (2016), Real (2008). Nevertheless, few studies use qualitative approaches, such as Ibrahim and Awad (2019), who used a structured interview questionnaire and observations to assess nurses' knowledge of environmental health and safety measures at Cairo University Hospital.

2.2.4 Safety culture

Safety culture has been studied and defined across different industries, yet no universal definition exists. A range of legislation and documentation has been issued to assist organisations in developing a positive safety culture (Fu *et al.*, 2013). Different authors have introduced different definitions (see (Choudhry *et al.*, 2007; Guldenmund, 2000)). Cooper (2000) stated that safety culture is a product of multiple goal-directed interactions between internal psychological factors, overt behaviours, and situational workplace aspects. This product is defined as "*that observable degree of effort by which all organisational members direct their attentions and actions toward improving safety on a daily basis*" (Cooper, 2000, p. 115). In the construction industry, Zou (2011, p. 12) defined safety culture as "*an assembly of individual and group beliefs, norms, attitudes, and technical practices that are concerned with minimising risks and exposure of workers and the public to unsafe acts and conditions in the construction environment*". Kristensen (2016, p. 105) defined safety culture as "*The shared assumptions, values, attitudes, and behaviours of professionals that characterise the* *safety of patients in a health care setting*". The Centre for Chemical Process Safety (CCPS) (1989, cited in CCPS, 2016, p. 13) defined safety culture as *"the combination of group values and behaviours that determine the manner in which process safety is managed"*. All these definitions of safety culture share a common focus on shared attitudes, values, and behaviours that shape safety within an organisation. While each definition highlights different aspects, they all agree that safety culture is a collective effort, influenced by individuals, teams, and the organisation as a whole to drive safety performance.

Safety culture reflects both the compliance level of the health, safety, and environment (HSE) system and the commitment of senior management, which plays a pivotal role in its implementation (Kristensen, 2016; Mubashar *et al.*, 2013; Zou, 2011). Despite the advancements in measuring safety culture, challenges remain due to the complexity and variability of safety culture across different industries and contexts (Guldenmund, 2000). Selecting appropriate models and data-gathering methodologies is crucial for obtaining measurable and repeatable results. Additionally, there is a lack of consensus on the specific factors that constitute safety culture (Maddin and Shanks, 2016).

Safety culture evaluation may take several forms, including safety audits, observations, one-to-one interviews, or questionnaires administered to relevant workers (Von Thaden *et al.*, 2003). Safety culture has been measured using various methodologies across different fields. For example, Gao *et al.* (2019) and Naji *et al.* (2021) used quantitative questionnaires in the oil industry. Morrow *et al.* (2014) also used surveys to assess safety culture in nuclear power operations. Naevestad (2017) employed three methodologies: small-scale survey, focused group meeting, and qualitative interviews with experts in the maritime transport sector. Sari *et al.* (2018) employed questionnaires to evaluate the safety culture among fishermen in the maritime industry. Kao *et al.* (2008) and Çakıt *et al.* (2019) measured safety culture in the petrochemical industry using a questionnaire. Vinodkumar and Bhasi (2010) have also used a questionnaire to measure safety culture. These diverse methodological approaches enable a more comprehensive evaluation of safety culture, capturing both quantitative metrics and qualitative insights.

2.2.5 Situational awareness

Endsley (1988, p. 97) defined situational awareness (SA) as "*the perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*". Situational awareness is a highly researched subject in human factors (Salmon and Stanton, 2013; Stanton, 2010; Wickens, 2008) and remains one of its most contentious issues due to measurement challenges and interdisciplinary perspectives.

Endsley's 1995 three-level model (perception, comprehension, projection) remains the most widely used framework for individual SA (Endsley, 1995; Endsley, 2015). Each level builds upon the previous one, enabling individuals to understand their situation better and make informed decisions. In the first level, perception, individuals detect and recognise relevant environmental elements. This involves identifying critical cues, such as changes in system status or potential hazards, that are necessary for understanding the current situation. Endsley emphasises that perception is the foundation of situational awareness, as failing to perceive key information can lead to errors in subsequent stages (Endsley, 1995; Thurston, 2016). The second level, comprehension, involves integrating the perceived information to understand the situation coherently. At this stage, individuals interpret the meaning of the cues they have detected, considering their relevance and implications within the broader context (Endsley, 1995; Gutzwiller, 2011). The third and highest level, projection, involves predicting future states of the environment based on the current situation and trends. This forward-looking capability allows individuals to anticipate potential outcomes and plan accordingly (Endsley, 1995).

While Endsley (1995) constructed individual situation awareness, team situational awareness extends beyond the individual level to encompass how a group collectively processes information to achieve a common understanding of their situation. It also requires effective communication and coordination among team members to ensure everyone has access to critical information (Harrald and Jefferson, 2007).

Researchers have developed various techniques to measure SA effectively, two of the most prominent being the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1988), and the Situation Awareness Rating Technique (SART) developed by (Taylor, 1990).

SAGAT is an objective method for measuring situational awareness during real-time or simulated tasks (Endsley, 2017). It involves periodically freezing the simulation or task environment and querying participants about their awareness of specific environmental elements. SAGAT is evidently applicable solely to simulated scenarios, not in real-life situations. SART is a subjective method that relies on participants' self-assessment of their situational awareness after completing a task (Taylor, 1990). Participants rate their awareness across predefined dimensions, such as familiarity with the situation, focus of attention, and information quality. Cross-industry comparisons of SA measurement techniques can reveal best practices and optimise assessment methods for specific high-risk industries.

Situational awareness has been considered a vital indicator of safety in several safety-critical contexts (Stanton *et al.*, 2001). Several studies have utilised questionnaires or interviews to assess SA, particularly in complex and high-risk environments such as aviation, healthcare, maritime, oil and gas and other industrial settings. For instance, Sneddon *et al.* (2013) have developed and tested a questionnaire to measure situation awareness in offshore drilling installations. Sætrevik (2013) employed a questionnaire to measure the SA of offshore maritime personnel. Saetrevik and Hystad (2017) used a questionnaire to measure the SA of workers on offshore attendant vessels. Blandford and Wong (2004) employed observation and interview techniques to measure SA in an emergency medical dispatch setting. Augenstein (2020) investigated SA using a mixed-methods approach, combining questionnaires and observations, in an emergency department within healthcare. Sharma *et al.* (2019) conducted semi-structured interviews to measure SA in the maritime sector. The varied approaches to assessing situational awareness across different industries underscore its critical role in safety and highlight the importance of selecting appropriate measurement techniques to capture its complexity effectively.

2.3 Models of the relationship between constructs in research

In academic research, understanding the relationships between two constructs is essential for advancing knowledge throughout diverse domains. Constructs are not directly observable; they are theoretical entities representing phenomena of interest. Before investigating the link between two constructs, researchers must ascertain the validity and reliability of their measurements (Cronbach, 1951; Messick, 1995). Correlation analysis (e.g. Pearson's correlation or regression) measures the strength and direction of the linear relationship between two variables, and it is quantified using the bivariate coefficient (r) (Cohen *et al.*, 2003, 2013).

Direct relationships occur between two constructs. Although correlation and regression analyses can reveal connections between constructs, they cannot inherently ascertain the direction of causality. Theoretical models frequently influence the direction of effect. For instance, if the theory posits that "job satisfaction" (X) influences "employee performance" (Y), the researcher may formulate a unidirectional hypothesis from X to Y (Judge *et al.*, 2001). Hypotheses frequently suggest a sequential sequence that underpins the assertion that X causes Y (Robins and Greenland, 1992). For example, in educational research, "student engagement" (X) is frequently posited to precede "academic achievement" (Y) (Fredricks *et al.*, 2004).

Moderation is another type of relationship between constructs. Moderation analysis (Figure 2.1) is a statistical method employed to investigate whether the magnitude or direction of the association between an Independent Variable (IV) X and a Dependent Variable (DV) Y is contingent upon the presence or value of a third variable, termed a moderator (Z) (Hayes, 2013). Moderation analysis identifies if a third variable (Z) influences the relationship's existence, magnitude (strong/weak), or direction (positive/negative) between the independent variable (X) and the dependent variable (Y) (Baron and Kenny, 1986).

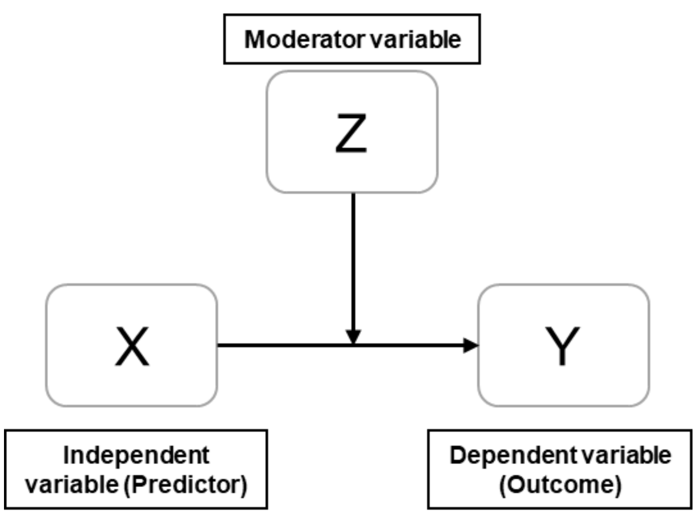

Figure 2.1: Basic Moderation Model (Turnes and Ernst, 2015).

Moderation is tested using statistical methods such as multiple regression (e.g. (Hofmann *et al.*, 2003; Smith-Crowe *et al.*, 2003)) and Structural Equation Modelling (SEM) (e.g.(Carballo *et al.*, 2022)). These methods examine how the relationship between an IV (X) and a DV (Y) varies depending on the level of a moderator (Z) (Klein and Moosbrugger, 2000).

A mediated relationship (also referred to as an indirect relationship) occurs when the effect of an IV (X) on a DV (Y) is transmitted through a third variable, known as a mediator (M). Relationships between constructs are quantified primarily through standardised regression coefficients (beta coefficients, β) in structural equation modelling or multiple regression. Mediation analysis is a fundamental approach used to examine the mechanisms through which an IV (X) influences a DV (Y) via an intervening (mediating) variable (M) (Hayes, 2013). Several techniques were developed to analyse mediation relationships. Baron and Kenny's (1986) causal steps approach primarily guided traditional mediation analysis (Baron and Kenny, 1986). However, their method has been widely critiqued for its requirement that a significant X→Y effect reduces statistical power, particularly in small samples or when indirect effects dominate (Hayes, 2013). Furthermore, it fails to directly quantify the indirect effect (ab), leaving researchers reliant on subjective interpretations of effect size reduction (MacKinnon, 2008). The Sobel test, introduced by Michael Sobel in 1982, was one of the earliest statistical methods designed to assess the significance of indirect effects in mediation analysis (Sobel, 1990). It addresses a critical limitation of Baron and Kenny's (1986) causal-steps approach by quantifying the magnitude of the mediated effect (ab) and testing its statistical significance (Sobel, 1990). Nevertheless, its reliance on the normality assumption of the product term (ab) introduces bias in small samples ($N < 500$) or when distributions are skewed, undermining its reliability in practice (MacKinnon *et al.*, 2002).

Modern resampling and nonparametric methods, such as bootstrapping (Preacher & Hayes, 2008), emerged to resolve the shortcomings of the previously mentioned approaches. Bootstrapping estimates confidence intervals for ab by resampling the data (e.g., 5,000 iterations); bypassing normality assumptions is particularly advantageous because real-world data often violate these assumptions, resulting in misleading results when using traditional parametric methods even in non-ideal conditions (Preacher and Hayes, 2008). The flexibility and accessibility of this method, as implemented in tools such as the PROCESS macro in

SPSS or Partial Least Squares Regression (PLS-R) software, have made it the standard for indirect effect testing (Hayes, 2018). It can also achieve higher power than the Sobel test without requiring large samples (Hayes, 2018).

Structural Equation Modelling (SEM) is one of the most advanced methods for estimating mediation effects in social sciences (Hayes, 2013). SEM enables the simultaneous estimation of direct and indirect effects in a model that incorporates mediators into a broader system of linked regression equations. SEM estimates mediation effects through the product of coefficients, which is particularly useful for complex mediation models (Gunzler *et al.*, 2013; Hayes, 2013), especially when dealing with multiple mediators or latent variables that are not directly observed (Hayes, 2013). SEM allows researchers to test theoretical models holistically, integrating observed and latent variables within a unified framework (Gunzler *et al.*, 2013; Hayes, 2013). This capability makes SEM suitable for analysing mechanisms underlying the relationship between independent and dependent variables. SEM's flexibility in handling observed and unobserved variables while modelling intricate relationships makes it indispensable in contexts where causality is inferred from multi-dimensional data (Robins and Greenland, 1992). By controlling for confounding variables, SEM provides a clearer picture of the causal mechanisms at play, offering more precision in estimating mediation effects (Gunzler *et al.*, 2013). However, the limitation of SEM is the requirement of a sample size of at least 100 for complex models, as noted by Lei and Lomax (2005). A rule of 10–20 cases per estimated parameter should be considered when using SEM (Kline and Little, 2015; Westland, 2010).

Mediation models can include single or multiple mediators. Single mediation models (Figure 2.2), commonly used in health and behavioural sciences, where one mediating variable is assessed, provide a straightforward means of understanding indirect effects (Mackinnon and Dwyer, 1993). It provides insights into causal pathways using regression or structural equation modelling (Baron and Kenny, 1986; Hayes, 2013). However, many real-world phenomena involve multiple mediators operating simultaneously, necessitating a more complex approach.

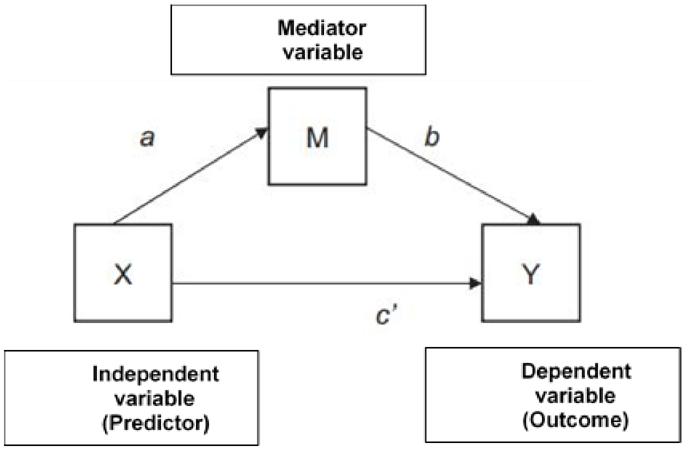

Figure 2.2: The single mediator model (Mackinnon and Dwyer, 1993).

Where: *a* represents the effect of X on M. *b* represents the effect of M on Y. c' represents the effect of X on Y.

Multiple mediation models (Figure 2.3) enable researchers to determine the relative contributions of different mediators, offering a more nuanced understanding of causal mechanisms. This approach captures multifaceted phenomena, offering a nuanced understanding of causal relationships that single mediators cannot fully explain (Hayes, 2013).

In mediation analysis, distinguishing between full and partial mediation is crucial for interpreting results. Full mediation occurs when the mediator fully accounts for the relationship between X and Y. In this scenario, the direct effect of X on Y becomes insignificant after controlling for the mediator, indicating that the entire influence of X on Y is transmitted through the mediator (Jung, 2021). In contrast, partial mediation occurs when the mediator explains only part of the relationship between X and Y. Even after accounting for the mediator, a significant direct effect of X on Y remains, suggesting that X influences Y both directly and indirectly.

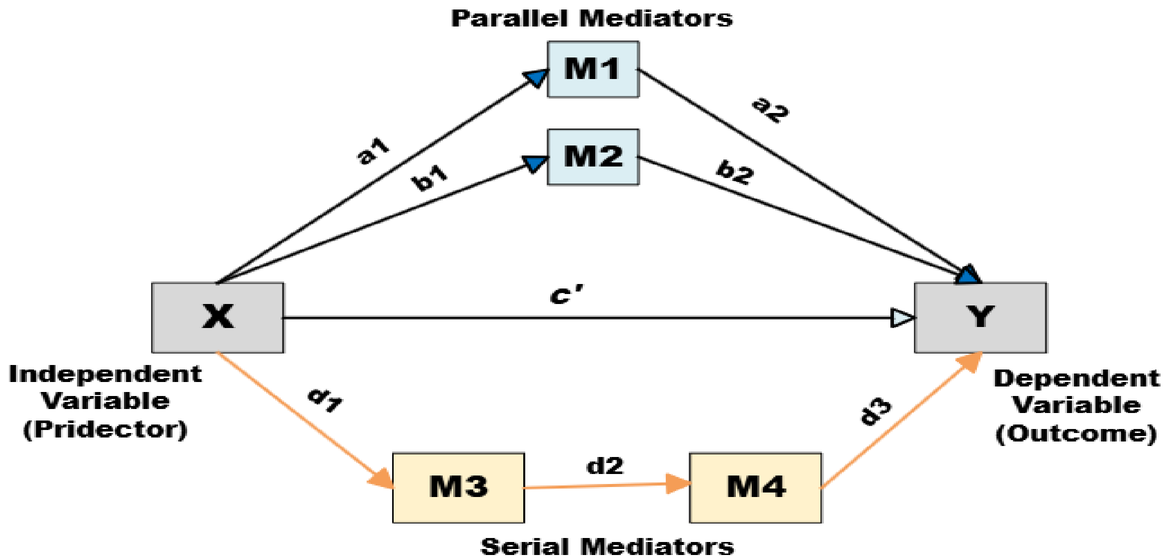

Figure 2.3: The Multiple mediation model (Parallel and serial) adopted in one figure from (Turnes and Ernst, 2015).

Where: M1, M2, represent parallel mediators, M3, M4, represent serial mediators. a1, b1 direct paths from predictor X to M1, M2. a2, b2 represent direct paths from M1, M2 to outcome Y. The path c' represents the direct effect of X on Y. The path d1 represents the path from X to the first serial mediator M3, d2 represents the path from M3 to the second serial mediator M4, and d3 represents the path from M4 to the outcome variable Y.

Variance Accounted For (VAF) is another method of distinguishing between full and partial mediations. Henseler (2020) defined VAF as '*the ratio of the indirect-to-total effect'*. VAF assesses the degree to which the mediation process accounts for the variance in the dependent variable. The suggested thresholds for VAF are as follows: VAF > 80% indicates full mediation, VAF < 20% indicates no mediation, and 20% ≤ VAF ≤ 80% indicates partial mediation (Hair *et al.*, 2014). VAF is calculated using formula 2-1:

$$\boldsymbol{VAF = \frac{Indirect\ effect}{Total\ effect} = \frac{a \times b}{a \times b + c'}} \ \% \qquad \text{2-1}$$

Where's: (*a)* is the standardised regression coefficient for the path from the IV to the mediator (M). It represents the effect of the independent variable on the proposed mechanism. While (*b)* is the standardised regression coefficient for the path from the mediator (M) to the DV, while controlling for the IV. It represents the effect of the mechanism on the outcome, holding the original cause constant. Whereas (c') is the standardised regression coefficient for the direct path from the IV to the DV, while controlling for the mediator (M). This is the effect of the independent variable on the outcome that is not explained by the mediator.

The indirect effect ($a \times b$) quantifies the portion of the IV's effect on the DV that is transmitted through the mediator M. On the other hand, the total effect of the IV on the DV ($a \times b$ + c') is the sum of the indirect effect and the direct effect.

For VAF and mediation analysis to be valid, the following assumptions should be considered:

1. Temporal ordering: IV precedes M, and M precedes DV (causal logic).
2. Linearity: relationships among variables are linear.
3. Measurement reliability: Indicators reliably reflect constructs (valid measurement model).
4. Correct specification: The model correctly defines paths; no missing key paths.

The VAF equation matters in mediation models. The goal of mediation analysis is to understand how and to what extent a mediator explains the relationship between an IV and a DV. VAF provides a quantitative index to classify mediation strength. In essence, VAF answers: "of the total influence the independent variable has on the dependent variable, what percentage is explained through the proposed mediator?”

Mediation analysis helps explain how one variable influences another through an intermediary variable, shedding light on the underlying mechanisms of relationships in social science research. Mediation was chosen for this study because mediators tell us how IV (risk perception) influences DV (safety compliance) (MacKinnon, 2008). Furthermore, a mediating factor can translate or transmit risk perception into safety compliance actions. In addition, it explains the mechanisms of how IV drives the outcomes DV, which is essential for understanding and optimising interventions. SEM is a powerful tool for mediation analyses, allowing researchers to test multiple relationships simultaneously and provide a clearer picture of causal mechanisms (Gunzler *et al.*, 2013). This study will use SEM to analyse mediation effects, ensuring a more rigorous and comprehensive evaluation of the proposed models.

2.4 Relationship between risk perception and safety compliance

Risk perception (RP) refers to individuals' subjective evaluation or understanding of risks. It is the subjective assessment of a particular event's probability and the degree of concern regarding its consequences (Gürcanlı *et al.*, 2015; Renn and Rohrmann, 2000; Sjöberg *et al.*, 2004). Safety compliance (SC) refers to the essential activities and measures individuals must undertake to maintain workplace safety, including adherence to safety regulations and practices such as wearing personal protective equipment (Christian *et al.*, 2009; Griffin and Neal, 2000; Kao *et al.*, 2019). Huang *et al.* (2019) argue that risk perception is a significant determinant of human behaviour. Therefore, enhancing individuals' risk perception is expected to result in less risk-taking and increased protective and safety-promoting behaviours (Sheeran *et al.*, 2014).

2.4.1 Direct relationship between risk perception and safety compliance

Xia *et al.* (2020) suggest that accidents may be associated with individuals' risk perception. Earlier studies have found a positive relationship between risk perception and safety compliance, quantified using the beta coefficient (β) or bivariate coefficient (r), as defined in Section 2.3. Ji *et al.* (2011) noted that risk perception directly influences the safety behaviours of airline pilots ($\beta = 0.26$, $p < 0.001$), as those with heightened risk perception engage in safer practices compared to their peers with diminished risk perception. Xia *et al.* (2016) surveyed construction workers and found that RP has a positive influence on safety compliance ($\beta = 0.432$, $p < 0.05$). Xia *et al.* (2017) found that RP significantly affects safety compliance among Chinese construction workers, with a regression coefficient of $\beta = 0.25$, $p < 0.01$. Similarly, Flin *et al.* (1996) explored RP among offshore oil workers after the Piper Alpha disaster, finding that RP formed through prior accident experiences and safety management practices is strongly related to compliance. This finding of a positive relationship aligns with Thepaksorn *et al.* (2018), who highlighted that RP of sawmill workers was significantly associated with the use of hearing protection devices (HPDs) ($\beta = 0.36$, $p = 0.008$), emphasising the role of training and awareness in reinforcing compliance. Arezes and Miguel (2008) also support this positive link by demonstrating that RP significantly influences safety compliance (use of HPDs) with $r = 0.609$, $p < 0.01$. Additionally, workers with higher RP used

HPDs by 52.22% more than those with lower risk perception. Arezes and Miguel (2005) investigated how risk perception influences the use of hearing protection devices (HPDs) among workers in various industrial settings, including those in the chemical, apparel, textile, and food industries, who are exposed to noise levels exceeding 85 dB. They found a positive influence of RP on safety compliance ($\beta = 0.419$, $p < 0.001$).

In contrast, other researchers argue that RP alone cannot directly influence compliance, highlighting mediating factors and conditional relationships. Xia *et al.* (2020) collected data from 311 workers in the construction industry and found that risk perception was negatively correlated to safety compliance ($\beta = -0.167$, $p < 0.05$). However, safety motivation mediated this correlation and reduced the negative effect ($\beta = -0.115$, $p < .05$). These results were attributed to workers' perception of risks as a job hindrance. Martin *et al.* (2016) argue that individuals in multi-hazard environments become desensitised to flood risks, leading to low compliance despite high RP. They found that 31.9% of respondents felt unprepared for future floods, despite having a high perception of risk, highlighting a disconnect between risk awareness and action. Their findings challenge the assumption that heightened RP results in safety behaviours, emphasising the role of environmental complexity in diminishing RP's impact. Similarly, Sullivan-Wiley and Gianotti (2017) demonstrate that high RP does not always translate into protective actions in multi-hazard contexts, due to mediators such as trust in institutions and self-efficacy. Omidi *et al.* (2023) employed a cross-sectional questionnaire in a steel-manufacturing company; they reinforced this by revealing that risk perception negatively impacts surface compliance[1] ($\beta = -0.12$, $p<0.001$) and deep compliance[2] ($\beta = -0.20$, $p<0.001$). These studies suggest that even well-adapted RP may fail to produce safety compliance.

[1] Surface compliance refers to the superficial adherence to safety rules and procedures, characterized by the outward demonstration of required behaviours without genuine engagement or understanding of their underlying purpose. Analogous to "surface acting", it involves minimal cognitive effort and lacks internalization of safety principles.

[2] Deep compliance refers to an individual's genuine and internalized commitment to adhering to rules, regulations, or safety protocols. It involves a thorough understanding of the underlying principles and purposes of these guidelines, leading to their seamless integration into daily practices. This form of compliance is driven by intrinsic motivation, where actions are aligned with personal and organisational values, emphasising the importance of safety or ethical standards without reliance on external pressures.

Hambach *et al.* (2011), in a qualitative study (focus groups) of 5 chemical companies, demonstrated that workers recognise high chemical risks and often remain resigned due to poor communication, a lack of participatory engagement, distrust in management and prevention advisers, which erodes compliance. For example, they found that non-compliance with personal protective equipment (PPE) is common due to discomfort (e.g., heat, poor fit) despite the awareness of dangers. Their qualitative approach provided deep insights, but it limited the scalability of the findings to broader industrial contexts.

2.4.2 Factors mediating the relationship between risk perception and safety compliance

The literature on factors that mediate the relationship between risk perception and safety compliance across different industries is relatively limited, particularly in the context of high-risk environments characteristic of chemical processing. An early contribution by Renn (1985) revealed that risk perception could act as either a hindrance or a challenge in determining appropriate safety behaviours, depending on the context. In situations where risk was perceived as an engaging challenge, it had a positive influence on safety compliance, leading to increased engagement in safety behaviours. In contrast, in cases where risk was seen as a hindrance, it negatively impacted safety behaviour. Safety behaviour has been identified as a type of compliance behaviour associated with safety by employees (Hassan *et al.*, 2019). Additionally, Rundmo (1996) established a foundational understanding of the relationship between risk perception and safety compliance, demonstrating that risk perception correlates with safety compliance but does not consistently predict compliance. The study emphasises the limitations of RP as a standalone factor to guarantee compliance, highlighting the need for broader contextual and organisational considerations. Rundmo did not specify the contextual factors influencing compliance, leaving a critical void in the literature.

To address this gap, recent studies have identified specific mediating factors that transform RP into actionable safety compliance. For instance, Al-Bsheish (2024) identified training as a critical mediator. This study demonstrated that the RP-SC direct relationship is non-significant ($\beta=0.076$, $p=0.418$), whereas structured safety training fully mediates the RP-SC relationship ($\beta=0.186$, $p=0.002$) among non-medical hospital staff, ensuring that RP translates into compliant behaviours. Similarly, Khandan *et al.* (2017) found that safety attitude and training mediate risk perception and safety compliance in the chemical industry, emphasising the importance of training in enhancing protocol adherence. This highlights the need to integrate cognitive and emotional components into training programs, particularly in industries with catastrophic risks.

Leadership also plays an important role in shaping the RP-SC relationship. Taylor and Snyder (2017) demonstrated that RP improves compliance ($\beta = 0.38$, $p = 0.001$), especially when framed in terms of immediate consequences and reinforced by supervisor commitment. Effective leadership ensures that employees perceive risks and act upon them responsibly. This finding aligns with broader organisational theories (e.g. Transformational Leadership Theory (Bass, 2006) and High-Reliability Organisations Theory (Sutcliffe, 2011)), suggesting that leadership fosters a culture of accountability and trust, which enhances compliance behaviours.

While mediating factors enhance the RP-SC relationship, certain variables may suppress it. For example, Wang and Xu (2022) also found that risk perception has a positive effect on safety compliance ($\beta = 0.148$, $p = 0.033$) among Chinese frontline construction workers. However, job satisfaction was identified as a suppressor of this positive relationship rather than a mediator ($\beta = -0.124$, $p = 0.030$). This suggests that when employees are dissatisfied with their jobs, their motivation to comply with safety protocols decreases, even if they accurately perceive the risks. Hence, job satisfaction highlights the importance of the distinction between relationship mediators and suppressors.

Together, these studies highlight the role of organisational factors in transforming high RP into actionable safety compliance. The mediating factors between risk perception and safety compliance underscore the insufficiency of RP to guarantee SC always, supporting the need for organisational and contextual interventions to bridge this gap.

While foundational studies by Renn (1985) and Rundmo (1996) established RP's dual role as a motivator or barrier, they highlighted the critical need for mediating mechanisms, particularly in high-risk industries such as chemical processing, to achieve meaningful compliance outcomes. Based on the findings in the literature, the influence of risk perception on safety compliance was positive (Ji *et al.*, 2011; Xia *et al.*, 2017; Xia *et al.*, 2016), negative (Martin *et al.*, 2016; Omidi *et al.*, 2023; Xia *et al.*, 2020) or mediated by other factors (Al-

Bsheish, 2024; Khandan *et al.*, 2017; Taylor and Snyder, 2017) or suppressed by factors like those in Wang and Xu (2022) research. These variations highlight the complexity of the RP-SC relationship and the need for nuanced approaches tailored to specific contexts.

Despite the current research on the mediating factors between risk perception and safety compliance, there seems to be a lack of published evidence regarding the roles of safety knowledge, safety culture, and situational awareness in mediating this relationship, particularly within the chemical and process industries. To the best of the author's knowledge, no studies have examined whether each of these constructs, safety knowledge, safety culture, and situational awareness, influences the link between risk perception and safety compliance in these high-risk industries.

Risk perception is influenced by several personal, societal, and institutional factors (Harclerode *et al.*, 2016). However, employers are more inclined to pursue strategies for intervention from individual and organisational elements to modify employees' risk perception. These concepts of safety knowledge, safety culture, and situational awareness do not operate in isolation or purely at the individual level. They are embedded in an organisation's broader systems and structures, and their effectiveness relies on the collective behaviours and interactions of the entire workforce. They are also part of broader safety management systems and frameworks.

Consequently, the subsequent sections 2.4 -2.6 will review the relevant literature and explore the connections among risk perception, safety knowledge, safety culture, situational awareness, and safety compliance.

2.5 The influence of safety knowledge on risk perception and safety compliance

Safety knowledge (SK) encompasses a worker's comprehension of safety-related information, including safety facts, regulations, and operational procedures (Nykänen *et al.*, 2020). It also involves an understanding of how to execute job tasks safely (Burke *et al.*, 2006; Burke and Signal, 2010; Griffin and Neal, 2000). This knowledge is derived from learning, experience, and habits (Okoye *et al.*, 2016) and enhances workers' abilities to detect hazards, prevent accidents, and mitigate risks (Hasanzadeh *et al.*, 2017; Huang and Yang, 2019). The relationship between safety knowledge and both risk perception and safety compliance is well-documented. Early research, such as Zohar (1980), established the foundational role of safety knowledge in promoting safe work practices and influencing safety training programs to reduce workplace accidents. Empirical studies, like Griffin and Neal (2000), found that safety knowledge determines safety compliance, underscoring its influence on safe behaviour. Safety knowledge is a crucial factor influencing risk perception and should be examined in research (Gómez-Bull *et al.*, 2023).

2.5.1 Relationship between safety knowledge and risk perception

Risk perception is crucial for incident prevention, as it directly influences how individuals identify hazards and engage in preventive behaviours (Samadipour *et al.*, 2022). Safety knowledge plays a significant role in shaping risk perception, particularly in high-risk industries such as the chemical processing sector, where it enables personnel to recognise hazards, reduce accidents, and mitigate risks arising from complex and potentially hazardous operations (Sidiq and Rohman, 2023). The relationship between safety knowledge and risk perception has been thoroughly examined across various industrial and academic contexts, revealing a consistent yet nuanced positive correlation. The strength of this relationship varies depending on the context, research methodology, and data analysis.

For example, Jahangiri *et al.* (2008) conducted a cross-sectional analysis of 236 Iranian petrochemical employees exposed to noise levels of 85 dB. They reported a significant positive correlation between workers' risk perception and their safety knowledge regarding hearing protection ($r= 0.609$, $p < 0.01$). Similarly, Thepaksorn *et al.* (2018) demonstrated that higher levels of safety knowledge and risk perception among sawmill workers in Thailand were associated with increased compliance with hearing protection devices (HPDs). However, the exact correlation coefficient was not reported. The moderate-to-strong correlation ($r= 0.609$) in Jahangiri et al.'s study indicates that safety knowledge accounts for a substantial portion of the variance in risk perception within noise-exposed environments, likely due to the immediacy and recognisability of auditory hazards. However, while both studies underscore the critical role of safety knowledge in enhancing risk perception and safety practices, the absence of advanced statistical techniques such as SEM in either study limits the ability to quantify the precise proportion of variance accounted for by safety knowledge.

Parallel findings emerge in other high-risk industries. Zhao *et al.* (2021) examined the influence of safety knowledge on risk perception among 287 workers in six Chinese chemical companies, employing Structural Equation Modelling (SEM) to analyse questionnaire data. Their findings revealed that safety knowledge significantly shaped perceived risk severity ($\beta = 0.27$, $p > 0.05$) but not perceived risk probability. In contrast, Putranti *et al.* (2023) utilised SEM to analyse survey data from 315 workers in an Indonesian plywood manufacturing firm, demonstrating that safety knowledge positively influenced both dimensions of risk perception, with standardised coefficients of 0.32 for perceived risk probability and 0.29 for perceived risk severity ($p < 0.05$). The divergence in findings, particularly regarding perceived risk probability, underscores the influence of contextual factors, such as the nature of hazards in chemical versus manufacturing environments, as well as the specificity of measurement. For instance, chemical risks may be less observable than mechanical hazards, resulting in weaker associations between safety knowledge and perceived risk probability.

A unique paradox emerges in healthcare education. Arenas *et al.* (2025) investigated biosafety knowledge and biological risk perception among 274 health science and nursing undergraduates, revealing a positive yet modest correlation ($r= 0.168$). While 48.9% of students demonstrated high biosafety knowledge, only 31.4% exhibited a medium to high biological risk perception, highlighting challenges in translating theoretical knowledge into practical risk awareness. This gap is particularly pronounced in fields such as nursing and medicine, where abstract biological risks lack the immediacy of industrial hazards. The weak correlation ($r = 0.168$) highlights the limited explanatory power of safety knowledge in shaping risk perception for intangible or delayed risks in healthcare, contrasting sharply with the stronger relationships observed in industrial settings. This variability emphasises the importance of contextual factors, such as hazard tangibility, in determining the strength of the relationship and influence. The limitation of the results to specific disciplines may restrict broader applicability to other high-risk industries with more immediate risks.

Conversely, Wrench (2007) emphasises that a lack of safety knowledge can lead to an inflated sense of control and an underestimation of risks, as inexperienced workers might fail to identify hazards, assess risks, or implement appropriate responses, thus perpetuating unsafe practices. The variability in findings, from strong correlations in industrial settings (e.g., r= 0.609 in Jahangiri et al. 2008) to weak correlations in healthcare (e.g., r= 0.168 in Arenas et al. 2025), suggests that the strength of the relationship depends not only on the level of safety knowledge but also on the nature of the risks. Research on tangible, immediate risk environments, such as chemical processing industries, tends to yield stronger relationships, whereas non-tangible or delayed risk environments result in weaker associations.

In conclusion, the relationship between safety knowledge and risk perception not only shapes how workers identify and respond to hazards but also significantly influences their adherence to safety protocols, directly impacting safety compliance, particularly in the chemical and process industries.

2.5.2 Relationship between safety knowledge and safety compliance

Safety knowledge is crucial for maintaining compliance in chemical processes, as it furnishes personnel with the essential information to recognise risks, adhere to established protocols, and effectively mitigate hazards (Chen, 2016). Safety knowledge is widely recognised as a key determinant of positive compliance, which is defined as adherence to safety protocols and regulations. Management implements initiatives to enhance employees' safety knowledge through training and educational programs, aiming to elevate compliance with safety procedures (Vredenburgh, 2002). However, even if staff are motivated and capable of adhering to safety rules and procedures, consistent and effective safety compliance will still be difficult to achieve without adequate knowledge of how to do so (Elling, 1987; Laurence, 2005). Griffin and Neal (2000) posited that safety knowledge equips workers with the capability to comprehend the risks associated with non-compliance, thereby enhancing adherence to safety rules. This relationship has been extensively examined across industries, revealing consistent findings as well as contextual variations.

The current safety literature suggests a direct correlation between safety knowledge and safety behaviours (Beus *et al.*, 2015; Beus *et al.*, 2016; Neal and Griffin, 2004). Consequently, safety information has become a crucial antecedent of individual safety behaviours (Jiang and Probst, 2016). The association between safety knowledge and compliance has been notably robust in healthcare settings. For instance, Chung (2018) employed a questionnaire to gather data from 223 employees at a university hospital. Through stepwise regression analysis, Chung reported a strong correlation between safety knowledge and compliance ($\beta = 0.431$, $p < .001$), accounting for approximately 39.9% of the variance. This suggests that nurses and hospital personnel with greater knowledge of safety exhibit significantly enhanced adherence to infection control and safety measures and protocols. These findings underscore the pivotal role of safety knowledge in regulated environments where adherence to protocols directly influences patient and worker safety.

In contrast, studies in dynamic and less regulated industries, such as manufacturing and construction, report weaker direct effects of safety knowledge on compliance. Kwon and Kim (2013) employed questionnaires and collected data from 131 workers in the manufacturing industry, along with Smart PLS, to assess the impact of safety knowledge and safety motivation on the safety of the work environment through their influence on safety compliance and safety participation. The results of the proposed model revealed that safety knowledge has a direct influence on safety compliance ($\beta = 0.266$, $p = 0.01$). More strikingly, Okoye *et al.* (2016), in the construction industry, analysed 148 questionnaires using Pearson's correlation coefficient (r) and found that safety knowledge correlation with safety compliance was very weakly positive ($r= 0.19$, $p > 0.05$). This suggests that higher levels of safety knowledge do not necessarily translate into better adherence to safety rules. However, reliance on Pearson's correlation limits the causal interpretation of the influence and may reduce its generalisability. Such discrepancies in the effect of safety knowledge on safety compliance underscore the need to consider the contextual factors specific to each industry to enhance its impact. The variability in the results of relationships highlights the critical role of industry-specific contexts such as the type of hazards, regulatory environment, and work dynamics, which are critical in determining how effectively safety knowledge translates into compliance.

Unique insights emerge from other contexts, such as recreational activities. Park and Cho (2015) collected data via self-reported questionnaires from 317 scuba divers from various diving shops. Pearson correlations revealed a strong positive correlation between safety knowledge and safety compliance ($r = 0.763$, $p < .001$), aligning with Griffin and Neal's (2000) assertion that knowledge underpins compliance. However, while the strong correlation in recreational settings highlights the potential universality of the knowledge-compliance relationship, it is still unclear whether knowledge drives compliance or vice versa.

Researchers have gone beyond direct effects and a singular relationship to explore how safety knowledge influences safety compliance as a mediator in mediation models. Basahel (2021) investigated the mediating role of safety knowledge in electrical substation construction projects in Saudi Arabia, employing SEM to analyse survey data from 636 participants. The results revealed a strong positive effect of safety knowledge on safety compliance ($\beta = 0.55$, $p < 0.001$). Furthermore, safety knowledge mediated the relationship between safety leadership and safety compliance ($\beta = 0.2585$, $p < 0.001$). Similarly, Subramaniam *et al.* (2023) examined the relationships among safety leadership, safety knowledge, and safety behaviour (compliance and participation) among hospital nurses in Malaysia. This study also utilised SEM to analyse survey data from 346 nurses. The results indicated a significant effect of safety knowledge on safety compliance ($\beta = 0.616$, $p < 0.01$), with safety knowledge mediating the relationship between safety leadership and safety compliance ($\beta = 0.342$, $p < 0.01$). Both Basahel (2021) and Subramaniam *et al.* (2023) employed advanced data analysis techniques; however, the assumption of full mediation in these studies warrants scrutiny. These studies did not report direct paths between the independent and dependent variables, thereby undermining their claims of full mediation. While they offer valuable insights into the mechanisms linking safety leadership to safety behaviour, they overlook the potential role of risk perception in influencing safety compliance through safety knowledge. By neglecting risk perception, these studies miss an opportunity to explore how workers' perceptions of risk might shape their understanding and application of safety knowledge.

Furthermore, Kao *et al.* (2019) examined the relationships among safety knowledge, safety attitudes, and safety behaviours within a construction company. Using a questionnaire, they gathered data from 177 workers and 42 supervisors at two time points, separated by one year. The data were then analysed using multilevel path analysis in Mplus software. The findings indicated that safety knowledge influences safety behaviours (compliance) directly ($\beta = 0.20$, $p < 0.01$). Additionally, safety attitudes partially mediated the relationship between safety knowledge and safety behaviours, demonstrating a significantly indirect effect ($\beta = 0.06$, 95% CI [0.02, 0.11]), although this effect is quite small. Notably, despite the robust statistical technique employed, the calculated variance accounted for (VAF = 5%) fell below the recommended thresholds (20% - 80%, see section 2.3) (Hair *et al.*, 2014; Henseler, 2020), which casts doubt on the strength of this mediation effect. This result suggests that safety knowledge directly drives compliance, rather than through the mediation of safety attitude.

In conclusion, safety knowledge is important in shaping safety compliance by enabling workers to recognise risks, understand protocols, and adhere to safety procedures. While its influence is robust in regulated environments, such as healthcare, the strength of this relationship varies significantly across industries, highlighting the importance of contextual factors, including hazard type, regulatory oversight, and work dynamics. The limitations of existing studies, such as the simplistic statistical methods, underscore the need for advanced methodologies to clarify causal relationships. Ultimately, enhancing safety knowledge remains a critical strategy for improving compliance and mitigating risks in the chemical and process industries.

The reviewed literature in sections 2.4.1 and 2.4.2 establishes that safety knowledge has a noteworthy positive correlation and influence on risk perception (Jahangiri *et al.*, 2008; Thepaksorn *et al.*, 2018; Zhao *et al.*, 2021) as well as safety compliance (Chung, 2018; Kwon *et al.*, 2016; Okoye *et al.*, 2016). However, many of these studies have limitations, such as basic statistical analysis methods and a lack of advanced statistical analysis (Jahangiri *et al.*, 2008; Okoye *et al.*, 2016; Park and Cho, 2015; Thepaksorn *et al.*, 2018). Although Basahel (2021) and Subramaniam et al. (2023) studied the mediating role of safety knowledge between safety leadership and safety compliance, they overlooked the opportunity to explore how workers' perceptions of risks might shape their understanding and application of safety knowledge. Despite substantial evidence linking safety knowledge to risk perception (Jahangiri *et al.*, 2008; Putranti *et al.*, 2023) and safety compliance (Basahel, 2021; Griffin and Neal, 2000), Mearns and Flin (1995) call for further investigations of safety knowledge in relation to risk perception and safety, a significant knowledge gap remains in understanding whether safety knowledge mediates the relationship between risk perception and safety compliance, particularly within chemical and process industries. Specifically, to the best of the author’s knowledge, no study has investigated whether safety knowledge mediates the relationship between risk perception and compliance. Thus, enhancing the understanding of the mediating role of safety knowledge in explaining the relationship between risk perception and safety compliance is likely to be advantageous for developing research and practice.

Existing studies predominantly treat safety knowledge as a cause of or consequence variable (e.g.,(Jahangiri *et al.*, 2008; Zhao *et al.*, 2021)) rather than interrogating its role as a cognitive mechanism that translates perceived risks into compliant behaviours in CPI contexts, where complex hazards (e.g., toxic gas exposure, reactor failures) demand precise risk perception and procedural adherence. This oversight limits theoretical clarity about how workers' risk perception translates into compliance action in CPI settings and hampers practical efforts to optimise safety interventions tailored to these industries. Safety knowledge is uniquely positioned to mediate (risk perception → safety compliance) relationship in CPI: it enables workers to interpret risks accurately (e.g., recognising severity vs. misjudging probability; (Zhao *et al.*, 2021)) and operationalise compliance (e.g., translating rules into action; (Griffin and Neal, 2000)). However, inconsistencies across industries, such as knowledge-compliance correlations in healthcare ($\beta = 0.431$) versus weak correlations in construction ($r = 0.19$; (Okoye *et al.*, 2016)), suggest contextual variability that mediation analysis could disentangle, which remains unexplored. Methodologically, mediation analysis might provide an opportunity to address these inconsistencies by (1) clarifying causality through advanced methods (e.g., SEM) that transcend the limitations of cross-sectional basic correlations (Park and Cho, 2015; Thepaksorn *et al.*, 2018); (2) resolving paradoxes like the disconnect between theoretical knowledge and practical risk perception (Arenas *et al.*, 2025); and (3) quantifying the proportion of compliance variance attributable to knowledge-driven mechanisms (VAF). It might provide a new insight into the relationship between the two constructs.

2.6 The influence of safety culture on risk perception and safety compliance

Safety culture has been extensively studied across various industries, yet its definition and precise role remain subjects of ongoing discussion. Cooper (2000) stated that safety culture is ''…. a *product of multiple goal-directed interactions between internal psychological factors, overt behaviours, and situational workplace aspects.…*''. This product is defined as ''…. *that observable degree of effort by which all organisational members direct their attentions and actions toward improving safety on a daily basis….''*. The prevalent definition of safety culture originates from the nuclear power sector. "*The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an* *organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures*" (ACSNI, 1993). Despite the extensive research addressing both theoretical and empirical aspects of safety culture, a consistent definition and evaluation of the construct remains elusive. For more definitions of safety culture see Wei and Kuo (2023).

Safety culture is widely recognised as a multidimensional concept in organisational and occupational safety research (Fernández-Muñiz *et al.*, 2007; Guldenmund, 2000). Its complexity arises from the interplay of attitudes, behaviours, systems, and practices collectively shaping how safety is prioritised and managed (Patankar and Sabin, 2010; Wiegmann *et al.*, 2004). Safety culture encompasses various dimensions that collectively foster a safe working environment, as shown in safety literature and organisational culture literature. These dimensions include but are not limited to: leadership (Flin and Yule, 2004; Halligan and Zecevic, 2011), safety attitudes (Lee and Harrison, 2000), management commitment to safety (Feng *et al.*, 2011; Gilkey *et al.*, 2003; Halligan and Zecevic, 2011), communication (Guldenmund, 2010; Halligan and Zecevic, 2011), employees' involvement in safety (Biggs *et al.*, 2013; Wu *et al.*, 2016), safety management system (Frazier *et al.*, 2013; Wu *et al.*, 2016).

The concept of safety culture is frequently interchanged with safety climate; nevertheless, in academic literature, they are generally considered distinct concepts (Cox and Flin, 1998). Safety culture is defined as including safety-related attitudes, actions, and perceptions, as well as the deeply ingrained beliefs and assumptions that individuals possess towards the company (Petitta *et al.*, 2017). Conversely, a safety climate is considered the manifestation of a safety culture in the behaviours and attitudes exhibited by employees (Cox and Flin, 1998). Therefore, the difference between the two concepts should be considered.

Safety culture is particularly critical in high-risk industries such as the chemical and process sectors (Naicker, 2022). In these industries, where even minor deviations from safety protocols can lead to catastrophic consequences, safety culture acts as the foundation for shaping employee attitudes and behaviours, developing a proactive mindset in which employees recognise risks and prioritise mitigating them by following safety rules and procedures (Zou, 2011).

2.6.1 Relationship between safety culture and risk perception

The interplay between safety culture and risk perception constitutes a critical nexus in occupational safety research, as both constructs shape employee behaviours, decision-making, and hazard mitigation outcomes. Safety culture, defined as the shared values, attitudes, and practices that prioritise safety within an organisation, plays a pivotal role in fostering heightened risk perception (Fu *et al.*, 2013). The ACSNI’s 1993 Human Factors Report underscores the importance of assessing employee risk perceptions to establish an effective safety culture, highlighting the foundational link between these two constructs (ACSNI, 1993). Safety culture and risk perception are important to prevent significant process incidents (Nordlöf *et al.*, 2015; Olewski *et al.*, 2016). A robust body of literature demonstrates that organisations with a strong safety culture exhibit enhanced risk perception among employees. For instance, Fleming and Buchan (2002) found that employees in organisations with a robust focus on safe work practices and a commitment to health and safety displayed better risk perception and a lower propensity for risk-taking compared to those in organisations lacking such a culture. Similarly, O'Toole (2002) highlights that when management decisively exhibits a commitment to safety, worker perceptions of the safety management system improve, leading to reduced risk-taking behaviour and decreased injury rates. While safety culture drives risk perception, the reverse relationship is also significant. Risk perception can influence the development and sustainability of a safety culture (Kao *et al.*, 2008). When employees consistently recognise and communicate risks, they contribute to a shared understanding of safety priorities, reinforcing cultural norms (McEvoy *et al.*, 2017). Furthermore, Chassang *et al.* (2024) argue that a strong safety culture fosters an environment where individuals are more attuned to risks and hazards, adopting preventive behaviours that further strengthen the organisation’s safety ethos. This reciprocity underscores the dynamic interplay between safety culture and risk perception, wherein each construct continually reshapes the other within the organisation's systems.

Marshall (2020) integrated safety culture and risk perception within the disaster risk reduction (DRR) framework, emphasising their complementary roles. The author demonstrated that a strong safety culture fosters a more accurate risk perception, thereby reducing disaster-related fatalities. Despite this review effectively integrating the concepts of risk perception and safety culture, providing a nuanced understanding of their interplay within disaster risk reduction, it lacks empirical validation and testing of the proposed framework. In line with this finding, Colim *et al.* (2021) observed a positive relationship between safety culture and risk perception. Colim and his colleagues examined safety culture and risk perception in a furniture manufacturing company in Portugal. The study revealed a positive relationship between workers' risk perception and organisational safety culture ($r = 0.227$, $p < 0.01$). However, despite combining interviews with observational data, the small sample size and descriptive data analysis could be weaknesses in its findings. Weyman (1999) further corroborates these findings by demonstrating that safety culture has a positive influence on individual risk perception.

In maritime contexts, Darbra *et al.* (2007) interviewed 77 Australian and New Zealand maritime pilots to examine how safety culture influences hazard risk perception among maritime pilots. Results show that organisational safety culture, particularly communication, significantly impacts risk perception. Pilots reported cooperative communication, which led to a better perception of equipment failures and poor boarding arrangements. Variations in risk perception were observed based on experience levels and job roles; however, the findings emphasise the importance of fostering a strong safety culture to enhance risk perception and decision-making in maritime operations. A limitation of this study is the use of a single qualitative method, which may not establish a robust influence or relationship. Zhao *et al.* (2021) further advanced this understanding in the chemical industry field by employing SEM in China's chemical industry. They examined the role of leadership and safety attitudes in shaping workers' risk perception in the chemical industry. The findings revealed that leadership has a statistically significant influence on risk probability ($\beta = 0.329$, $p < 0.001$) and severity ($\beta = 0.234$, $p < 0.001$) perceptions. Additionally, attitudes significantly influence the perception of risk probability ($\beta = 0.140$, $p < 0.001$) and risk severity ($\beta = 0.327$, $p <0.000$). By employing SEM, the study offers a nuanced understanding of relationships between variables. These studies underscore the sector-specific mechanisms through which safety culture shapes risk perception.

Contrasting evidence suggests that the impact of safety culture on risk perception is context-dependent, with inverse or null relationships observed in high-risk industries and informal sectors. Kao *et al.* (2008) investigated the relationship between safety culture and risk perception in five petrochemical plants in Taiwan, utilising a survey based on the International Atomic Energy Agency's (IAEA) safety culture model. Their findings indicated that safety culture is significantly correlated with workers' risk perceptions ($r= -0.206$, $p < 0.001$). The negative value indicates an inverse relationship; as one factor increases, the other decreases. This could imply that when employees have a positive view of their organisation's safety culture, they perceive lower risks. Conversely, when employees have more negative views of their organisation's safety culture (e.g., they don't believe management truly cares about safety, or they see unsafe practices as common), they tend to perceive higher risks in their work environment, which makes logical sense. While the authors acknowledge this negative relationship ($r= -0.206$, $p<0.001$), they do not delve deeply into its implications. For instance, they could explore whether high-risk perception catalyses improving safety culture or whether it reflects systemic issues within the organisation. Overall, the simple correlations limit causal inferences about the directionality of relationships. For example, does poor safety culture lead to heightened risk perception, or does high-risk perception erode confidence in safety systems, which may limit its broader applicability. Similarly, Sari *et al.* (2018) investigated fishing vessel accidents in Indonesia using a questionnaire and a sample of 200 fishermen, along with SEM to analyse the data. They highlighted that safety culture has a negative, insignificant impact on risk perception ($\beta = -0.024$, $p = 0.721$). The non-significant result likely reflects a true lack of association, suggesting that informal safety practices decouple safety culture from risk perception. The authors state, "*The better safety culture, the less likely to have an accident*", but the data does not empirically support this conclusion. These findings highlight the complex and context-dependent nature of the relationship between safety culture and risk perception, suggesting that while a strong safety culture may lower perceived risk in some settings, its influence is not universal. Variations in industry type, formal versus informal safety practices, and methodological limitations may account for the inconsistencies observed, underscoring the need for deeper exploration into the mechanisms that shape this relationship.

In conclusion, the relationship between safety culture and risk perception is dynamic and context-dependent, influencing occupational safety outcomes, especially in chemical process industries. A strong safety culture fosters heightened risk perception, enabling employees to better identify and mitigate hazards, as evidenced by studies in various industries (Fleming and Buchan, 2002; O'Toole, 2002). Conversely, risk perception also plays a crucial role in shaping and reinforcing safety culture, establishing a reciprocal relationship that highlights the importance of both constructs in promoting safe work environments (Kao *et al.*, 2008; McEvoy *et al.*, 2017). However, the strength and nature of this relationship vary across industries, with some high-risk sectors exhibiting inverse or null associations (Kao *et al.*, 2008; Sari *et al.*, 2018). These inconsistencies underscore the need for rigorous, industry-specific research to address methodological limitations, including small sample sizes, cross-sectional designs, and reliance on basic descriptive analyses. Future studies can provide deeper insights into how safety culture and risk perception interact to enhance safety compliance.

2.6.2 Relationship between safety culture and safety compliance

Safety culture is recognised as an important element that promotes the value of safety within an organisation (O'Toole, 2002). A substantial body of literature suggests that a strong safety culture has a positive influence on safety compliance, particularly a worker's adherence to procedures that ensure workplace safety (Cooper and Phillips, 2004; Neal and Griffin, 2006). The organisational safety culture provides contextual signals that employees use to determine whether to act safely or unsafely during job activities (CCPS, 2016; Morrow *et al.*, 2014).

Safety culture encompasses multiple dimensions, including management commitment, safety communication, and procedural adherence, all of which significantly influence compliance behaviours. A robust safety culture hinges on management practices that signal organisational priorities (Cox and Flin, 1998; Guldenmund, 2000; Lee and Harrison, 2000). For instance, Vinodkumar and Bhasi (2010) investigated the influence of six safety management practices on safety behaviours (compliance and participation) in hazard process industrial units in India. They used a questionnaire to collect data and conducted path analysis using AMOS software. They established a correlation between management practices, specifically safety management commitment and safety compliance ($\beta = 0.19$, $p < 0.01$). This suggests that employees' perception of management's prioritisation of safety, as manifested through corrective actions, provision of protective equipment, and visible leadership in safety meetings, creates an environment where compliance becomes normative. Their findings establish management's role in fostering a culture prioritising adherence to safety procedures. Such findings by Vinodkumar and Bhasi (2010) align with Hofmann *et al.* (1995), who argue that management's overt safety behaviours (e.g., enforcing rules and attending safety audits) signal organisational priorities, compelling employees to align their behaviours with these expectations.

Beyond management practices, safety culture is represented significantly in safety communication, and safety rules and procedures shape compliance. Hassan *et al.* (2019) investigated the relationship between safety communication, safety rules and procedures, and safety compliance behaviour among Malaysian small and medium enterprises (SMEs) workers. They adapted questionnaires and a robust sample of 382 workers from 50 SMEs. They used SPSS software to perform regression analysis, effectively quantifying the variance explained by safety communication, rules, and procedures. The study reported that ($R^2 = 0.457$), meaning that the independent variables could explain 45.7% of the variance in safety compliance behaviour. The study also reported a moderate positive relationship between safety communication and safety compliance behaviour ($\beta = 0.425$, $p < 0.001$). While the study provides valuable insights into the role of safety communication in shaping compliance behaviour, several limitations and areas for improvement can be identified. Despite these critical results, the study has several notable limitations. Although the framework included safety rules and procedures as an independent variable, the study's failure to report its regression coefficients or statistical significance undermines the comprehensiveness of the analysis. It raises questions about its impact on safety compliance behaviour. The R^2 value of 0.457 indicates that the independent variables explain 45.7% of the variance in safety compliance behaviour; however, the study did not report the individual correlation coefficients for each independent variable. This omission mirrors broader methodological gaps in operationalising safety culture's multifaceted nature (Guldenmund, 2000).

In oil and gas refineries, Kalteh *et al.* (2022) investigated safety motivation and safety knowledge as mediating factors between safety culture and safety compliance in the context of an oil and gas refinery. They used a questionnaire to collect data from 276 participants and used SEM for data analysis. Their findings confirm a significant direct relationship between safety culture and safety compliance ($\beta = 0.783$) rather than through mediators, with safety culture explaining approximately 50% of the variance in safety performance ($R^2 = 0.54$). The study suggests that the direct influence of safety culture on safety behaviours is more impactful than its indirect effects through mediators. However, this study has several limitations in terms of data reporting. The study reported that safety motivation and safety knowledge were not significant mediators; however, the individual indirect effect was not reported. All reported coefficients are missing the p-value, which determines the significance level of correlations. Additionally, despite measuring the two dimensions of safety performance (compliance and participation), the study missed the opportunity to address which of them is mainly influenced by safety culture. Comparatively, Christian *et al.* (2009) observed that the relationship between safety culture and safety participation was more substantial than with safety compliance. Another critical point is the lack of significant mediation effects, which were not adequately explained, raising the question of why these paths were not confirmed.

Kuswara (2017) further reinforces the direct link between safety culture and compliance in the oil and gas industry. The research employs a quantitative approach using questionnaires and path analysis to examine the interrelationship between safety culture and safety compliance. Seventy-two employees were surveyed, and the results revealed that safety culture has a significant influence on safety compliance ($\beta = 0.689$, $p < 0.001$). The use of structural equation modelling is a strength that provides statistical rigour. Building on this, Hafeez *et al.* (2022) surveyed 385 nurses and found that safety culture has a significant impact on safety compliance ($\beta = 0.53$, $p < 0.001$).

Similar trends of safety culture and safety compliance relationships exist in the healthcare sector. McDiarmid and Condon (2005) reported that staff who perceived that the hospital exhibited a strong safety culture and safety commitment were nearly three times more compliant with universal precautions for bloodborne pathogens than those who did not. Kwon and Kang (2020) also reported that a positive safety culture improves hospital employees' safety compliance.

Structural constraints may amplify cultural impacts in small and medium-sized enterprises (SMEs). Asad *et al.* (2022) employed a questionnaire and a sample of 100 participants from SMEs in Pakistan, along with SEM, to test the relationships. The study demonstrated that safety culture and climate have a significant impact on safety performance, with safety culture exerting a stronger influence ($\beta = 0.524$, $p < 0.001$) and safety climate ($\beta = 0.268$, $p < 0.05$). Safety culture's impact is nearly twice as strong as safety climate's, suggesting that safety culture (shared values, attitudes, and long-term norms) is more critical to safety outcomes. The study provides actionable insights, emphasising the importance of fostering a robust safety culture to enhance safety compliance. Conversely, Ayi and Hon (2018) investigated this relationship among Canadian academic laboratory university students using a survey and a sample of 56 participants. Survey results were analysed descriptively. The results revealed that while 90% valued safety, 60% admitted inconsistent PPE use, and 27% skipped risk assessments. This misalignment highlights the weak translation of cultural values into compliant behaviours. However, the robustness of these findings is questioned due to the use of descriptive analysis, which may not adequately capture causal relationships. With only 56 participants, predominantly young and early-career, the findings may not represent broader academic demographics, which reduces statistical power and generalisability. This study could have benefited from including deans or administrators, key influencers of institutional culture. A mixed-method approach (e.g., interviews and audits) would help validate self-reported data. Methodological challenges recur throughout this body of work. The frequent use of self-report questionnaires, while practical, raises concerns about social desirability bias, as seen in studies by Ayi and Hon (2018), Asad *et al.* (2022), and Hassan *et al.* (2019). Furthermore, while tools like structural equation modelling (SEM) lend statistical rigour, their benefits are undermined when key details (such as p-values or indirect effect sizes) are omitted. A mixed-methods approach, blending quantitative rigour with qualitative insights like interviews or audits, might overcome these limitations and offer a richer, more nuanced picture of safety compliance.

Despite robust literature linking safety culture to risk perception and safety compliance (Hafeez *et al.*, 2022; Kao *et al.*, 2008; Kuswara, 2017; Zhao *et al.*, 2021), a gap persists in understanding whether safety culture mediates the relationship between risk perception and safety compliance, particularly within high-risk chemical and process industries (CPI).

Specifically, to the best of the author's knowledge, no study has empirically tested whether safety culture mediates the relationship between risk perception and compliance. Existing studies predominantly treat safety culture as a cause or consequence variable (e.g., (Hassan *et al.*, 2019; Kao *et al.*, 2008)) rather than interrogating its role as a mechanism that translates perceived risks into compliant behaviours in CPI contexts, where operational challenges such as high-pressure reactions and flammable material handling require heightened perception of risks and strict adherence to safety protocols. This oversight limits theoretical clarity about how workers' risk perception translates into compliance actions in CPI settings and hampers practical efforts to optimise safety interventions tailored to these industries.

Safety culture is uniquely positioned to mediate the risk perception-safety compliance relationship in CPI, as it fosters a heightened perception of risks (e.g., recognising severity vs. misjudging probability; Zhao et al., 2021) and operationalises compliance (e.g., translating rules into action; Vinodkumar and Bhasi, 2010). However, inconsistencies across industries, such as moderate culture-compliance correlations in healthcare ($\beta = 0.53$; (Hafeez *et al.*, 2022)) versus weak or inverse correlations in petrochemicals ($r = -0.206$; (Kao *et al.*, 2008)), suggest contextual variability that mediation analysis could disentangle, which remains unexplored. Testing the mediation role of safety culture in the CPI is important because it shapes how individuals interpret and respond to risks, ensuring that risk perception translates into consistent safety compliance. Moreover, it advances a nuanced framework to reconcile relationship inconsistencies, especially in the CPI, where errors have catastrophic consequences.

2.7 The influence of situational awareness on risk perception and safety compliance

Endsley (1995) defined situational awareness (SA) as ''*the perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future''*. Situational awareness is a highly researched subject in human factors (Salmon and Stanton, 2013; Stanton, 2010; Wickens, 2008) and remains one of its most contentious issues due to measurement challenges and interdisciplinary perspectives. Situational awareness has been linked to the perception of risks and safety compliance to prevent accidents and improve operational safety in many risky industries, such as chemical processing, aviation, and emergency response (Stanton, 2010). As initially articulated by Endsley (1995), situational awareness encompasses recognising environmental components, interpreting their significance, and anticipating their forthcoming conditions. This cognitive construct is crucial for individuals working within dynamic and intricate contexts, wherein prompt and precise decision-making can distinguish between safety and catastrophe. Risk perception is significantly shaped by the extent of an individual's situational awareness (Endsley, 1995). Many researchers have examined the positive relationship between situational awareness, risk perception, and safety compliance across various contexts and industries, such as Lonsdale (2004); Mohammadfam *et al.* (2021); Morita and Burns (2011); Naderpour *et al.* (2014b); Stanton *et al.* (2001).

Therefore, Operators should maintain an optimal level of situational attention to perceive risks, assess dangers correctly, and comply with safety procedures to avoid encountering incidents. For instance, technologies such as real-time monitoring systems and artificial intelligence (Dekker, 2011; Reason, 2016) have been developed to provide overall monitoring, which in turn supports individual operators' situational awareness and risk perception. The integration of these technologies raises the critical issue of how to make them work with, rather than against, operators' cognitive abilities, especially in terms of safety compliance.

2.7.1 Relationship between situational awareness and risk perception

Failures in situational awareness (SA) and risk perception (RP) were identified as fundamental causes of the Deepwater Horizon 2010 oil spill (Hoyle and Peres, 2017; President, 2011). The Deepwater Horizon drilling rig catastrophe in the Gulf of Mexico, which resulted in the deaths of 11 individuals and precipitated the most severe oil spill in US history, exemplifies the risky nature of this industry's operations. The continuous analysis of the causal events of Deepwater Horizon reveals deficiencies in situational awareness, risk perception and evaluation (President, 2011). In the context of the chemical process industries, the dangers are significant due to the inherent risks associated with hazardous substances and the complexity of operational processes. These industries often involve continuous operations, high levels of automation, and the potential for severe accidents resulting from equipment failure, human error, or unexpected external factors (Kletz, 2001). Sneddon *et al.* (2006) used Endsley's three-level model of SA, perception, comprehension, and projection to categorise and analyse errors identified in offshore drilling incidents. The findings reveal that most errors (67%) occur at the perceptual level, with workers failing to monitor or observe relevant data due to distractions or poor vigilance. This highlights the importance of risk perception and situational awareness in preventing incidents and enhancing workplace safety.

Judging risk is a critical part of SA, as it demonstrates how operators interpret information, think ahead, and formulate decisions (Reader and O’Connor, 2014). Past research has investigated the links between situational awareness and risk perception across high-risk industries (Kinateder *et al.*, 2015; Limited, 2003). For instance, Limited (2003) identified the fundamental factors contributing to falls from height, revealing that workers' situational awareness and risk perception were primary determinants of such incidents. The study proposed that this was partially attributable to familiarity with the hazard and complacency regarding the risk, such as the belief that 'it will not happen to me.'. Insufficient risk perception contributes to accidents, as individuals acknowledge hazards yet fail to adjust their behaviour accordingly, exhibiting heightened risk awareness for high-level tasks while underestimating risks associated with low-level tasks (Hussain *et al.*, 2024). Clift (2004) demonstrated that risk perception fluctuates according to the individual and their level of expertise, with familiarity in a situation likely diminishing the perception of risk.

Previous studies indicate that level 1of Endsley’s 1995 situational awareness model (situation perception) in various industries is based on the extent of risk perception (Cacciabue, 2004; Montewka *et al.*, 2014; Slovic, 1987; Smith *et al.*, 1984). Situational awareness and risk perception are connected constructs integral to decision-making under uncertainty and risk management in high-risk industries (Morita and Burns, 2011). Inevitably, lapses in situational awareness during emergencies, as discussed by Kakimoto and Yoshida (2022), will lead to poor risk perception, as exhibited in associated risk assessments, which can delay reactions and have repercussions for safety.

Risk perception is a determinant that influences an individual's reaction to dangerous situations (Rohrmann, 2008). Xie *et al.* (2025) reveal that accurate risk perception enhances situation awareness among airline pilots ($\beta = 0.156$, $p < 0.01$). This establishes a theoretical foundation that demonstrates the link between risk perception and situational awareness in high-risk environments, with the Deepwater Horizon disaster serving as a stark reminder of the catastrophic consequences that occur when this relationship breaks down.

2.7.2 Relationship between situational awareness and safety compliance

According to Kharoufah *et al.* (2018) review of accidents in commercial air transport between 2000 and 2016, situational awareness was the most significant human cause of accidents, followed by non-compliance with procedures. The relationship between situational awareness and safety compliance appears complex. Sneddon *et al.* (2013) found that reduced levels of SA were significantly associated with heightened unsafe behaviour in the workplace. According to Sneddon *et al.* (2006), workers in offshore industries with high situational awareness also sometimes engage in unsafe behaviours influenced by external and workplace factors, such as production demands and time constraints. The literature consistently agrees that a lack of situational awareness is a prominent factor most responsible for accidents in the chemical and process industries (Grigoleit *et al.*, 2017; Naderpour *et al.*, 2014a). Endsley (1988) asserts that situational awareness is the paramount and immediate indicator of individuals' safety performance in safety-critical sectors, particularly in aviation, gas and mining, and construction. This assertion is supported by the viewpoint that situational awareness encompasses safety-related cognitions and competencies (Endsley and Garland, 2000).

Stanton *et al.* (2001) conducted a theoretical review to present three prominent situational awareness (SA) models. First, Endsley’s 1995 Three-Level Model conceptualises SA as a hierarchical cognitive process involving three stages: (1) perception of environmental elements (e.g., data from instruments or surroundings), (2) comprehension of their meaning relative to goals (e.g., interpreting fuel levels and weather to assess flight safety), and (3) projection of future states (e.g., anticipating aircraft conflicts). This model prioritises SA as a product, the outcome of cognitive processing, and is widely applied in high-stakes domains like aviation and healthcare. In contrast, the Interactive Sub-Systems Approach (Bedny and Meister, 1999) frames SA as a reflective, goal-driven cognitive process. It posits eight functional blocks representing mental activities. SA arises from interactions between individual factors (e.g., mental models, goals) and environmental feedback loops. This theory highlights internal cognitive mechanisms, explaining how errors in mental models or task prioritisation can degrade SA. The Perceptual Cycle Model (Smith and Hancock, 1995) shifts the focus to the process of SA as a dynamic interaction between humans and their environment. Individuals anticipate environmental states using mental models, seek confirmatory information, and update their understanding iteratively. The review explores how SA failures contribute to accidents. While the theoretical insights are interesting, the lack of empirical validation undermines their ability to link SA directly to safety outcomes.

In addition, Sneddon *et al.* (2006) adopted a mixed-methods approach, including accident analysis and interviews, to investigate situational awareness (SA) in offshore oil and gas operations. The results reveal that 67% of SA errors occur at the perceptual level, and the study indicates a significant implication of the situational awareness error for safety compliance. Similarly, Salmon and Stanton (2013) critically evaluated existing situational awareness (SA) literature as a safety-critical concept. While SA is frequently cited as a causal factor in accidents (e.g., aviation crashes, rail collisions, offshore drilling disasters), the authors argue that SA-related research has had minimal real-world impact on improving safety. They identified SA as essential in mitigating risks across safety-critical domains, focusing more on aviation. Despite the theoretical depth of these studies, there is a notable absence of quantitative analysis and rigorous examination of the relationship between SA and safety compliance due to a lack of consensus and measurement difficulties (different measurement scales).

Research on large technological systems suggests that an operator's failure to achieve situational awareness during critical events often leads to misjudgments of the risks associated with equipment malfunctions and operational hazards (Naderpour *et al.*, 2015). The 2005 explosion at the Texas City refinery is an important case in point; it was partly attributed to a failure of operators to achieve situational awareness due to misperception of high-pressure risks, further reinforcing the crucial relationship between effective SA and safety compliance (CSB, 2007). Flin *et al.* (2008) argue that situational awareness is a foundational skill that connects the perception of risks to safety-related decisions and actions, such as compliance with safety protocols.

The literature properly recognises the importance of risk perception in driving situational awareness and how situational awareness can lead to better safety compliance by investigating the correlation between them in different workplace settings. However, a significant gap in the literature remains due to the lack of empirical investigation (quantitative) regarding whether situational awareness mediates the relationship between risk perception and safety compliance, particularly within the chemical and process industries. A good level of risk perception can improve the SA of personnel, thereby improving safety compliance practices and reducing accident likelihood.

2.8 Summary of literature review and research hypothesis

This chapter has reviewed the relationships between study constructs, risk perception, safety compliance, safety knowledge, safety culture and situational awareness. This review has found that risk perception has both direct positive and negative effects on safety compliance. It has also identified several factors that mediate the relationship between risk perception and safety compliance, including safety attitude, training, and leadership. Other factors, however, may suppress this relationship, such as job satisfaction. This chapter also identified a positive correlation between risk perception and each of safety knowledge, safety culture and situational awareness. On the other hand, safety knowledge, safety culture, and situational awareness have been identified as having a positive influence on safety compliance. Despite the extensive research on these topics and relationships, the chapter identified a clear research gap that no previous studies have examined: the mediating roles of safety knowledge, safety culture, and situational awareness in the relationship between risk perception and safety compliance, particularly in the chemical and process industries. This gap highlights the need for further research to investigate whether these factors impact the relationship between risk perception and safety compliance in the CPI.

Based on the identified research gap concerning the unexamined mediating roles of safety knowledge, safety culture, and situational awareness in the context of the chemical and process industries, the following three hypotheses (Figures 2.4-2.6) were formulated to specifically investigate how these constructs translate risk perception into safety compliance within the CPI. These hypotheses are:

Hypothesis 1: Safety knowledge mediates the relationship between risk perception and safety compliance in the CPI.

Figure 2.4: Hypothesis 1

Hypothesis 2: Safety culture mediates the relationship between risk perception and safety compliance in the CPI.

Figure 2.5: Hypothesis 2

Hypothesis 3: Situational awareness mediates the relationship between risk perception and safety compliance in the CPI.

Figure 2.6: Hypothesis 3

Chapter 3: Research Methodology, Mixed Method Approach

3.1 Introduction

The study adopted a mixed-method approach, combining quantitative and qualitative techniques, to comprehensively address the research objectives. This chapter is divided into three key sections, detailing the purpose and value of using a mixed-method approach, quantitative research methodology, and qualitative research methodology. This structure reflects the rationale for employing an integrated research design, which allows for a comprehensive exploration of the research objectives.

Section 3.2 outlines the methodological framework and justifies its relevance for achieving research objectives. It also highlights how an explanatory sequential mixed-method design utilises quantitative findings to inform the qualitative phase data collection.

Section 3.3, the quantitative phase, involved a structured and systematic data collection and analysis approach, ensuring rigorous testing of the hypothesised relationships between variables. This section describes several key components to ensure clarity and methodological rigour.

Section 3.4 Qualitative Research Methodology outlines the second phase of this study, designed to explore more profound insights into the findings from the quantitative analysis. This phase focuses on understanding the factors that influence the relationship between situational awareness and safety compliance within the Chemical Process Industries (CPI), based on the results from the quantitative phase. Additionally, to confirm the identified relationships in the former phase. This structured methodological framework ensures that the research findings are statistically robust and contextually nuanced.

3.2 Research approach

In the literature, the common approaches employed in safety research are either quantitative, qualitative or a mix of both. Quantitative and qualitative research approaches clearly differ in terms of how data are collected and analysed. Quantitative research focuses on the objective measurement of data collected through surveys that are analysed numerically using statistical techniques (Wilson, 2019). Qualitative research, like interviews, primarily focuses on providing a deep understanding of issues and problems within the social sciences. It utilises words as data collected and analysed in various ways (Braun and Clarke, 2013). Table 3.1 presents the advantages and disadvantages of quantitative and qualitative research methods.

Table 3.1: Advantages and disadvantages of research methods (Wilson, 2019)

Feature	Quantitative	Qualitative
Advantages	Reduce subjectivity, consistent and repeatable data collection and analysis. Findings can be generalised to larger populations. Easier to identify patterns, correlations, and causal relationships. Greater accuracy of results – gained by employing pre-established statistical techniques.	An in-depth understanding that offers rich insights into complex phenomena. It enables flexibility in data collection and analysis, allowing for the exploration of new ideas and emerging themes. Useful for exploring understudied or complex issues.
Disadvantages	Limited Depth of analysis. It may overlook the deeper meanings and nuances behind behaviours, attitudes, or experiences, which qualitative methods can capture. Limited ability to explore unexpected findings. Requires large samples to ensure statistical significance, which can be costly and time-consuming.	Limited generalizability of findings to larger populations due to small sample sizes. Collecting and analysing data (e.g., interviews) can be time-consuming. Less Structured, which can make it harder to replicate studies or compare findings.

On the other hand, mixed-methods research involves the use of two types of data collection methods, encompassing both quantitative and qualitative approaches. There are two main approaches used in mixed-methods research: the explanatory sequential approach and the exploratory mixed approach, where the quantitative and qualitative data collection is conducted in a different order. In the explanatory sequential approach, the researcher executes the two types of data collection sequentially, prioritising quantitative methods initially to address the study's objectives, followed by qualitative approaches to elucidate the quantitative findings. It uses qualitative data to explain or elaborate on initial quantitative data. However, it is time-consuming. In contrast, the exploratory sequential approach involves applying the qualitative methods first to investigate a phenomenon and primarily address the study's objectives, followed by quantitative methods to evaluate the generalisability of the initial qualitative findings to a broader population.

This approach is ideal for understudied topics and useful when little is known about a phenomenon. Creswell and Clark (2017) have suggested a few considerations to be considered when selecting the appropriate mixed-method research approach, as follows:

- The nature of the research problem (quantitative or qualitative oriented);
- The availability and access to instruments for measuring the concepts;
- Access to participants for a second phase data collection;
- Ability to conduct the research in two separate phases;
- The researcher's resources (e.g. time and money).

Based on the above considerations, this research adopts an explanatory sequential mixed-method approach because:

- The researcher and the research problem exhibit a predominant quantitative orientation, thereby justifying the initiation of procedures with a quantitative phase.
- The researcher possesses the necessary knowledge and has access to statistical instruments for measuring the primary concepts of interest.
- The researcher is capable of returning to participants for a subsequent round of qualitative data collection.
- The researcher can conduct the research in two distinct phases.
- The researcher operates with a limited time frame and requires a design that facilitates the collection and analysis of only one type of data at a time.

This research employed an explanatory sequential mixed-methods approach, beginning with the quantitative phase. During this phase, data was collected through a survey and analysed using statistical techniques. The qualitative phase aimed to gain a deeper understanding of the findings and results from the quantitative phase. In this stage, data was gathered through interviews and analysed using the thematic analysis technique.

3.2.1 Overview of the mixed-methods used in this study

The explanatory sequential design is employed in developing and implementing the mixed-methods approach in this study. It involves a structured transition from quantitative to qualitative data collection, where an earlier phase informs the later one. This integration unfolds in several stages to ensure a comprehensive address of the research objectives. The overall flow of the mixed-method study is illustrated in Figure 3.1.

Firstly, during the quantitative phase, the survey was designed based on previous literature. The survey was administered to participants over a period of five months. Responses were refined and prepared for analysis using statistical techniques in SPSS. The statistical techniques employed in this study included factor analysis to establish the validity of the study constructs. Additionally, convergent validity and composite reliability assessments are conducted to ensure the validity and reliability of the study constructs for subsequent analyses. The hypotheses of mediation were tested using SEM.

Secondly, the quantitative phase was followed by a qualitative phase, involving interviews, to investigate both non-supported and supported hypotheses and provide a more in-depth exploration of the relationships between the constructs. This phase began with developing questions for interviews based on the survey items. Some participants from the previous phase were contacted and invited to participate in this phase. Interviews were conducted online, audio-recorded, transcribed, and revised to ensure the accuracy of the data transcription. Data was analysed using thematic analysis. The qualitative phase provided deeper insights into potential contextual or operational factors that may not be fully captured in the quantitative phase and verified the supported hypotheses. The qualitative phase aimed to contribute to contextual understanding and validation of the quantitative results. Through in-depth interviews, the researcher gathered detailed participant narratives to better understand the relationship between constructs and how these constructs are perceived and practised in real-world settings. This phase helped validate and expand upon the quantitative findings, offering a richer and more nuanced understanding of the dynamics between constructs. This aligns with Creswell’s assertion that mixed-method approaches can enhance theoretical development by integrating diverse data types (Creswell and Creswell, 2018).

For each phase, data were initially analysed to extract key findings from the study. This was followed by a further discussion to form a holistic view of the research problem. By integrating these two phases, the study offers a more complete understanding of the relationship and mediating roles of the constructs.

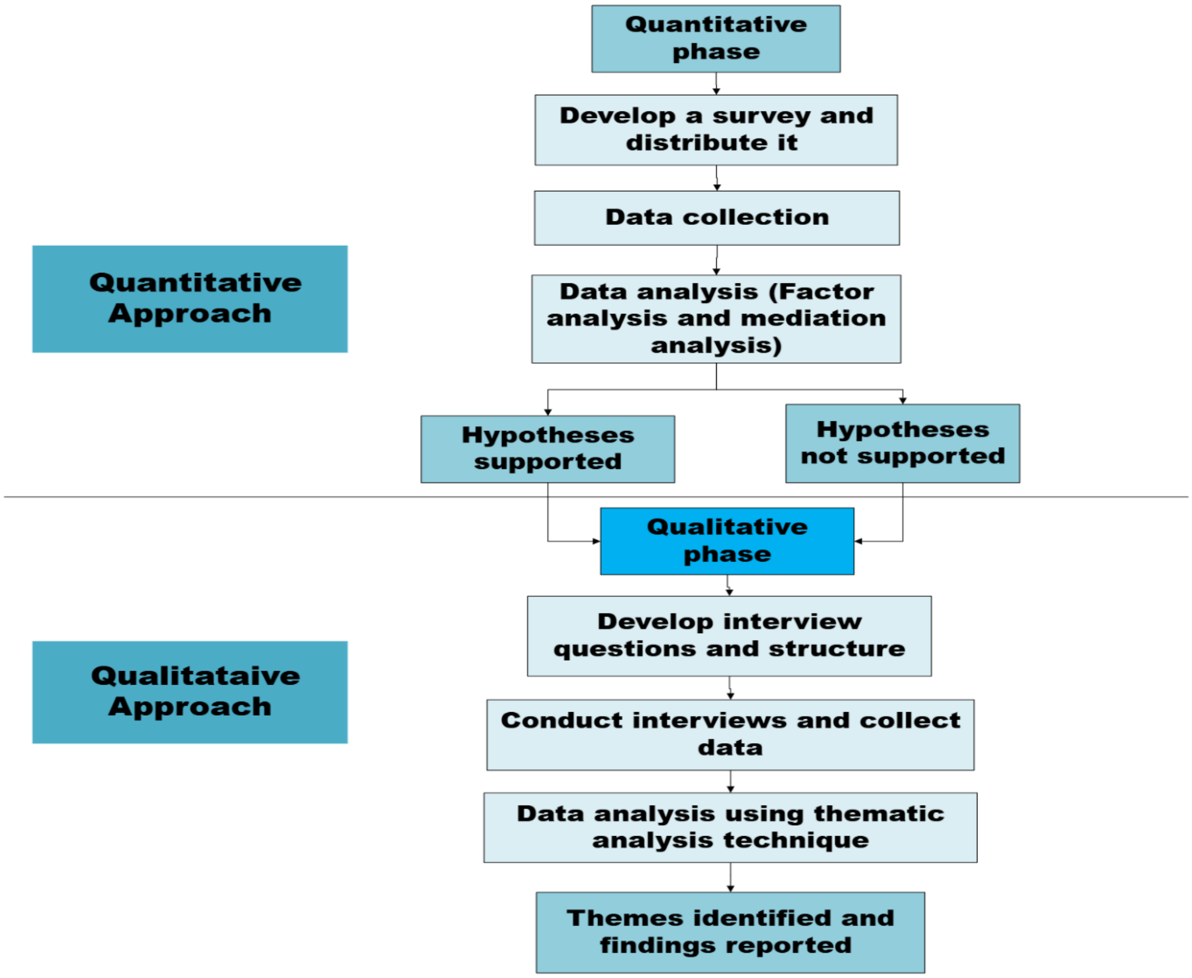

Figure 3.1: Mixed-methods research approach

3.3 Quantitative research methodology

The steps involved in the quantitative phase are illustrated in Figure 3.2. As stated in Section 1.3, the overall aim of the study is to assess whether each of the proposed constructs (safety knowledge, safety culture, and situational awareness) mediates the relationship between risk perception and safety compliance in the CPI.

This research phase began with the development of a survey to measure the key constructs. Items were drawn from previous studies and then piloted and refined for content validity and reliability. Following refinement, the finalised survey was distributed to collect data. Following collection, the data underwent a thorough cleaning process to prepare it for statistical analysis. The prepared data was analysed using a set of advanced quantitative analysis techniques to examine the relationships between constructs. Finally, hypotheses were tested, and the results were then used to inform the next phase of this mixed-methods approach.

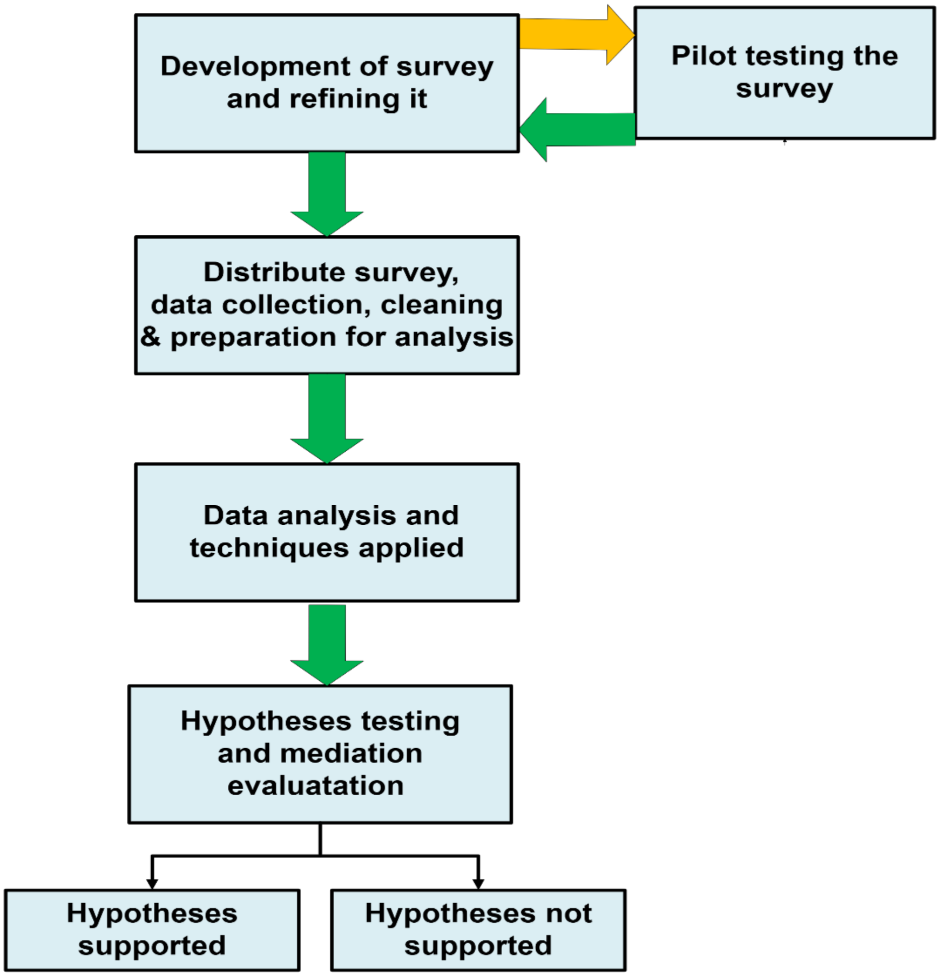

Figure 3.2: Steps of the quantitative research methodology

3.3.1 Development of the survey

This step employed a quantitative approach, collecting data from employees in the CPI sector via an online survey. As this research phase aims to measure relationships and mediation effects quantitatively, this approach is selected because it enables the efficient collection of large datasets, given that the research problem is more quantitatively oriented.

The survey was structured into six sections, with the first section used to capture the demographic data of the participants, and the others used to measure the five constructs. A total of 81 items were assembled from precursor literature. These items were selected because they have been tested and validated in prior studies, providing confidence in their accuracy and consistency in measuring constructs. Additionally, ensuring that constructs are captured in a multidimensional manner enables statistical analysis.

The first section collects demographic information, including participants' gender, age group, educational background, current job title, and industry experience. It also queries their work history over the past five years, detailing departmental assignments, job locations (site or office), and any incidents involving accidents or near misses. This demographic data is crucial for contextualising responses and identifying patterns across participant groups (Creswell and Clark, 2017).

This second section examines risk perception using 12 items adapted from Qin *et al.* (2021). These items are designed to capture participants' perceptions and evaluations of risks in their work environment, reflecting contemporary views on risk perception. Sample item (Once exposed to a hazard, my health will be severely affected). See full survey in Appendix A.

The third section measures adherence to safety protocols and procedures to evaluate safety compliance. This section comprises four items. These four items have been approved in many studies as sufficient for measuring safety compliance (Neal and Griffin, 2006; Vinodkumar and Bhasi, 2010; Xia *et al.*, 2016). Sample item (I use all necessary safety equipment to do my job). See full survey in Appendix A.

The fourth section evaluates safety knowledge using 20 items adapted from established studies (Real, 2008; Vinodkumar and Bhasi, 2010). This section assesses participants' understanding of safety procedures (4 items), the provision of training (5 items), their willingness to seek safety information (6 items), and their knowledge of control measures (5 items), ensuring that the items are relevant and can capture safety knowledge through statistical techniques. Sample item (I know how to perform my job in a safe manner). See full survey in Appendix A.

The fifth section evaluates safety culture using 25 items. This section measures attitudes and beliefs about safety (7 items), management’s commitment to safety (8 items), and the effectiveness of communication and learning from past incidents (10 items), drawing on items developed by (Çakıt *et al.*, 2019; HSE, 2005; Vinodkumar and Bhasi, 2010). Sample item (Management considers safety to be equally important as production). See full survey in Appendix A.

The final section focuses on situational awareness, utilising 20 items sourced from Kiani *et al.* (2015), Sneddon *et al.* (2013), and Zahra *et al.* (2015). These items cover critical components, including concentration (9 items), anticipation of hazards (5 items), attention (3 items), and distractions (3 items), providing a comprehensive evaluation of situational awareness. Sample item (I find it difficult to concentrate for long periods of time). Full survey in Appendix A.

The survey uses a 5-level Likert scale for responses. Participants indicate their agreement with each statement on a scale from (1= Strongly Disagree) to (4= Strongly Agree), with an additional option of (5= I do not know) to accommodate uncertainty or irrelevance (Bautista, 2020; Reinecke, 2020). This methodology ensures that the responses reflect participants' knowledge and opinions.

The development of the measurement items involved adapting items from established sources to fit the context of the CPI while maintaining their conceptual integrity. For instance, risk perception items were reworded and rephrased to align with the targeted population, ensuring that the final survey effectively measures the relevant constructs and provides reliable data for the study (Creswell and Clark, 2017). Sample items are illustrated in Table 3.2 with the full list provided in Appendix B.

Table 3.2: Sample of the rephrased items of the risk perception construct

Original items	**Modified items**
1. Once infected with COVID-19, my health will be severely affected.	1. Once exposed to a hazard, my health will be severely affected.
2. Even a person is cured of COVID-19, there will be sequelae.	2. Even if a person recovers from an injury, there will be lasting effects.
3. Once the COVID-19 breaks out again, it will negatively impact the society immediately.	3. If a risk is not well controlled, it will negatively impact employees and the company at large. p

3.3.1.1 Ethical considerations in the quantitative phase

Ensuring ethical integrity in the quantitative phase of this study was a fundamental priority. Ethical guidelines were carefully followed to protect participants' rights, privacy, and data security while maintaining transparency in the research process. Compliance with institutional and professional ethical standards, including those set by the University of Strathclyde Ethics Committee and the British Psychological Society (BPS), ensured that all procedures aligned with best practices in research ethics. The followings outline the ethical measures taken in this phase, with the key considerations to guarantee voluntary participation, informed consent, and strict confidentiality in handling data:

1. Participation is voluntary, and participants must consent before participating in the study. The Participant Information Sheet (PIS) (Appendix C) and Privacy Notice (Appendix D) were made available to participants to read before starting the survey. In addition, participants can withdraw at any time without reason before submitting their responses.
2. Study objectives were clearly communicated to participants at the beginning of the survey.
3. No personally identifiable information was collected for anonymity, and the data analysis did not include any email addresses provided for the follow-up qualitative phase.
4. For confidentiality, data was collected through a survey platform (Qualtrics) hosted on university servers. The raw data was only seen by the researchers involved. Data will be stored on the university’s secure storage drive (i:\ drive) for five years and then securely destroyed, in accordance with the British Psychological Society (BPS) Guidelines.
5. Departmental Ethics Committee reviewed the ethical application. Questions and recommendations provided by the committee were addressed by refining the survey and data collection procedure. The committee reviewed the changes before the final approval.

3.3.1.2 Refining of the survey through pilot testing

A crucial phase in creating a new survey instrument involves testing it on a small group of people. The feedback gathered from the pilot participants was instrumental in refining the survey, ensuring that it accurately captured the intended information and aligned closely with the overarching research objectives (Thomas, 2004). This pilot study was conducted with the participation of 10 individuals who were not experts in the field of study. That is, they evaluated the general appearance of the survey, mainly whether the items were feasible, readable, made straightforward use of language, consistent in style and formatting, and whether the scales were appropriate and the questions were understood. The feedback recommended a few changes to improve the survey, including rewording certain items. The feedback also recommended using more appropriate wording for the Likert scale for items related to knowledge of safety procedures. The rationale for using frequency scale items concerning the application of learned safety procedures was that participants of the pilot study found that a frequency scale was more intuitive, straightforward, and better matched the nature of the items than agreement scales. The scale wording was revised as follows: 1 = Never, 2 = Sometimes, 3 = Often, 4 = Always, and 5 = I do not know. The improvement implemented enhances the survey's clarity, validity, and reliability before its large-scale distribution.

The potential problem caused by using different scales is the distortion of reliability and validity metrics. Mixing scales could deflate item correlations, reducing Alpha values and making Alpha unreliable (Finn and Kayande, 2004). Therefore, if internal consistency (Cronbach's Alpha) is poor, the different scales should be eliminated.

3.3.2 Sampling techniques and distribution of the survey

The targeted population for this research are employees working in the Chemical and Process Industries. Participant selection was primarily defined by affiliation with Chemical Process Industries (CPI), targeting employees across relevant sub-sectors. Selection leveraged a multi-channel approach combining pre-existing industrial contacts with outreach via social media to broaden access to participants and mitigate self-selection bias as much as possible.

Sampling initially targeted known industrial contacts within the CPI industries. Additionally, CPI employees and communities across social media platforms, including LinkedIn, Twitter, and Facebook (Fricker and Schonlau, 2002; Heckathorn, 2011) were also targeted. This multi-channel approach aimed to minimise the risk of bias associated with any single recruitment method, addressing the potential overrepresentation of digitally active individuals or those more willing to engage in online research (Bethlehem, 2010), and to ensure as much as possible a broad reach and equal opportunity for participation across different industries of the target CPI population.

The sample size was determined following guidelines by Burmeister and Aitken (2012), which recommend a minimum ratio of 20:1 between the sample size and the number of parameters in a regression model for mediation analysis. Therefore, the proposed model required a minimum sample size of 100 participants for the five parameters. A range of 100 to 500 participants was targeted to ensure statistical robustness.

The data was collected using an online survey administered via the Qualtrics platform. Online surveys have gained prominence over the past two decades, offering advantages such as a broad reach, efficiency in data collection, and the ability to facilitate simultaneous participation (Dillman, 2011; Wright, 2005). For specialised fields like CPI, digital platforms provide a practical means to access a broader audience (Kramer *et al.*, 2014). The survey's design leveraged the convenience of web-based tools, enabling researchers to gather responses efficiently from multiple participants (Evans and Mathur, 2005). The survey's link was emailed to known industrial contacts working in CPI. It was also posted on multiple social media platforms. These platforms included LinkedIn, Twitter, and Facebook, which were used to broaden reach and participation, thereby engaging with a broad and diverse range of respondents.

At the end of the survey, participants were invited to voluntarily provide their contact information if they wished to be considered for future research phases. This approach facilitates ongoing engagement with interested respondents and supports the longitudinal aspects of the research. Therefore, some participants have agreed to participate and have been contacted to take part in the next phase of the research.

3.3.3 Data collection, cleaning and preparation

A. Data collection

The survey was open for five months (February – June 2022) to accommodate various schedules and increase the likelihood of obtaining a representative sample. The number of participants was monitored over this period. To maximise participation, follow-up reminders were sent, resulting in a total of 451 responses being recorded.

B. Data Cleaning and Preparation

This process involved data screening to identify the incomplete responses, addressing responses with missing values, coding responses, and testing data homogeneity to ensure the reliability and validity of the dataset and subsequent analyses. Of the 451 responses that had been recorded, 25 records were declines from individuals to participate, resulting in 426 responses being assessed for missing data. Responses containing missing data (more than 5% at random responses) need to be excluded from further analysis to maintain the validity and reliability of the dataset. Out of the 426 responses, 290 were deemed valid and complete, while 136 were found to be incomplete. Based on (Schafer, 1999)**,** a missing value of up to 10% at random responses was considered acceptable (with no more than one missing value on the same scale). When applied to the 136 cases, it resulted in 32 cases meeting this specified criterion. Therefore, the total sample size used in the initial data analyses was 322. The data were then coded and converted into a numerical scale using the Likert scale response. For the response of 'I do not know', it was treated as a 'missing value', and the scale was kept ranging from 1 to 4.

The criterion for a maximum of 10% missing values at random among the responses was applied to the 322 responses (Schafer, 1999), resulting in 302 responses that met this criterion. The missing values of the 302 responses were addressed using a single imputation method (Little and Rubin, 2019) in SPSS, as they were substituted with the mean. The total number of responses used in the data analysis was 302. This sample size aligns with Burmeister and Aitken (2012) rule of 20:1, as described in Section 3.3.2.

Most of the items within the constructs were positively worded, while a few others were negatively phrased, although all used the same Likert-scale response format. Negative items were intentionally included alongside positive items to mitigate the risk of acquiescence bias, where respondents might habitually agree or disagree with statements regardless of content (Podsakoff *et al.*, 2003). Their presence encourages respondents to engage more thoughtfully with each question. The negatively worded items were reverse-coded before analysis. For the 4-point Likert scale used in this study, responses were transformed as follows: 1→4, 2→3, 3→2, and 4→1, ensuring that higher scores consistently represented higher levels of the construct. This step is methodologically essential to create a unidirectional rating scale for computation.

The use of reverse-worded items may introduce method effects rather than purely reflecting the target construct. Respondents can misinterpret negations or complex phrasing, especially in self-administered surveys, which may lead to inconsistent response patterns. Statistically, this can manifest as lower factor loadings, reduced internal consistency (Joseph F. Hair *et al.*, 2019; Podsakoff *et al.*, 2003). Therefore, although reverse coding corrects the numerical direction, it does not fully eliminate potential cognitive processing differences between positively and negatively worded items. To address this potential problem, the reverse-coded items were carefully checked during data screening. Item loadings, reliability coefficients, and measurement model diagnostics were examined to ensure that negatively worded indicators behaved consistently with their respective constructs. Items showing weak loadings or cross-loadings were evaluated for wording effects rather than theoretical misfit. This step is essential because, if not assessed, wording artefacts may bias the structural relationships estimated in the subsequent mediation analysis.

3.3.4 Techniques for evaluating individual constructs

Data analysis employed a structured approach to statistical analysis, ensuring the robustness of the constructs measured by the survey. Levene's test assesses whether the variances of two or more groups are equal. It was initially applied to assess the homogeneity of variances between participants' responses. Test parameters are illustrated in Table 3.3.

The descriptive and inferential analyses are performed to examine the interrelationships among a collection of survey items. It utilises factor analysis to ascertain whether participants' responses to specific subsets are more closely aligned with each other than with responses to other subsets, thereby analysing the dimensionality of the items (Bandalos, 2018; Fabrigar and Wegener, 2012; Kline, 2018; Raykov and Marcoulides, 2008; Tabachnick *et al.*, 2013). The analysis can be grouped into three stages: Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and assessment of the construct's reliability and validity (DiStefano and Hess, 2005; Shrestha, 2021). Each construct was evaluated independently. This approach enables a combination of essential analysis for evaluating the accuracy and interpretability within the data. All analyses were conducted using SPSS (v. 28).

Table 3.3: Summary of Levene's Test and T-test for Equality of Means Parameters

Statistical Test	Parameter	Purpose	Interpretation
Levene's Test for Equality of Variances	-	Assess whether the variances of two or more groups are equal.	If the F statistic is significantly large, it indicates that the variances are likely unequal.
	F Statistic	The ratio of the variance between groups to the variance within groups.	A higher F value suggests a greater disparity in variances between the groups being compared.
	p-value	Indicates the probability of observing the data if the null hypothesis (that variances are equal) is true.	A p-value < 0.05 typically indicates a significant difference in variances among the groups. Conversely, a p-value > 0.05 indicates no significant difference, supporting the assumption of homogeneity of variances.
T-test for Equality of Means	-	Determine whether there is a significant difference between the means of the two groups.	A larger absolute value of the t-statistic indicates a greater difference between the means relative to the variability within the groups. A positive t-statistic indicates the first group mean is larger, while a negative t-statistic indicates the opposite.
	t-statistic	Measures the size of the difference relative to the variation in the sample data.	Calculated as the difference between the group means divided by the standard error of the difference.
	p-value	Assesses the probability of observing the data if the hypothesis that there is no difference between the means is true.	A p-value < 0.05 suggests a statistically significant difference between the group means. A p-value > 0.05 indicates no significant difference in means.
	Mean Difference	Represents the difference between the average values of the two groups being compared.	Quantifies the effect size of the difference. A larger mean difference suggests a stronger effect, while a smaller mean difference suggests a weaker effect.

EFA was used to identify the underlying factor structure of the constructs and determine whether there were any commonly shared features among the items used in each construct of the survey. Multiple assessments were undertaken to evaluate the adequacy and appropriateness of the data for EFA. Initial assessments, which offer validation for items measuring constructs, include the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity (Field, 2018; Pituch and Stevens, 2015). These assessments are:

- Correlation coefficients for the bivariate correlation matrix ($r \geq 0.3$) between items;
- Sampling adequacy for the overall dataset was assessed using the Kaiser-Meyer-Olkin measure, with individual variable values exceeding the minimum absolute value of 0.5.
- Bartlett's test of sphericity is statistically significant ($p < .05$).

The parameters used and their purpose are summarised in Table 3.4. This was followed by the use of Principal Component Analysis (PCA) with oblique (Oblimin) rotation to extract correlated factors, thereby enhancing the comprehensibility of the resulting factor solution (Tabachnick and Fidell, 2007). This approach is often employed in psychological and social science research (Costello and Osborne, 2005), as it identifies the principal components that explain the most variance in the data, thereby helping to simplify the dataset while preserving as much variance as possible. It serves as a foundational step to uncover patterns and groupings within the data. Additionally, Cronbach's alpha. More details on the statistical tests and parameters used in this analysis are summarised in Table 3.4.

Additionally, Confirmatory Factor Analysis (CFA) was applied to validate the structure identified, ensuring the model’s fit with the observed data (DiStefano and Hess, 2005). In performing CFA, the Maximum Likelihood Estimation (MLE) method was employed because of its efficacy in accommodating slight deviations from normality (Reisinger and Mavondo, 2007). It evaluates the skewness and kurtosis scores for the data's univariate normality, along with other CFA parameters listed in Table 3.5 for testing whether the data fit the hypothesised measurement model and confirming the constructs' reliability and validity (Byrne, 2010). The purposes of the CFA parameters and cut-off values are also presented in Table 3.5.

Table 3.4: EFA Statistical Tests and Parameters

Test	Purpose	Parameters	Interpretation
Kaiser-Meyer-Olkin (KMO)	Assess the adequacy of the sample size for factor analysis, and whether the data are suitable for PCA.	KMO value	A KMO value close to 1 suggests that factor analysis is appropriate, while values below 0.5 indicate that it may not be suitable (Shrestha, 2021).
Eigenvalue	Is a measure that indicates the amount of variance in the observed variables explained by a particular factor or component	Eigenvalue	An eigenvalue greater than one is traditionally used as a criterion. It indicates that the factor captures a larger portion of the total variance across all variables, suggesting it is more important or influential in the underlying structure of the data (Costello and Osborne, 2019).
% of variance	Measure the proportion of total variance explained by a factor	%	The percentage of total variance explained can be as low as 50-60% in social sciences. Higher % = better representation (Koyuncu and Kılıç, 2019).
Bartlett's test of sphericity	To assess whether variables are sufficiently correlated to make factor analysis appropriate	Approx. Chi-square	A larger chi-square value indicates stronger evidence that the variables are correlated and that factor analysis may be a suitable approach (Bartlett, 1950).
		df	Degree of freedom of the test
		Sig.	A significant test ($p < 0.05$) indicates that correlations among items are sufficient to conduct factor analysis (Bartlett, 1950).
Principal Component Analysis (PCA)	To reduce the dimensionality of the dataset while preserving as much variance as possible.	Loading values	Factor loadings greater than 0.4 are considered acceptable (Pett *et al.*, 2003).
	To indicate the proportion of each variable's variance that the factors can explain.	Communalities	Higher communalities indicate that the factors explain a larger proportion of variance in a variable, suggesting good factor representation (Hadi *et al.*, 2016).
Cronbach's alpha	To measure the internal consistency of a set of items on a scale, indicate how closely related the items are as a group.	α	α above 0.70 indicates acceptable reliability, while values below 0.60 suggest the scale needs to be revised (Hajjar, 2018).

Table 3.5: CFA Fit Indices used in the study

Parameter	Purpose	Interpretation
Skewness	Measures the asymmetry of the distribution of a variable. It helps assess whether the data deviates from normality, which can affect parameter estimates, standard errors, and model fit indices.	The absolute value, which ranges from -1 to 1, is acceptable for a normal distribution (Byrne, 2016; Kline, 2018).
kurtosis	Measures the peakedness of the distribution. Indicates whether the data have heavier or lighter tails than a normal distribution.	The absolute value range from -2 to 2 is acceptable for a normal distribution (Byrne, 2016; Kline, 2018).
Chi-square (χ^2)	To assess the overall fit of the model to the observed data.	A significant chi-square indicates poor fit; however, this statistic is sensitive to sample size (Byrne, 2013; Hu and Bentler, 1999)
Degrees of freedom (df)	Represents the number of independent pieces of information in the model, which influences the chi-square statistic.	It helps to determine the model's fit; a higher number indicates more constraints in the model fit (Byrne, 2013).
p-value (P)	Indicates the probability of obtaining a chi-square statistic as extreme as the observed value, assuming the null hypothesis is true.	A p-value < 0.05 typically suggests poor model fit, while a p-value > 0.05 indicates adequate fit (Byrne, 2013).
Inferential fit index	Provides a ratio to evaluate the model's fit, considering model complexity.	A ratio of χ^2/df < 3 generally indicates an acceptable model fit (Byrne, 2013)
Comparative Fit Index (CFI)	Measures the relative improvement in the fit of the target model compared to a baseline model.	CFI values > 0.90 indicate a good fit, while values > 0.95 suggest an excellent fit (Byrne, 2013).
Tucker-Lewis Index (TLI)	Adjusts the CFI for model complexity, accounting for the number of parameters estimated.	TLI values > 0.90 indicate a good fit; values close to 1 suggest an excellent fit (Byrne, 2013).
Root Mean Square Error of Approximation (RMSEA)	Assesses how well the model approximates the observed data, with values closer to 0 indicating a better fit.	RMSEA<0.06 indicates a good fit, while values up to 0.08 are acceptable. Values > 0.10 suggest poor fit (Byrne, 2013).
Standardised Root Mean Square Residual (SRMR)	Indicates the average discrepancy between observed and predicted correlations, with values closer to 0 indicating a better fit.	SRMR values < 0.08 indicate a good fit, with lower values suggesting better model approximation (Byrne, 2013).

In addition to EFA and CFA, parameters were calculated to assess the internal consistency of the constructs. This includes Composite Reliability (CR), Average Variance Extracted (AVE) and Pearson correlation coefficients, as summarised in Table 3.6. These metrics ensure that the items within each construct consistently measure the same underlying concept and that the constructs are reliable and valid (Fornell and Larcker, 1981).

Composite reliability (CR) is frequently used as an indicator of internal consistency among items within each construct. This supports the reliability of the measurement model for further analysis (Hair *et al.,* 2020). In contrast to Cronbach's alpha, composite reliability assesses items based on their loading factors, rather than assuming that all items are equally reliable. Values between 0.70 and 0.90 are considered satisfactory (Hair *et al.*, 2011; Joseph F Hair *et al.*, 2019). Composite Reliability and Average Variance Extracted were computed to confirm the reliability and establish convergent validity, while convergent validity was further evaluated by examining factor loadings. The analysis assessed the strength and direction of the relationships between the constructs. CR and AVE are calculated using the following formulas:

$$CR = \frac{(\sum \boldsymbol{\lambda})^{\mathbf{2}}}{(\sum \boldsymbol{\lambda})^{\mathbf{2}} + \sum\left(\mathbf{1} - \boldsymbol{\lambda}^{\mathbf{2}}\right)} \quad \text{(Cheung et al., 2023; Kantor, 2023).} \tag{3-1}$$

Where: λ= standardised factor loadings of items, (∑λ) = sum of factor loadings, $\sum(1-\lambda^2)$ = sum of error variances.

$$\text{AVE} = \frac{\sum(\boldsymbol{\lambda}^{\mathbf{2}})}{\mathbf{n}} \quad \text{(Cheung et al., 2023; Kantor, 2023)} \tag{3-2}$$

Where λ is the standardised factor loadings of items and ***n*** is the number of items measuring that specific construct. For the CR and AVE to be valid, the following assumptions should be considered:

1. The items are highly correlated, and dropping one item should not alter the conceptual meaning of the construct.
2. Each set of items is assumed to measure a single, unified construct.

3. Items should load primarily on their intended construct.

AVE validation precedes and legitimises mediation analysis by confirming that each latent construct reliably captures its theoretical domain before interpreting pathways. The relevance of AVE to the mediation model is methodological rather than causal. Mediation analysis (indirect effects) relies on valid constructs. If AVE is low, constructs suffer from measurement error, which attenuates path coefficients and biases indirect effect estimates (Fornell and Larcker, 1981). Establishing AVE ensures that the mediator and outcome constructs possess sufficient convergent validity and subsequent SEM mediation paths are estimated on psychometrically sound constructs (Hair *et al*., 2013; Taherdoost, 2016).

CR confirms the internal consistency reliability of each construct (Hair *et al.*, 2020). Establishing CR ensures that constructs in the mediation model exhibit sufficient internal consistency, so that observed indirect effects reflect substantive theoretical mechanisms rather than artefacts of unreliable measurement (Hair *et al.*, 2011; Joseph F Hair *et al.*, 2019).

Pearson correlation coefficients were used to explore the relationships between constructs, as they are effective in measuring the linear relationship between two continuous variables (Gerber and Finn, 2005), providing preliminary insights into their interdependencies (Cohen, 1988).

Table 3.6: Parameters used to assess the validity and reliability of the constructs

Parameter	Purpose	Interpretation
Composite Reliability (CR)	To assess the reliability of a latent variable constructed from multiple indicators, it incorporates both the variance explained by the indicators and the error variances.	CR values above 0.70 are generally considered indicative of good reliability, ensuring that the construct measures consistently across items (Joseph F. Hair *et al.*, 2019; Hair *et al.*, 2011).
Convergent Validity using Average Variance Extracted (AVE)	To evaluate the amount of variance that a construct captures from its indicators relative to the amount of variance due to measurement error.	An AVE value of 0.50 or higher suggests acceptable convergent validity, indicating that the construct explains at least half of the variance in its indicators. (Rasoolimanesh *et al.*, 2015).
Internal Consistency Reliability	To measure the internal consistency of a set of items on a scale, indicate how closely related the items are as a group	Cronbach's Alpha values above 0.70 indicate acceptable reliability; values below 0.60 suggest the scale needs to be revised (Hajjar, 2018; Tavakol and Dennick, 2011).
Pearson correlation coefficients	To assess the strength and direction (positive vs negative) of the linear relationship between two continuous numerical variables, indicating the degree of association between them.	Correlation coefficients range from -1 to +1. Correlation Values of 0 to .30 are considered weak; .31 to .60 are considered moderate, while greater than .60 (absolute value) are considered strong correlations (Gerber and Finn, 2005).

3.3.5 Testing hypotheses and evaluating mediation

Once the data validity for each construct was confirmed, the study can then assess the proposed three single mediation hypotheses outlined in section 2.8 as follows:

H1: Safety knowledge mediates the relationship between risk perception and safety compliance.

H2: Safety culture mediates the relationship between risk perception and safety compliance.

H3: Situational awareness mediates the relationship between risk perception and safety compliance.

Structural Equation Modelling (SEM) was selected to examine these hypotheses due to its capability to simultaneously test multiple relationships and directions of relationships, and provide the overall fit of the theoretical model. SEM is performed using AMOS software (version 28). AMOS was deemed appropriate because it could provide more precise calculation measures through bootstrapping (Igartua and Hayes, 2021). The models were tested using bootstrapping with 5000 resamples to generate confidence intervals for the indirect effects, as suggested in other studies (Preacher and Hayes, 2008). The relationship between two constructs and the direction of the relationship was expressed in terms of the beta coefficient, with the accuracy and significance estimated along with other statistical parameters. Table 3.7 summarises the parameters used to describe the relationship. Baron and Kenny (1986) have illustrated that a variable mediates the relationship between two other variables when the basic relationship is reduced when the mediating variable is included in the regression equation. The fitness of the overall model was described using the same CFA parameters as those in the analysis of the individual construct (see Table 3.5). Additionally, Variance Accounted For (VAF) measures the degree to which the mediation process accounts for the variability of the dependent variable (Hair *et al.*, 2017). The VAF is calculated using the following formula by Ditlevsen *et al.* (2005).

According to Zhao *et al.* (2010), a general rule of thumb is that if the VAF is below 20%, it indicates scant mediation. Conversely, if the VAF falls between 20% and 80%, it could be regarded as a typical case of partial mediation.

The findings of the quantitative research are used to guide the qualitative stage of this mixed-method study.

Table 3.7: SEM Parameters used to assess the mediation

Parameter	Purpose	Interpretation
Beta coefficient (β)	To quantify the relationship between an independent variable and a dependent variable, indicating the expected change in the dependent variable for a one-unit change in the independent variable.	A higher absolute value of the Beta coefficient indicates a stronger relationship, with positive values indicating a positive relationship and negative values indicating an inverse relationship (Field, 2018).
Standard Error (S.E.)	To measure the accuracy of the Beta coefficient, which indicates the degree of variability in the estimate due to sampling error.	Smaller Standard Error values suggest more precise estimates of the Beta coefficient; larger values indicate less reliability (Field, 2018).
Critical Ratio (C.R.)	To assess the significance of the Beta coefficient, the ratio of the Beta coefficient to its Standard Error.	A Critical Ratio (C.R.) greater than 1.96 (or less than -1.96) typically indicates that the Beta coefficient is statistically significant at the 0.05 level (Field, 2018).
p-value (p)	To determine the probability of observing the results (or more extreme) if the null hypothesis is true, indicating the statistical significance of the results.	A p-value less than 0.05 indicates statistical significance, suggesting strong evidence against the null hypothesis, while a p-value greater than 0.05 suggests insufficient evidence to reject it (Preacher and Hayes, 2008).
Bootstrapping Confidence Interval (95% CI) [Lower, Upper]	To provide a range of values within which the true population parameter is expected to lie with 95% confidence, indicating the precision of the estimate.	If the Confidence Interval does not cross zero, it indicates a statistically significant indirect effect at the .05 significance level; narrower intervals suggest more precise estimates (Preacher and Hayes, 2008).
Variance Accounted For (VAF)	It measures the degree to which the mediation process accounts for the variability of the dependent variable.	According to Zhao *et al.* (2010), a general rule of thumb is that, if the VAF is below 20%, it indicates a scant mediation. Conversely, if the VAF is between 20% and 80%, it could be considered a typical case of partial mediation.

3.4 Qualitative research methodology

The second phase of the mixed-methods approach involves a qualitative study to explore the factors influencing the relationships between constructs. Section 3.4.1 outlines the rationale for employing interviews in the qualitative phase. Section 3.4.2 describes the development of semi-structured interview questions and the ethical considerations. Section 3.4.3 describes the recruitment procedure and considerations for participants, including the determination of the sample size. Section 3.4.4 describes the process of conducting interviews to collect data. Section 3.4.5 describes the thematic analysis framework to analyse data.

3.4.1 Research approach for the qualitative study

Qualitative research typically focuses on cultivating a profound comprehension rather than aiming for extensive coverage (Boddy, 2016). Research interviews aim to delve into individuals' perspectives, encounters, convictions, and/or driving factors regarding particular topics. Qualitative techniques, such as interviews, are thought to yield a deeper understanding of social phenomena compared to purely quantitative approaches such as surveys. Consequently, interviews are most suitable when seeking in-depth insights from individual participants regarding the subject of the study (Gill *et al.*, 2008).

There are three types of interviews: structured, semi-structured, and unstructured. Structured interviews refer to a specific type of interview method characterised by structured questionnaires, predominantly composed of fixed-choice questions, administered in a standardised fashion, encompassing closed and open-ended elements (Agarwal, 2019). They are characterised by a predetermined set of questions with limited flexibility for probing or exploring new topics (Mueller and Segal, 2015).

Semi-structured interviews, the most prevalent among qualitative research techniques (Alvesson and Deetz, 2020), involve asking pre-established questions that delineate the scope of the research area. These interviews are guided by a set of predetermined topics meant to be explored during the interview process. It is characterised by the balance between structure and flexibility, allowing interviewers to probe further or adapt their queries based on respondents' answers. It also enables a deeper exploration of complex issues while maintaining consistency and reliability (Mueller and Segal, 2015).

Unstructured interviews involve informal discussions that are suitable when interviewers lack prior knowledge of all the essential information beforehand (Patton, 2002). These interview types have no predetermined set of questions and rely heavily on the interviewer's skill and judgment (Mueller and Segal, 2015).

This research employs a mixed methods approach, where the outcomes from the quantitative phase can be utilised to structure the interview and inform the formulation of interview questions. Compared to the structured interview, where the setting of questions and procedure resembles a questionnaire, the semi-structured interviews can serve as a valuable supplementary tool to the quantitative phase of the study, enhancing and providing greater depth to other research methods (Adams, 2015). This type of interview provides extensive information, allowing for follow-up inquiries, the exploration of additional details, the validation of earlier responses, and the linking of various subjects (Choy, 2014). Additionally, it fosters a relaxed environment conducive to meaningful conversations (Kallio *et al.*, 2016). The stages of the qualitative study are illustrated in Figure 3.3 below.

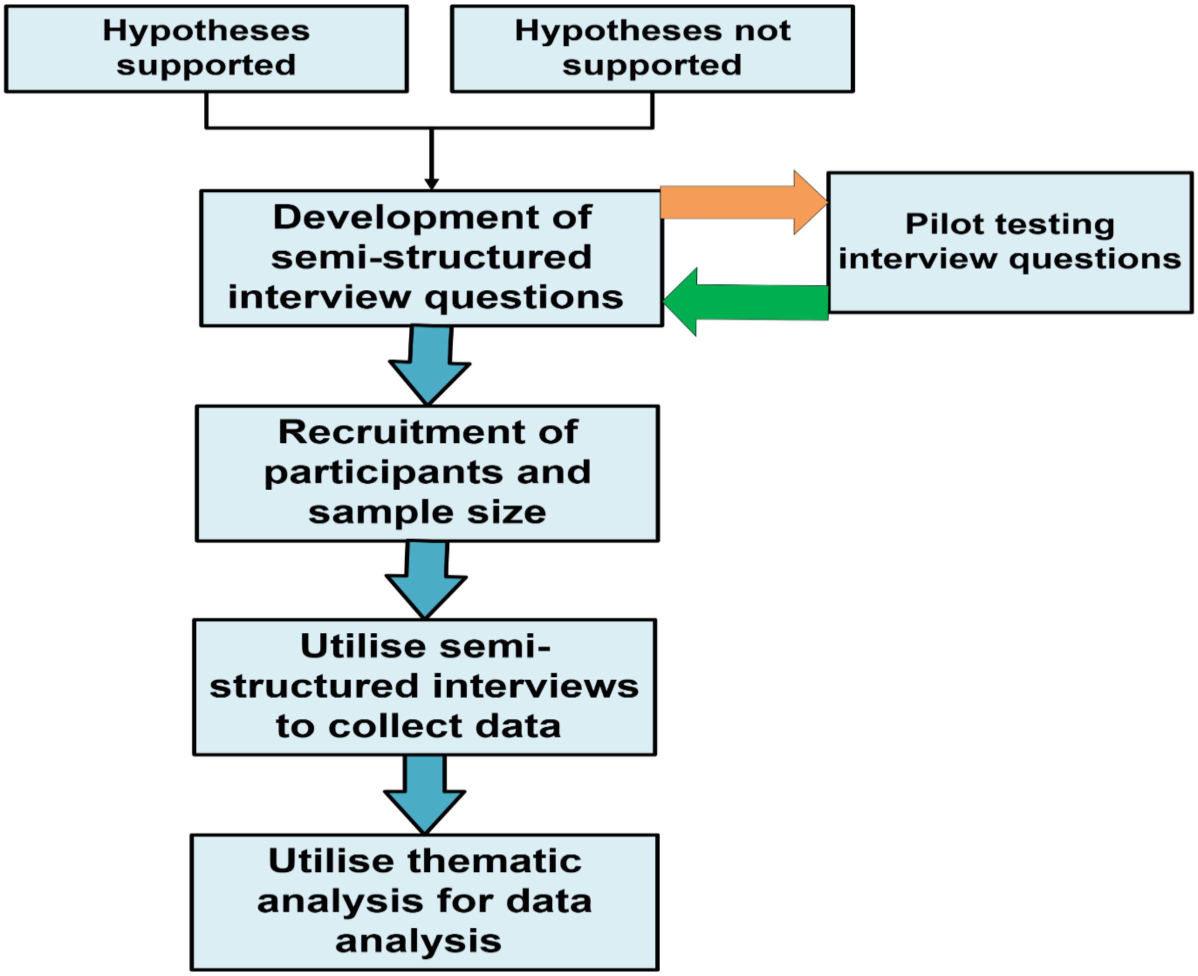

Figure 3.3: Stages of the qualitative research methodology

3.4.2 Development of semi-structured interview questions

The development of the interview guide in this study is directly informed by findings from the quantitative study, specifically focusing on the factors influencing situational awareness and safety compliance in the chemical and process industries. The interview guide is structured into three sections (See interview questions in Appendix E). The first part is an introductory section that establishes rapport and explains the study's purpose, followed by a main section comprising eight questions, six of which focus on potential factors that could affect the correlation between situational awareness and safety compliance in the workplace. The final section of the interview includes five confirmatory questions to assess the relationships between study constructs identified in the survey results. As the survey findings identified a statistically significant correlation between study constructs (e.g., risk perception positively influences safety knowledge), this phase aimed to assess these correlations qualitatively to support the quantitative results. Therefore, questions were straightforward, asking participants their opinion on each relationship. The coding and analysis of the data regarding these five questions will be discussed later in Section 3.4.5.

Once the interview questions were prepared, a pilot interview was conducted with a process engineer who was not part of the final study sample. The pilot aimed to identify any potential issues with question clarity and timing, as well as assess the effectiveness of the interview structure in eliciting the desired information. This process also verified that the interview guide was appropriate for achieving the research objectives.

Developing and refining the interview guide through the pilot interview ensured the questions were straightforward and could capture in-depth insights, providing a strong foundation for conducting the interviews. This preparation enabled a smooth interview process, allowing participants to engage openly and the researcher to gather detailed data by probing emerging themes during the conversation.

3.4.2.1 Ethical considerations in the qualitative phase

Ethics are at the heart of any research involving people (Lindorff, 2010; Mandal *et al.*, 2011); this study is no exception. Every step has been designed to respect participants' rights and well-being, from protecting their privacy to ensuring they fully understand what they agree to (Corti *et al.*, 2000; Petrova *et al.*, 2016). Participation is entirely voluntary, with clear safeguards to maintain confidentiality and comply with data protection laws (Morris and Schneider, 2010). These measures are not just boxes to tick; they are about creating a research process that is fair, transparent, and built on trust. Ethical considerations for the qualitative phase are:

1. Voluntary Participation: Participation in the interviews is entirely voluntary, and participants can withdraw at any time before or during the interview process without giving a reason. This ensures that the principle of autonomy is upheld.
2. Informed Consent: Participants were required to read and understand the Participant Information Sheet and Privacy Notice before agreeing to participate. This guarantees they

are aware of the purpose of the study, what their involvement entails, and their rights, ensuring informed consent is obtained

3. Confidentiality and Anonymity: Identifiable data, such as personal information and company names, will be anonymised during transcription and analysis. Only aggregated and anonymised data will be included in publications, ensuring confidentiality and preventing identification.
4. Right to Withdraw: Participants can withdraw their consent and request the deletion of their interview recordings before or during the session. Once the recordings are transcribed and anonymised, withdrawal of specific data is no longer possible, as individual responses cannot be identified.
5. Data Protection: The research complies with data protection legislation like the Data Protection Act 2018. Data will be stored securely on encrypted systems managed by the University of Strathclyde, ensuring its safety and integrity.
6. Limited Access to Data: Only the research team has access to the collected data, and it will not be shared with external organisations, safeguarding the privacy of participants.
7. Retention and Destruction of Data: Transcriptions will be retained for five years and then securely destroyed. This retention period aligns with institutional policies and ethical guidelines.
8. The University of Strathclyde Ethics Committee granted ethical approval for the research.

Based on these principles, an application was submitted to the departmental ethics committee for this phase of the study. Feedback was provided and incorporated to refine the approach, which was then granted the research Ethical approval.

3.4.3 Recruitment of participants

In this qualitative study, the sampling strategy follows a purposive sampling approach, targeting participants who are likely to provide information related to the research question. Specifically, participants were individuals who had previously participated in the quantitative survey and expressed a willingness to participate in follow-up interviews by providing their email addresses. This targeted approach ensures that the participants have direct experience with situational awareness and safety compliance in the chemical and process industries, which is crucial for addressing the research question.

In contrast to quantitative studies, qualitative research often employs smaller sample sizes to gather detailed data, thereby providing a deeper understanding of participants' experiences. This allows the results to be transferable to other contexts or groups rather than generalisable (Bradshaw *et al.*, 2017). The sample size of this study was determined based on the principle of data saturation, where no new themes or insights emerged from additional interviews, indicating that the data collected was sufficient to answer the research question (Fusch *et al.*, 2018; Marshall *et al.*, 2013).

The sample size for this qualitative study was determined through alignment with established saturation guidelines. Hennink and Kaiser (2022) report that saturation typically occurs with 9–17 interviews in homogeneous populations. The present study aims to recruit between 20 and 30 participants, which aligns with recommendations for achieving saturation in qualitative studies (Cohen *et al.*, 2000; Hennink and Kaiser, 2022). The target sample within this range was deemed methodologically appropriate. This decision also reflected practical considerations, including the limited timeframe for data collection, and the recognition that qualitative inquiry prioritises depth and nuance over statistical generalisability (Braun & Clarke, 2006). Following ethical approval, recruitment was initiated through targeted invitation emails sent to 30 individuals who had expressed prior interest in participating. Each invitation included the Participant Information Sheet (Appendix F) and a Privacy Notice (Appendix G), ensuring informed consent. Ultimately, 20 participants agreed to participate, a number deemed both sufficient to achieve saturation and feasible within the study’s practical constraints.

3.4.4 Data collection and transcription

The researcher employed interviews as the data collection method to obtain comprehensive insights from the participants regarding the topic. The interviews give strong emphasis on building rapport to ensure participants feel comfortable and willing to share open and honest insights into their experiences (Bradshaw *et al.*, 2017). Once rapport was established, the interviews were recorded with the participants' consent. During the interviews, thoughtful questioning, sensitive probing techniques, and reflective listening were employed to encourage in-depth responses. As participants shared their experiences, additional questions were asked to explore emergent topics and interesting insights in greater detail, as suggested in other studies (Salmons, 2014). The duration of the interviews ranged from forty-five to sixty minutes. All interviews were conducted via Zoom or Skype, and the audio recording tools built into the softwares were used. The researcher subsequently transcribed these recordings.

After the initial transcription, the researcher revisits the audio recording several times to ensure the text accurately reflects the conversation, correcting any potential errors in spelling, wording, or phrasing. This careful review helps avoid misinterpretation or loss of important information. The transcription process also involved anonymising the data by removing identifying information to protect participants' confidentiality and privacy. In compliance with ethical standards, the recordings were deleted within 24 hours after transcription, and the transcribed data were securely stored on the university's OneDrive platform, ensuring the safety and confidentiality of the collected data (Salmons, 2014). At this point, the data is ready for the thematic analysis stage.

3.4.5 Utilise the Thematic Analysis framework to analyse data

This study employed thematic analysis as the primary method for analysing the qualitative data gathered from the semi-structured interviews. As described by Braun and Clarke (2006), thematic analysis is a flexible and robust approach to identifying, analysing, and reporting patterns (or themes) within data. It is especially suitable for exploring complex and nuanced data, making it an ideal method for investigating factors that influence the relationship between situational awareness and safety compliance in the chemical and process industries. The data analysis process followed the six-phase guide proposed by Braun and Clarke (2006).

There are typically two possible approaches to coding: deductive and inductive (Braun and Clarke, 2006). Due to its ability to provide a focused lens for data analysis, deductive coding is particularly useful for addressing specific research questions that aim to confirm or explore established constructs or relationships. Inductive coding is a method of coding in which codes are generated directly from the data; it does not rely on any previously established theories or concepts. It is utilised to capture nuanced insights, particularly when investigating new or significantly less understood phenomena. Therefore, both deductive and inductive coding were used.

Deductive coding in thematic analysis is a methodology-driven approach where pre-existing concepts guide the analysis (Braun and Clarke, 2006). Deductive coding was used to analyse questions that aimed to confirm the relationships between study constructs (e.g., risk perception and safety knowledge), which were identified in the quantitative phase. The relationships identified previously served as a guide for coding the data collected from the interviews. On the other hand, the six-step inductive coding approach, illustrated in Figure 3.4, was used to investigate underlying factors that affect the relationships between situational awareness and safety compliance. The implementation of each step is explained as follows.

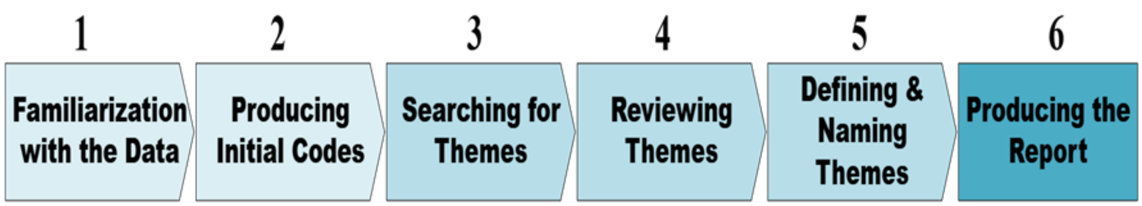

Figure 3.4: Thematic analysis process (inductive coding approach) by Braun and Clarke (2006)

The first step involved familiarising oneself with the data by thoroughly reading and re-reading the interview transcripts while listening to the audio recordings. This immersion was crucial for capturing the full breadth and depth of participants' responses, allowing the researcher to develop an initial understanding of the data's subtleties and emerging patterns. Detailed notes and observations were recorded during this phase, which formed the foundation for the subsequent coding process.

The second step generated initial codes by systematically identifying and labelling relevant segments of the text based on their relevance to the research questions. Each code represented a distinct concept or idea expressed by the participants, capturing both explicit and implicit meanings. The software (NVivo 12 Pro) was employed to organise and manage these codes, facilitating a structured approach to handling and categorising the significant portions of data.

This tool enabled efficient data management, streamlining the organisation of codes and ensuring the systematic capture of all relevant insights for further analysis.

After coding, the third step involved searching for themes by examining the relationships and patterns among the codes. This study then consolidated the codes with comparable meanings to formulate themes that encapsulated the fundamental nature of the participants' experiences. For example, several codes pertaining to "safety training," "experience," and "overconfidence" can be categorised within the overarching theme of "Individual factors”.

The fourth step reviewed the initial themes to ensure they accurately represented the data and were coherent and distinct. Themes that were too broad or lacked supporting data were modified or, in some cases, eliminated. This refinement ensured that the final themes were distinct and provided a clear and reliable interpretation of the participants' perspectives. This involved carefully refining the themes to ensure they captured the essence of the data.

In the fifth step, the refined themes were assigned descriptive and concise titles that effectively communicated their meaning. A theme captures a common, recurring pattern across the dataset, clustered around a central organising concept. A theme was developed by identifying repeated ideas that recur across interviews, clustering related codes around a singular, unifying concept. This concept becomes the theme. On the other hand, a sub-theme was developed by grouping codes that share a specific focus on a core idea. All codes under it align with the same specific idea and do not overlap with other sub-themes. A subtheme exists ‘underneath’ the umbrella of a theme. This then led to the final step, where the findings on each theme were discussed in a detailed discussion, including their connections to the research questions, with direct quotations from the participants used to illustrate key points and provide context for the analysis.

To ensure methodological rigour in theme development, this study adopted clear criteria for identifying and illustrating themes. A theme highlights a significant aspect of the data in relation to the research question (Braun and Clarke, 2006). In qualitative analysis, there is no definitive rule for how much of the data set must demonstrate a theme for it to be recognised (Braun and Clarke, 2006). For example, Clarke and Kitzinger (2004) identified six themes, one of which is developed in only two talk shows, based on significance rather than frequency, across 26 episodes of talk shows featuring lesbians and gay parents. In this study, themes were required to appear in at least four interviews to ensure relevance while avoiding over-fragmentation. Direct quotes were included to illustrate the themes that met this threshold. This approach balances Clarke and Kitzinger's (2004) emphasis on "significance over frequency" with the need for discernible patterns in a sample of 20. Thus, a theme appearing in four interviews was deemed sufficiently prevalent to reflect a shared perspective. By following Braun and Clarke's (2006) six-phase framework, the analysis maintained depth, consistency, and credibility, ensuring the validity of the findings.

Chapter 4: Quantitative Data Analysis and Results

This chapter consists of seven main sections. Section 4.1 presents an initial assessment of the homogeneity of responses to perform descriptive analysis. Section 4.2 presents the initial descriptive analysis to provide an overview of the dataset and summarise the data's characteristics. Section 4.3 presents the factor analysis of the study's constructs to evaluate the underlying structure of the constructs to ensure their validity for further analysis. Section 4.4 presents the analysis of validity and reliability for the constructs to further support the results of the factor analysis. Section 4.5 examines the strength of relationships between constructs using the bivariate correlation coefficient. Section 4.6 presents mediation analysis and hypothesis testing of the proposed models. Finally, Section 4.7 presents a summary of the chapter.

4.1 Initial assessment of the homogeneity of responses

As illustrated in Table 4.1, the majority of the 302 participants belonged to two main departments: Production (138, 46%) and Health and Safety (H&S) (64, 21%), representing approximately two-thirds of the sample.

Table 4.1: Participants' frequency across departments

Department	Frequency	Percentage
Health and Safety	64	21%
Production	138	46%
Maintenance	30	10%
Utilities	12	4%
Mechanical	13	4%
Electrical	16	5%
Instrumentation	17	6%
Other	12	4%
Total	302	100%

As the response within these two groups (Production and Health and Safety) could greatly influence the overall response, Levene's test was applied to assess the homogeneity of variances between participants' responses in H&S and production departments. Levene's test was developed to assess the equality of variances across two or more groups in a dataset (Levene, 1960). The definition of the parameters used in Levene's test is summarised in Table

3.3, Section 3.3.4. As shown in Table 4.2, the p-value from Levene's test parameters indicates equal variances (p-value >0.05) for all constructs

Interestingly, situation awareness exhibits a significantly larger F value with the p-value closer to the significant level of the test (0.05), compared to other constructs. A higher F value suggests a greater disparity in variances between the groups being compared. Non-significant p-values (all constructs > 0.05) indicate no significant difference in variances between the groups for all constructs. For Situational Awareness, the p-value (0.06) approaches the 0.05 threshold, suggesting potential variability in responses between groups. However, equal variances can be assumed for all constructs, justifying the use of the standard t-test to test the homogeneity.

Table 4.2: Summary of Levene's and T-test on the difference between departments H&S and Production

Main groups H&S & Production	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	p-value*	t-statistic	p-value*	Mean Difference
Risk Perception	.070	.792	.033	0.973a	.003
Safety Compliance	.088	.767	.288	0.773a	.024
Safety Knowledge	.032	.858	1.068	0.287a	.083
Safety Culture	.054	.816	.195	0.846a	.014
Situational Awareness	.728	.06	1.193	0.69a	.021
*Asymptotic significances (2-sided test) displayed. The significance level p-value is .05. a. Statistically insignificant difference. N =202. Degree of freedom (df) = 200					

The t-test for equality of means tests whether the mean scores of the two groups (H&S vs. Production) differ significantly. All p-values > 0.05 indicate no statistically significant differences in means between the groups for any construct. Mean differences (e.g., 0.003 for risk perception, 0.024 for safety compliance) are negligible, aligning with the non-significant results. Largest t-statistic (1.068 for safety knowledge, 1.193 for situational awareness) still falls far below the critical value for significance (±1.96 at p = 0.05). The lack of significant differences in means (t-test) suggests that employees in H&S and production departments exhibit similar levels of risk perception, safety compliance, safety knowledge, safety culture, and situational awareness. The assumption of sample homogeneity of variances is met. Thus, the sample is considered homogeneous (Gastwirth *et al.*, 2009).

Despite the homogeneity of the sample, as illustrated, the researcher decided to exclude participants from the H&S department from the dataset because safety professionals often have a more objective outlook on operational risks, focusing on procedural compliance and systemic controls (Rae *et al.*, 2018). In contrast, the immediacy of their personal safety dominates the perceptions of frontline workers. This creates a different cognitive framework for evaluating risk. By excluding H&S department participants, the researcher aimed to ensure that the data are grounded in the direct, personal experience of operational risk, which is essential for the validity and interpretability of the findings. Therefore, the final sample size after omitting the H&S participants is 238, which is used in the subsequent analysis.

4.2 Descriptive statistics

This section provides background information on the participants. The study's sample of 238 individuals reveals a professional landscape across various industries (Table 4.3). Gender representation is predominantly male at 83.6% (199 participants), compared to just 16.4% female (39). Early-career engineering graduates, both males and females, exhibit similar motivations regarding their career pathway selections (VanAntwerp and Wilson, 2015). However, according to Hunt (2016), many women leave the engineering profession due to reasons such as low pay and limited opportunities for promotion. The higher the male share, the greater the excess female exits from the field. Other literature, such as Singh *et al.* (2018), suggests that family–related constraints and dissatisfaction with working conditions lead women to leave engineering occupations early in industries like the CPI.

Educational backgrounds show concentration, with bachelor's degree holders comprising the majority at 58% (137), while postgraduate qualifications (MSc and PhD) account for 25% (59). The age distribution is most pronounced in the 27-42 age range, with an equal representation of 34% (80) in each bracket, suggesting a prime career-stage sample. Departmentally, Production emerges as the clear leader, accounting for 58% (138), significantly outnumbering other departments, such as Maintenance, at 13% (30). Industry-wise, the chemical sector dominates at 51% (121), followed by oil and gas at 27.3% (65). Professional roles are similarly concentrated, with Engineers at 38% (90) and Operators at 33% (79), reflecting a technical, operational-focused sample.

Table 4.3: Demographic Profile of Participants

Gender						
Male			Female			
199 (83.6%)			39 (16.4%)			
Education						
Secondary School	Bachelor	MSc	PhD	Other		
9 (4%)	137 (58%)	48 (20%)	11 (5%)	33 (14%)		
Age group						
18-26	27-34	35-42	43-50	51-58	>58	
21 (9%)	80 (34%)	80 (34%)	47 (20%)	8 (3%)	2 (1%)	
Department						
Production	Maintenance	Instrumentation	Electrical	Mechanical	Utilities	other
138 (58%)	30 (13%)	17 (7%)	16 (7%)	13 (5%)	12(5%)	12(5)
Industry						
Chemical	Oil and Gas	Energy	Nuclear	Food & drinks	Minerals	other
121 (51%)	65 (27.3%)	16 (7%)	9 (4%)	7 (3%)	7 (3%)	13(5)
Job role						
Engineer	Operator	Technician	Specialist	Area manager	Senior manager	Other
90 (38%)	79 (33%)	15 (6%)	14 (6%)	14 (6%)	7 (3%)	19(8%

Furthermore, regarding the experience of accidents, injuries, or near misses, a significant majority of respondents, 179 (75%), reported not having experienced any such incidents. However, 59 (25%) had experienced accidents or had been involved in them in the past five years. Among these 59, the majority, 43, reported no injuries; 14 sustained minor injuries, and only 2 suffered major injuries.

4.3 Factor analysis of constructs

Factor analysis represents a critical methodological strategy for establishing the conceptual integrity and measurement precision of complex research constructs (Bandalos, 2018; Fabrigar and Wegener, 2012; Kline, 2018; Raykov and Marcoulides, 2008; Tabachnick *et al.*, 2013). In this study, we employed a sophisticated two-stage factor analysis approach, integrating Exploratory (EFA) and Confirmatory (CFA) Factor Analysis to systematically validate the multidimensional nature of our measurement constructs to achieve:

- Construct validation: To examine the relationships between observed variables and underlying theoretical constructs
- Measurement refinement: To identify and eliminate potentially redundant or conceptually ambiguous measurement items

This research focused on five constructs: risk perception, safety compliance, safety knowledge, safety culture, and situational awareness. In EFA, we utilised Principal Component Analysis (PCA) with Oblimin rotation to systematically decompose the interrelationships among the survey items (Tabachnick and Fidell, 2007). This allowed us to reveal the structural dimensions of constructs and assess the interdependencies between measurement items (Kline and Little, 2015). The CFA further validated the factor structure identified through EFA, assessing the extent to which the measured variables accurately represent theoretical constructs and evaluating the model's overall fit and construct reliability (DiStefano and Hess, 2005). Methodological considerations included adhering to recommended sample size guidelines (50-300 participants or more), based on the number of observations per variable, such as twenty-to-one (Pituch and Stevens, 2015) (section 3.3.2), verifying normality assumptions through skewness and kurtosis assessments, and thoroughly evaluating factor loadings and construct dimensionality.

This two-stage factor analysis approach verifies the constructs and provides greater confidence in subsequent analytical procedures. This approach demonstrates a sophisticated method of establishing construct validity. Multiple evaluations have been performed to ascertain the suitability and adequacy of the data for PCA, as detailed in Section 3.3.4, to conduct the EFA (Field, 2018). The following subsections will present the EFA and CFA for each construct.

4.3.1 Factor analysis for risk perception

As described in Section 3.3.1, the concept of risk perception was assessed using 12 items. These items represent four dimensions: perceived health threat of risks, perceived severity of risks, perceived controllability, and perceived affect possibility. The EFA and CFA were performed to evaluate the validity of the risk perception construct within the context of this research, acknowledging that the risk perception items utilised in this study were adapted from a previous study in the literature, as described in Section 3.3.1.

1) Exploratory Factor Analysis (EFA)

The EFA was performed to identify shared common characteristics or significant patterns among the 12 risk perception items analysed. An examination of the bivariate correlation matrix revealed that all items exhibit correlations with an absolute value greater than 0.3, as shown in Table H1, Appendix H. These correlations provide the basis for these items to be connected and to measure the same construct. The initial Kaiser-Meyer-Olkin (KMO) measure for the overall data was 0.879, as shown in Table 4.4, indicating a high level of sampling adequacy. Additionally, the individual loading values ranged from 0.710 to 0.856, all of which exceeded the minimum threshold of 0.5. These values indicate that each item is strongly related to the respective factor. Bartlett's test of sphericity yielded a p-value <0.001, indicating statistical significance as necessary to perform factor analysis. Bartlett's test of sphericity confirms that the correlations among variables are sufficient to proceed with EFA, meaning the data are suitable for uncovering latent structures. These results suggest that Principal Component Analysis (PCA) can be performed.

Table 4.4: KMO and Bartlett's Test of Sphericity for Risk Perception

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.879
Bartlett's Test of Sphericity	Approx. Chi-Square	1241.867
	df	166
	Sig.	<.001

The PCA identified four factors with eigenvalues greater than one, in accordance with the eigenvalue-one criterion (also known as the Kaiser criterion) (Field, 2018; Pituch and Stevens, 2015) . The exploratory factor analysis presented four factors in Table 4.5. This table presents the underlying factor structure of the risk perception construct. The PCA revealed four factors associated with the structure of risk perception, accounting for a total of 66% (Kantor, 2023) of the variance extracted from the 12 items, as shown in Table 4.5. The perceived health threat of risk accounts for 18.12% of the total variance, representing a central component of respondents' risk perception. This may suggest that respondents regard the perceived health threat of risk as the most fundamental element in their risk perceptions.

Table 4.5: Results of exploratory factor analysis for risk perception

Oblique Rotated Factor Loadings					
	Factor1	Factor2	Factor3	Factor4	Communality
Item	PHTR	PSR	PCR	PAP	
PHTR1	0.758				0.574
PHTR2	0.831				0.690
PHTR3	0.732				0.536
PSR1		0.753			0.567
PSR2		0.804			0.646
PSR3		0.766			0.587
PCR1			0.856		0.732
PCR2			0.723		0.523
PCR3			0.720		0.518
PAP1				0.724	0.524
PAP2				0.843	0.710
PAP3				0.710	0.504
Eigenvalue	2.67	2.37	1.99	1.71	
% of variance	18.12	17.55	16.78	15.19	
Cronbach's alpha	0.785	0.736	0.76	0.7	

Table 4.5 above illustrates that all communalities possess values exceeding the minimum threshold of 0.5, ranging from 0.504 to 0.732, suggesting they are well-represented by the model (Gebremedhin *et al.*, 2022; Hadi *et al.*, 2016; Mohd Matore *et al.*, 2019). The factor loadings obtained ranged from 0.710 to 0.856, consistent with the minimum value of 0.5. This indicates each item has a substantial relationship with the underlying risk perception construct. Furthermore, the reliability and internal consistency of the four factors were assessed using Cronbach's Alpha values, which ranged from 0.7 to 0.785, exceeding the minimum acceptable threshold of 0.6 (Hair *et al.*, 2018). The risk perception construct, comprising 12 items (four factors), exhibited a Cronbach's alpha of 0.892. The reliability increases with the number of homogeneous items, which are interrelated dimensions of a unified risk perception construct.

2) Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) is a statistical technique that verifies the factor structure of a set of observed variables (Suhr, 2006). The four factors extracted in EFA are employed in CFA. The data's univariate normality was assessed using skewness and kurtosis scores to perform CFA. The analysis revealed no significant deviation from normality, as the skewness and kurtosis values fell within the ranges of ±1 and ±2, respectively (Byrne, 2016; Kline, 2018). These values can be found in Table 4.6. Consequently, the Maximum Likelihood Estimation (MLE) method was employed to perform CFA in AMOS software (Reisinger and Mavondo, 2007). As detailed in Table 3.5 below, the initial measurement model demonstrated a good fit, with all fit indices aligning with the acceptable values outlined in Section 3.3.4.

Table 4.6: CFA results for the measurement model of Risk Perception

Model fit indices	χ^2	df	p	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.06
Initial model	97.193	47	0.001	2.068	0.96	0.94	0.04	0.041
χ2: Chi-square. df: Degrees of freedom. p: p-value. χ2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual								

Additionally, Table 4.7 presents the standardised factor loadings for the risk perception construct. These factor loadings confirm that the hypothesised four-factor structure (identified in Table 4.5) is statistically viable. Table 4.7 demonstrates that the standardised factor loadings for the measurement model varied between 0.546 and 0.873, and they were statistically significant, with a p-value < 0.001. Standardised factor loadings indicate the strength of each item's association with the risk perception construct, with values closer to 1.0 representing a stronger relationship (Kline and Little, 2015). Almost all values are above 0.6, suggesting a moderate to strong relationship. These moderate-to-high loadings confirm that the items collectively measure each factor effectively, with each factor being well-represented by its respective items (Hair *et al.*, 2013; Joseph F. Hair *et al.*, 2019). The significant factor loadings further confirm that the items reliably measure the intended latent variables (factors), supporting the use of these factors in further analysis (Tabachnick *et al.*, 2013).

Table 4.7:The CFA standardised factor loadings for risk perception

CFA Standardised Factor Loadings*				
Item	PHTR	PSR	PCR	PAP
PHTR1	0.728			
PHTR2	0.873			
PHTR3	0.679			
PSR1		0.653		
PSR2		0.683		
PSR3		0.739		
PCR1			0.729	
PCR2			0.683	
PCR3			0.746	
PAP1				0.661
PAP2				0.746
PAP3				0.546

Notes: N = 238.

PHTR= perceived health threat of risks. PSR= Perceived Severity of Risks. PCR= Perceived controllability of Risks. PAP= Perceived Affect Possibility.

*All standardised factor loadings are significant at p < 01.

4.3.2 Factor analysis for safety compliance

As mentioned in Section 3.3.1, safety compliance was assessed using four items. The construct's validity was assessed through EFA and CFA.

1) Exploratory Factor Analysis (EFA)

The EFA was performed to identify shared common characteristics or significant patterns among the four safety compliance items analysed. An examination of the bivariate correlation matrix revealed that all items exhibit correlation with an absolute value greater than 0.3, as shown in Table H2, Appendix H. The initial Kaiser-Meyer-Olkin (KMO) measure for the overall data was 0.879, indicating a high level of sampling adequacy

Table 4.8. Additionally, the individual loading values ranged from 0.720 to 0.816, as presented in Table 4.9, all of which exceeded the minimum threshold of 0.5. These values indicate that each item is strongly related to safety compliance. Bartlett's test of sphericity yielded a p-value <0.001, indicating statistical significance as necessary to perform Principal Component Analysis (PCA).

Table 4.8: KMO and Bartlett's Test of Sphericity for safety compliance

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.754
Bartlett's Test of Sphericity	Approx. Chi-Square	240.623
	df	6
	Sig.	<.001

Table 4.9: Results of Exploratory Factor Analysis for safety compliance

Oblique Rotated Factor Loadings		
Item	SC	Communality
SC1	0.747	0.558
SC2	0.816	0.665
SC3	0.808	0.653
SC4	0.720	0.518
Eigenvalue	2.363	
% of variance	60%	
Cronbach's alpha	0.764	
Notes: N = 238. Factor loadings greater than 0.4 are considered acceptable (Pett et al., 2003). SC= Safety Compliance. The total variance explained = 60%. Cronbach's alpha for Safety compliance = 0.764		

Following the initial analysis, Principal Component Analysis (PCA) identified one factor with an eigenvalue greater than 1, as determined by the eigenvalue-one criterion (Field, 2018;

Pituch and Stevens, 2015). This factor accounted for 60% of the variance in the data, which is considered acceptable in social science according to Koyuncu and Kılıç (2019) (Table 3.4). The results are presented in Table 4.9. All communalities exceed the minimum threshold of 0.5, indicating that each item makes a meaningful contribution to the safety compliance construct. The Cronbach's Alpha value for safety compliance is 0.764, above the minimum acceptable value of 0.6 (Hair *et al.*, 2018). This indicates good internal consistency, suggesting that the four items consistently measure the same underlying construct of safety compliance.

2) Confirmatory Factor Analysis (CFA)

The four items used in EFA are used in CFA. The data's univariate normality was evaluated using skewness and kurtosis scores to perform CFA. The analysis revealed no significant deviation from normality, as the skewness and kurtosis values fell within the ranges of ±1 and ±2, respectively (Byrne, 2016; Kline, 2018). These values can be found in Table I2, Appendix I. Consequently, the Maximum Likelihood Estimation (MLE) method was employed. As detailed in Table 4.10 below, the initial measurement model demonstrated a good fit, with all fit indices aligning with the acceptable values outlined in Table 3.5.

Table 4.10: CFA results for the measurement model of safety compliance.

Model fit indices	χ^2	*df*	*p*	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	4.588	2	0.037	2.294	0.98	0.95	0.05	0.029

χ^2: Chi-square. df: Degrees of freedom. p: p-value. χ^2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual

Additionally, Table 4.11 demonstrates that the standardised factor loadings for the measurement model varied between 0.661 and 0.763, and they were statistically significant with a p-value < 0.001. Standardised factor loadings indicate the strength of each item's association with the safety compliance construct, where values closer to 1.0 represent a stronger relationship (Kline and Little, 2015). Nearly all values are above 0.6, suggesting a moderate to strong relationship.

Table 4.11: Results of CFA Standardised Factor Loadings of Safety Compliance.

CFA Standardised Factor Loadings*	
Items	SC
SC1	0.641
SC2	0.763
SC3	0.730
SC4	0.661
Notes: N = 238. **SC**= Safety Compliance. *All standardised factor loadings are significant at p < 0.01.	

These high loadings confirm that the items effectively measure the construct, which is well-represented by its respective items (Hair *et al.*, 2013; Joseph F. Hair *et al.*, 2019). These factor loadings confirm that each item has a meaningful relationship with the latent construct (safety compliance). The significant factor loadings further confirm that the items reliably measure the intended latent variable, supporting the use of this construct in further analysis (Tabachnick *et al.*, 2013).

4.3.3 Factor analysis for safety knowledge

Following the details provided in Section 3.3.1, the concept of safety knowledge was evaluated as an independent construct. This evaluation involved using 20 items to assess this construct. These items represent safety training, knowledge of control measures, seeking safety information, and knowledge of safety procedures. The items used in the study were obtained from various previous studies in the literature, as described in Section 3.3.1.

1) Exploratory Factor Analysis (EFA)

The EFA was performed to identify shared common characteristics or significant patterns among the 20 safety knowledge items analysed. An examination of the bivariate correlation matrix revealed that all items exhibit correlation with an absolute value greater than 0.3, as shown in Table H3, Appendix H. The initial Kaiser-Meyer-Olkin (KMO) measure for the overall data was 0.938, indicating a high level of sampling adequacy (Table 4.12). Additionally, the individual loading values ranged from 0.712 to 0.880, all of which exceeded the minimum threshold of 0.5. These values indicate that each item is strongly related to the factor. Bartlett's test of sphericity yielded a p-value <0.001, indicating statistical significance as necessary to perform Principal Component Analysis.

Table 4.12: KMO and Bartlett's Test of Sphericity for safety knowledge

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.938
Bartlett's Test of Sphericity	Approx. Chi-Square	3341.014
	df	190
	Sig.	.000

Following the initial analysis, the Principal Component Analysis (PCA) identified four factors with eigenvalues greater than one, as determined by the eigenvalue-one criterion (Field, 2018; Pituch and Stevens, 2015).

The factor analysis revealed four factors, as shown in Table 4.13. Principal Component Analysis (PCA) revealed four factors in the safety knowledge structure, accounting for 65.676% of the variance extracted from the 20 items (Kantor, 2023). The safety training factor explains the highest variance (18.728), representing a central component of respondents' safety knowledge. This suggests that respondents consider training to be the most fundamental aspect of safety knowledge.

Table 4.13: Results of exploratory factor analysis for safety knowledge

Oblique Rotated Factor Loadings					
Item	ST	KCM	SSI	KSP	Communality
ST1	0.762				0.582
ST2	0.760				0.578
ST3	0.794				0.630
ST4	0.855				0.732
ST5	0.809				0.654
KCM1		0.812			0.660
KCM2		0.880			0.774
KCM3		0.834			0.696
KCM4		0.810			0.656
KCM5		0.800			0.640
SSI1			0.835		0.698
SSI2			0.799		0.639
SSI3			0.841		0.707
SSI4			0.760		0.577
SSI5			0.807		0.652
SSI6			0.782		0.611
KSP1				0.808	0.652
KSP2				0.814	0.662
KSP3				0.729	0.531
KSP4				0.712	0.506
Eigenvalue	4.863	4.13	3.8	3.41	
% of variance	18.728	16.564	16.050	14.334	
Cronbach's alpha	0.772	0.812	0.770	0.765	

Notes: N = 238. Factor loadings greater than 0.4 are considered acceptable (Pett *et al.*, 2003).
Communality = the sum of squared factor loadings.
ST= safety training, KCM = knowledge of control measures, SSI= seeking safety information, KSP= knowledge of safety procedures.
The total variance explained is about **65.676%**.
Cronbach's alpha for safety knowledge = **0.928**

Table 3.14 above demonstrates that all communalities possess values exceeding the minimum threshold of 0.5, ranging from 0.506 to 0.774, suggesting that they are well-represented by the model (Gebremedhin *et al.*, 2022; Hadi *et al.*, 2016; Mohd Matore *et al.*, 2019), which implies that each item contributes meaningfully to the construct. The factor loadings obtained ranged from 0.712 to 0.880, consistent with the minimum value of 0.5. This indicates each item has a substantial relationship with the underlying safety knowledge construct. Furthermore, the reliability and internal consistency of the four factors were assessed using Cronbach's Alpha values, which ranged from 0.765 to 0.812, exceeding the minimum acceptable threshold of 0.6 (Hair *et al.*, 2018). The safety knowledge construct (20 items) exhibited a Cronbach's Alpha of 0.928.

2) Confirmatory Factor Analysis (CFA)

The four factors extracted in EFA are used in CFA. The data's univariate normality was evaluated using skewness and kurtosis scores to perform CFA. The analysis indicated no significant deviation from normality, as the skewness and kurtosis values were within the range of ±1 and ±2, respectively (Byrne, 2016; Kline, 2018), as shown in Appendix I. Consequently, the Maximum Likelihood Estimation (MLE) method was employed. As detailed in Table 4.14 below, the initial measurement model demonstrated a good fit, with all fit indices aligning with the acceptable values outlined in Section 3.3.4.

Table 4.14: CFA results for the measurement model of the safety knowledge

Model fit indices	χ^2	*df*	*p*	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	307.619	157	.000	1.959	0.95	0.94	0.059	0.038

χ^2: Chi-square. *df*: Degrees of freedom. p: p-value. χ^2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual.

Moreover, Table 4.15 demonstrates that the standardised factor loadings for the measurement model varied between 0.598 and 0.822, and they were statistically significant with a p-value < 0.001. Standardised factor loadings indicate the strength of each item's association with the safety knowledge construct, with values closer to 1.0 representing a stronger relationship (Kline and Little, 2015). Nearly all values are above 0.6, suggesting a moderate to strong relationship. These moderate-to-high loadings confirm that the items collectively measure each factor effectively, with each factor being well-represented by its respective items (Hair *et al.*, 2013; Joseph F. Hair *et al.*, 2019). These factor loadings indicate how much variance in each item is explained by the construct it's intended to measure. The significant factor loadings further confirm that the items reliably measure the intended construct, supporting the use of these factors in further analysis (Tabachnick *et al.*, 2013).

Table 4.15: Results of CFA standardised factor loadings of safety knowledge

CFA Standardised Factor Loadings*				
Items	ST	KCM	SSI	KSP
ST1	0.715			
ST2	0.722			
ST3	0.655			
ST4	0.680			
ST5	0.758			
KCM1		0.614		
KCM2		0.598		
KCM3		0.691		
KCM4		0.807		
KCM5		0.793		
SSI1			0.772	
SSI2			0.815	
SSI3			0.822	
SSI4			0.627	
SSI5			0.708	
SSI6			0.722	
KSP1				0.794
KSP2				0.809
KSP3				0.707
KSP4				0.629

Notes: N = 238.
*All standardised factor loadings are significant at $p < 0.01$.
ST= safety training, KCM = knowledge of control measures, SSI= seeking safety information, KSP= knowledge of safety procedures.

4.3.4 Factor analysis for safety culture

In accordance with the details provided in Section 3.3.1, the concept of safety culture was evaluated as an independent construct. This evaluation involved using 25 items to assess this construct. These items represent attitudes and beliefs, management safety commitment and communication, and learning from the past. The safety knowledge items used in the study were obtained from various previous studies in the literature, as described in Section 3.3.1.

1) Exploratory Factor Analysis (EFA)

The EFA was performed to identify shared common characteristics or significant patterns among the 25 safety culture items analysed. An examination of the bivariate correlation matrix revealed that most items exhibit correlations with an absolute value greater than 0.3, as shown in Table H4 Appendix H. The initial Kaiser-Meyer-Olkin (KMO) measure for the overall data was 0.931, indicating a high level of sampling adequacy (Table 416). Additionally, the individual loading values ranged from 0.728 to 0.856, all of which exceeded the minimum threshold of 0.5, indicating that each item is strongly related to the factor. Bartlett's test of sphericity yielded a p-value <0.001, indicating statistical significance as necessary for PCA. In the initial analysis, four factors were identified with eigenvalues greater than the one-eigenvalue criterion, as determined by Field (2018) and Pituch and Stevens (2015).

Table 4.16: KMO and Bartlett's Test of Sphericity for safety culture

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.931
Bartlett's Test of Sphericity	Approx. Chi-Square	4257.475
	df	300
	Sig.	.000

Items **Ab7** and **Msc8** exhibited some issues, including low factor loadings, cross-loading, and low communality, which were associated with a decrease in Cronbach's alpha. Low factor loadings indicate a weak association with the respective factors. Items exhibiting low factor loadings have minimal impact on factor definition and may introduce noise into the model (Costello and Osborne, 2019; Stevens, 2002). Cross-loading suggests that an item may assess multiple constructs or lack sufficient distinctiveness, which can create ambiguity and diminish the clarity of the factor structure (Brown, 2015; Kline, 2018). Low commonalities indicate that a significant portion of their variance remains unexplained by the factor model (Hair *et* *al.*, 2018; Tabachnick *et al.*, 2013). Low communality values indicate poor alignment of an item with the underlying construct. The items adversely affected the reliability of the factors, resulting in diminished internal consistency. This indicates a lack of consistency with the other items in the respective factors (DeVellis and Thorpe, 2021; Field, 2018). Therefore, these items (Ab7 and Msc8) were removed from the model.

Following the re-conduct of the Principal Component Analysis (PCA), a three-factor structure was identified. This structure met the criterion of having eigenvalues greater than one. Using the remaining 23 items, the analysis extracted 67% of the variance from the data

Table 4.17: Results of exploratory factor analysis for safety culture

Oblique Rotated Factor Loadings				
Item	CL	MSC	AB	Communality
CL1	0.794			0.632
CL2	0.847			0.718
CL3	0.846			0.716
CL4	0.837			0.701
CL5	0.797			0.635
CL6	0.813			0.660
CL7	0.728			0.530
CL8	0.773			0.599
CL9	0.828			0.686
CL10	0.856			0.733
Msc1		0.787		0.619
Msc2		0.735		0.540
Msc3		0.796		0.633
Msc4		0.802		0.643
Msc5		0.728		0.530
Msc6		0.783		0.613
Msc7		0.775		0.600
Ab1			0.796	0.634
Ab2			0.734	0.538
Ab3			0.746	0.556
Ab4			0.740	0.548
Ab5			0.763	0.582
Ab6			0.756	0.571
Eigenvalue	6.19	5.29	4.01	
% of variance	25.03	22.99	19.25	
Cronbach's alpha	0.858	0.825	0.777	
Notes: N = 238. Factor loadings greater than 0.4 are considered acceptable (Pett *et al.*, 2003). **CL**= Communication and Learning from past., **MSC**= Management Safety Commitment, **AB**= Attitudes and Beliefs The total variance explained = 67%. Cronbach's alpha for safety culture = 0.934				

All communalities in Table 4.17 exceed the minimum threshold of 0.5, ranging from 0.530 to 0.733, indicating that they are well represented by the model (Gebremedhin *et al.*, 2022; Hadi *et al.*, 2016; Mohd Matore *et al.*, 2019). The factor loadings obtained ranged from 0.728 to 0.856, consistent with the minimum value of 0.5. This indicates each item has a strong relationship with the underlying safety culture construct. The obtained Cronbach's Alpha values (ranging from 0.77 to 0.858) exceeded the minimum acceptable threshold of 0.6 (Hair *et al.*, 2018), confirming the internal consistency of each factor. The safety culture construct (23 items) has a Cronbach's Alpha coefficient of 0.934, indicating that the construct exhibits internal consistency and reliability.

2) Confirmatory Factor Analysis (CFA)

The three factors extracted in the EFA were utilised in the CFA. The data's univariate normality was evaluated using skewness and kurtosis scores to perform CFA. The analysis revealed no significant deviation from normality, as the skewness and kurtosis values were within the range of ±1 and ±2, respectively (Byrne, 2016; Kline, 2018). These values are presented in Appendix I. Consequently, the Maximum Likelihood Estimation (MLE) method was employed. As detailed in the table below, the initial measurement model demonstrated a good fit, with all fit indices aligning with the acceptable values outlined in Table 3.5, Section 3.3.4.

Table 4.18: CFA results for the measurement model of safety culture

Model fit indices	χ^2	***df***	***p***	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	502.556	214	0.001	2.348	0.93	0.91	0.048	0.045
χ^2: Chi-square. *df*: Degrees of freedom. p: p-value. χ^2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual								

Moreover, Table 4.19, demonstrates that the standardised factor loadings for the measurement model varied between 0.613 and 0.815, and they were statistically significant with a p-value < 0.001. Standardised factor loadings indicate the strength of each item's association with the safety culture construct, with values closer to 1.0 representing a stronger relationship (Kline and Little, 2015). All values are above 0.6, suggesting a strong relationship. These high loadings confirm that the items collectively measure each factor effectively, with each factor being well-represented by its respective items (Hair *et al.*, 2013; Joseph F. Hair *et al.*, 2019). The significant factor loadings further confirm that the items reliably measure the intended latent variables, supporting the use of these factors in further analysis (Tabachnick *et al.*, 2013).

Table 4.19: The CFA standardised factor loadings for safety culture

CFA Standardised Factor Loadings*			
Items	CL	MSC	AB
CL1	0.621		
CL2	0.677		
CL3	0.717		
CL4	0.751		
CL5	0.808		
CL6	0.815		
CL7	0.721		
CL8	0.623		
CL9	0.764		
CL10	0.655		
Msc1		0.781	
Msc2		0.728	
Msc3		0.784	
Msc4		0.799	
Msc5		0.731	
Msc6		0.778	
Msc7		0.780	
Ab1			0.620
Ab2			0.745
Ab3			0.755
Ab4			0.631
Ab5			0.775
Ab6			0.613
Notes: N = 238. CL: Communication and Learning from the past, MSC: Management Safety Commitment, AB: Attitudes and Beliefs. *All standardised factor loadings are significant at $p < 0.01$.			

4.3.5 Factor analysis for situational awareness

The concept of situational awareness was evaluated as an independent construct using 20 items that represented concentration, anticipation, attention, and distraction. The situational awareness items used in the study were obtained from various previous studies in the literature, as described in Section 3.3.1.

1) Exploratory Factor Analysis (EFA)

The EFA was performed to identify shared common characteristics or significant patterns among the 20 situational awareness items analysed. An examination of the bivariate correlation matrix revealed that all items exhibit correlations with an absolute value greater than 0.3, as shown in Table H5, Appendix H.

Table 4.20: KMO and Bartlett's Test of Sphericity for situational awareness

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.936
Bartlett's Test of Sphericity	Approx. Chi-Square	3450.88
	df	190
	Sig.	.000

The initial Kaiser-Meyer-Olkin (KMO) measure for the data was 0.936, indicating a high level of sampling adequacy. Additionally, the individual KMO values ranged from 0.516 to 0.901, all of which exceeded the minimum threshold of 0.5. These values indicate that each item is strongly related to the respective factors. Bartlett's test of sphericity yielded a p-value <0.001, indicating statistical significance as required. Table 4.21demonstrates that all communalities possess values exceeding the minimum threshold of 0.5, ranging from 0.529 to 0.741. The factor loadings obtained ranged from 0.727 to 0.861, consistent with the minimum value of 0.5. Furthermore, the internal consistency and reliability of the factors were assessed using Cronbach's Alpha. The obtained Cronbach's Alpha values (ranging from 0.725 to 0.878) exceeded the minimum acceptable threshold of 0.6 (Hair *et al.*, 2018). The situational awareness construct has a Cronbach's Alpha coefficient of 0.924.

Table 4.21: Results of exploratory factor analysis for situational awareness

Oblique Rotated Factor Loadings					
Item	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Con1	0.861				0.741
Con2	0.851				0.724
Con3	0.838				0.702
Con4	0.791				0.626
Con5	0.804				0.646
Con6	0.755				0.570
Con7	0.788				0.621
Con8	0.800				0.641
Con9	0.729				0.531
Ant1		0.816			0.667
Ant2		0.727			0.529
Ant3		0.820			0.672
Ant4		0.754			0.569
Ant5		0.750			0.562
Att1			0.727		0.529
Att2			0.750		0.536
Att3			0.815		0.664
Dis1				0.782	0.611
Dis2				0.812	0.659
Dis3				0.834	0.695
Eigenvalue	6.500	3.145	2.357	2.150	
% of variance	28.498	16.723	9.750	9.664	
Cronbach's alpha	0.878	0.759	0.787	0.725	
Notes: N = 238. Factor loadings greater than 0.4 are considered acceptable (Pett et al., 2003). Con= Concentration, Ant= Anticipation, Att= Attention, Dis= Distraction. The total variance explained = 64%. Cronbach's alpha for situational awareness = 0.924					

2) Confirmatory Factor Analysis (CFA)

The four factors extracted in EFA are used in CFA. The data's univariate normality was evaluated using skewness and kurtosis scores to perform CFA. The analysis revealed no significant deviation from normality, as the skewness and kurtosis values fell within the acceptable ranges of ±1 and ±2, respectively (Byrne, 2016; Kline and Little, 2015). These values can be found Appendix I. Consequently, the Maximum Likelihood Estimation (MLE) method was employed. As detailed in Table 4.22 below, the initial measurement model demonstrated a good fit, with all fit indices aligning with the acceptable values outlined in Section 3.3.4.

Table 4.22: CFA results for the measurement model of situational awareness

Model fit indices	χ^2	*df*	*p*	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	420.88	162	0.001	2.598	0.92	0.91	0.06	0.045
χ^2: Chi-square. *df*: Degrees of freedom. *p*: p-value. χ^2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual								

Table 4.23: The CFA standardised factor loadings for situational awareness

CFA Standardised Factor Loadings*				
Items	Con	Ant	Att	Dis
Con1	0.728			
Con2	0.739			
Con3	0.659			
Con4	0.622			
Con5	0.631			
Con6	0.782			
Con7	0.792			
Con8	0.735			
Con9	0.785			
Ant1		0.787		
Ant2		0.766		
Ant3		0.803		
Ant4		0.819		
Ant5		0.629		
Att1			0.736	
Att2			0.873	
Att3			0.888	
Dis1				0.868
Dis2				0.773
Dis3				0.622
Note: N = 238. *All standardised factor loadings are significant at p < 0.01.				

Moreover, Table 4.23 demonstrates that the standardised factor loadings for the measurement model varied between 0.622 and 0.888, and they were statistically significant with a p-value of less than .001. Standardised factor loadings indicate the strength of each item's association with the situational awareness construct, with values closer to 1.0 representing a stronger relationship (Kline and Little, 2015). Nearly all values are above 0.6, suggesting a moderate to strong relationship. These moderate-to-high loadings confirm that the items collectively measure each factor effectively, with each factor being well-represented by its respective items (Hair *et al.*, 2013; Joseph F. Hair *et al.*, 2019). The significant factor loadings further confirm that the items reliably measure the intended latent variables, supporting the use of these factors in further analysis (Tabachnick *et al.*, 2013).

4.4 Constructs' validity and reliability analysis

Ensuring measurement validity and reliability is essential to verify that research constructs accurately and consistently represent the intended concepts. Survey measures should only be utilised when researchers have proof of validity and reliability in their study context (Knekta *et al.*, 2019). Validity determines if measures accurately reflect the constructs, whereas reliability evaluates their consistency across items. This research utilised three assessments: Convergent validity assesses the degree to which items correlate strongly to measure a construct (Carlson, 2012). Composite reliability evaluates the reliability of a latent variable (construct) constructed from multiple items (Hair *et al.*, 2020). Internal consistency reliability, measured by Cronbach's alpha, examines the degree of relatedness among items within each construct. These assessments collectively confirm the accuracy and reliability of the constructs, thereby reinforcing the measurement foundation of the study.

4.4.1 Convergent validity assessment

Convergent validity assesses whether the items of a specific construct converge, meaning they are associated and exhibit a strong shared variance (Hair *et al*., 2013; Taherdoost, 2016). The estimation of convergent validity was based on the standardised factor loadings of 0.5 or higher, which were statistically significant. Additionally, the Average Variance Extracted (AVE) needed to be 0.5 or higher, according to Hair *et al*. (2013). The approach by

Rasoolimanesh *et al*. (2015), which utilises an AVE threshold value of 0.50, indicates acceptable convergent validity. To establish convergent validity, we examined the AVE; all constructs demonstrated good convergent validity with values above 0.60, as shown in Table 4.24. This indicates that the items of each construct possess adequate shared variance and are therefore reliable for measuring the construct (Fornell and Larcker, 1981).

Table 4.24: Results of constructs' convergent validity

Construct	AVE	Meets Threshold
Risk Perception	0.607	Yes
Safety compliance	0.62	Yes
Safety Knowledge	0.609	Yes
Safety culture	0.64	Yes
Situational Awareness	0.61	Yes

4.4.2 Composite reliability assessment

Composite reliability (CR) is frequently used as an indicator of internal consistency of items for construct reliability assessments (Hair *et al.*, 2020). Table 4.25 illustrates that all CR values exceed the minimum threshold of 0.70, which supports construct reliability (Hair *et al.*, 2011; Joseph F Hair *et al.*, 2019). Therefore, construct reliability has been achieved.

Table 4.25: Results of constructs composite reliability

Construct	CR	Meets Threshold
Risk Perception	0.93	Yes
Safety compliance	0.77	Yes
Safety Knowledge	0.96	Yes
Safety culture	0.96	Yes
Situational Awareness	0.96	Yes

4.4.3 Internal consistency reliability (Cronbach’s Alpha) analysis

The statistical reliability of a scale is crucial for establishing its usefulness. Cronbach’s Alpha evaluates the extent to which a set of items in a questionnaire or test measures the same underlying construct, ensuring that items within a scale or instrument are interrelated, cohesive, and consistently measure the same thing (Tavakol and Dennick, 2011). The value of Cronbach's alpha can range from 0 to 1, with values closer to 1 indicating greater internal consistency (Cronbach, 1951). According to Schmitt (1996), if Cronbach's α for the number of items measuring a concept is ≥ 0.7, the measurement of that concept is considered reliable. As a result, all constructs have achieved construct reliability, as shown in Table 4.26.

Table 4.26: Constructs Comparative Fit Index and Cronbach's alpha (α)

	Constructs	No. of items	Comparative Fit Index (CFI)	Cronbach's alpha (α)
1	Risk perception	12	0.96	0.892
2	Safety compliance	4	0.98	0.764
3	Safety Knowledge	20	0.95	0.928
4	Safety Culture	23	0.93	0.934
5	Situational awareness	20	0.92	0.924

4.5 Correlation coefficient assessment

The assessment of the correlation coefficient measures the strength of the relationship between constructs (Gerber and Finn, 2005). Table 4.27 presents the Pearson correlation coefficients among the five constructs, along with their means (M) and standard deviations (SD). All correlations were significant at the 0.01 level (two-tailed). Risk perception showed moderate correlations with all other constructs. It was correlated with safety compliance (r= 0.496), safety knowledge (r= 0.587), safety culture (r= 0.543, p < 0.01), and situational awareness (r= 0.323).

In Table 4.27, safety compliance demonstrated positive associations with most of the constructs. It correlated moderately with safety knowledge (r= 0.565) and safety culture (r= 0.543), and weakly with situational awareness (r= 0.175). This weak correlation suggests that situational awareness does not always translate into compliance and vice versa.

Safety knowledge demonstrated a strong correlation with safety culture (r= 0.823) and a moderate correlation with situational awareness (r= 0.345), as shown in Table 4.27. The former result suggests that an organisation's shared values, beliefs, and practices regarding safety are deeply intertwined with individual employees' knowledge and understanding of safety procedures and protocols within the CPI. Additionally, the moderate correlation of (r= 0.345) suggests that, in the CPI context, safety knowledge alone may be insufficient for developing robust situational awareness. Furthermore, safety culture exhibited a moderate correlation with situational awareness (r= 0.529). This suggests that fostering a positive safety culture may concurrently improve employees’ situational awareness and ability to recognise and respond to immediate safety challenges.

Table 4.27: Means, standard deviations and Pearson correlation coefficient

Variable	**RP**	**SC**	**SK**	**SCR**	**SA**
RP	1				
SC	.496**	1			
SK	.587**	.565**	1		
SCR	.543**	.543**	.823**	1	
SA	.323**	.175**	.345**	.529**	1
Mean (M)	3.086	3.106	3.101	3.002	2.897
Standard deviation	0.452	0.460	0.442	0.424	0.560
No of items	12	4	20	23	20

** Correlation is significant at the 0.01 level (2-tailed).

SK= Safety Knowledge. SA= Situational Awareness. SCR= Safety Culture. RP= Risk Perception. SC= Safety Compliance.

Table 4.27 also shows the mean values of each construct. As described in Section 3.3.4, the initial data cleaning and preparation resulted in a final Likert scale of 1-4, used for all valid responses. Therefore, a mean above 2.5 would be considered the average response in agreement with the survey items. Results in Table 4.27 indicate that the participants agree they possess a good level of safety knowledge (M = 3.086), a good safety culture exists within their organisations (3.106), they can perceive risks (3.101), and a good level of compliance with safety regulations (3.002). The standard deviation of the responses for these four constructs is similar, indicating good consistency within the responses, and the majority of participants agree on the constructs mentioned above. For situational awareness, the slightly lower mean of the response (2.897, compared to other constructs) indicates that respondents were comparatively less confident in their SA than in other constructs. The standard deviation for the situational awareness (0.560) reflects a higher variability in responses. It suggests that workers in the chemical process industries exhibit significantly different levels of situational awareness. This variability suggests that SA is a cognitive construct which could be susceptible to individual differences or workplace characteristics.

To conclude, the correlation analysis revealed that all constructs were positively interrelated. There was a strong correlation between safety knowledge and safety culture, while most of the other correlations were moderate. Notably, the correlation between situational awareness and safety compliance was weak, with a value of less than 0.3. These results establish a robust empirical basis for the subsequent structural equation modelling and mediation analysis.

4.6 Mediation analysis for hypothesis testing

Mediation analysis is utilised to understand the precise mechanism through which an independent variable (risk perception) affects a dependent variable (safety compliance) via the intermediary role of a mediator variable. Having established the validity and reliability of the study's five constructs through statistical techniques, the study now proceeds to test the hypothesised mediation models. The construct validation phase began with factor analysis (Section 4.3), using Exploratory Factor Analysis (EFA), which identified the underlying factor structure. This was followed by Confirmatory Factor Analysis (CFA), which validated the specified measurement model and confirmed the factor loadings across all constructs. Subsequent assessments provided evidence of construct validity and reliability (Section 4.4): convergent validity was confirmed for all constructs through Average Variance Extracted (AVE) values exceeding 0.60; composite reliability demonstrated internal consistency above 0.70; and Cronbach's Alpha further verified the reliability of each construct, all exceeding 0.70. The correlation coefficients (Section 4.5) provided preliminary evidence of the theoretically expected relationships between constructs. With these foundations firmly established, the study is now positioned to conduct a mediation analysis using structural equation modelling, which will test the specific pathways through which risk perception influences safety compliance via the proposed mediators in the context of the chemical process industries.

The mediation analysis used separate single-mediator models to clearly identify how each construct functions independently. Estimating safety knowledge, safety culture, and situational awareness separately allows each indirect effect to be interpreted without statistical interference from the others. This is particularly relevant where mediators are conceptually distinct but empirically correlated, as simultaneous estimation may introduce multicollinearity or suppression effects that obscure individual pathway significance.

However, modelling mediators in parallel, as illustrated in Fig. 4.1, provides important analytical and theoretical advantages. A parallel mediation framework allows the estimation of unique indirect effects while accounting for shared variance among mediators, thereby reflecting the likelihood that safety knowledge, safety culture, and situational awareness operate concurrently rather than in isolation. This approach is especially valuable in safety-critical environments where cognitive, organisational, and perceptual mechanisms may jointly influence compliance behaviour. It also enables comparison of the relative strength of each mediator and reduces the risk of biased or inflated indirect effects arising from omitted correlated variables.

Nonetheless, the single-mediator approach has limitations. It does not account for inter-mediator covariance, cannot capture potential interaction or suppression effects between mediators, and restricts conclusions regarding the combined mechanisms linking risk perception to safety compliance.

The three proposed mediation models with three single mediators between risk perception and safety compliance are:

1) Risk Perception → Safety Knowledge → Safety Compliance (H1)
2) Risk Perception → Safety Culture → Safety Compliance (H2)
3) Risk Perception → Situational Awareness → Safety Compliance (H3)

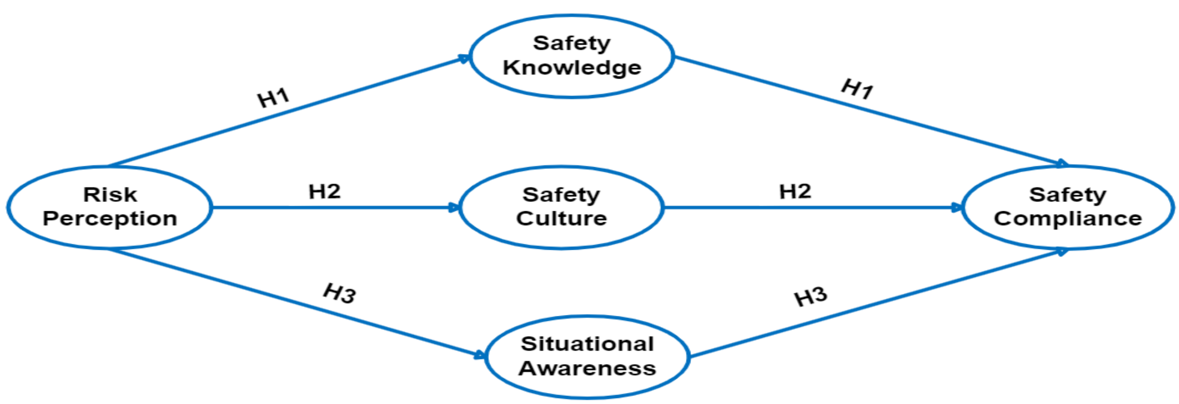

Figure 4.1: Hypothesised Mediation Models

4.6.1 Hypothesis 1: Safety knowledge mediates the relationship between risk perception and safety compliance.

SEM was employed to test the hypothesis, and the mediation model fit indices are expressed using confirmatory factor analysis (CFA) indices. The CFA indices describe the validity of the model, which should be examined before interpreting structural paths and mediation results. As shown in Table 4.28 below, the model demonstrated a good fit with all indices meeting the minimum cut-off values.

Table 4.28: Mediation model fit indices for Hypothesis 1

Model fit indices	χ^2	*df*	*P* <0.05	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	891.33	589	<0.01	1.513	0.92	0.91	0.047	0.0586

χ^2: Chi-square. *df*: Degrees of freedom. *p*: p-value. $\chi 2$/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual

The mediation analysis assessed the direct and indirect influence of risk perception on safety compliance, with safety knowledge serving as the mediator, as illustrated in Figure 4.2, which shows the values and the directions of the relationships.

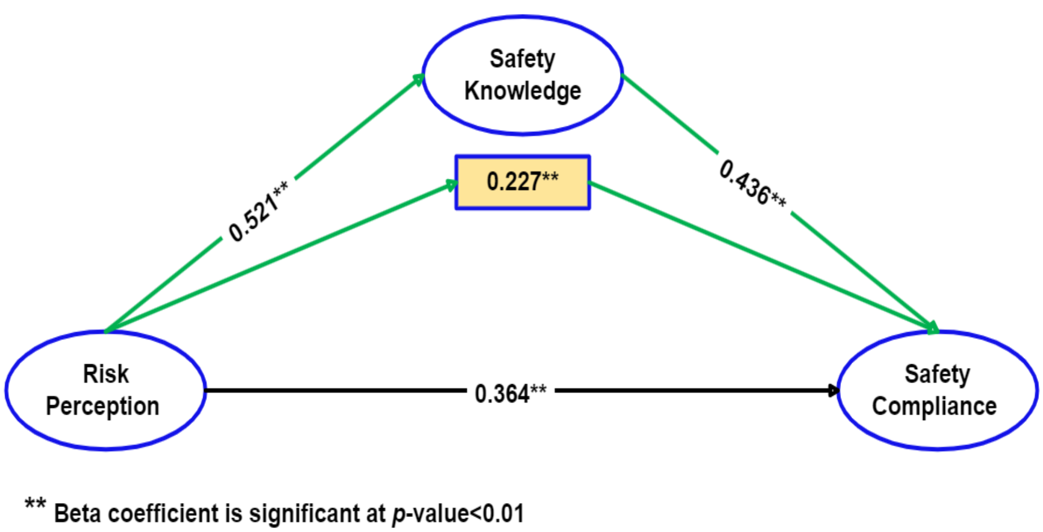

Figure 4.2: Hypothesised Model 1 illustrating the direct and indirect effects of risk perception on safety compliance via safety knowledge

The findings of this analysis are outlined in Table 4.29, with the definition of the measures of the model provided in Table 3.7. The beta coefficients of the direct and indirect effects are illustrated in Figure 4.2. The SEM analysis revealed that risk perception had a positive and statistically significant direct impact on safety knowledge with a β of 0.521, suggesting that an increase in risk perception correlates with an increase in safety knowledge. This strong direct effect suggests that individuals who perceive higher levels of risk are more likely to acquire and retain safety-related knowledge. This beta value is in line with the correlation coefficient value of (r=0.587) in Table 4.27, which shows a moderate relationship between risk perception and safety knowledge.

Table 4.29: Standardised direct and indirect effects of hypothetical model 1.

	Path	**β**	**S.E**	**C.R. (t-value)**	**p**	**95% CI [Lower, Upper]**
Direct effect	RP → SK	0.521	0.077	5.638	<0.01	[0.361,0.675]
	SK→ SC	0.436	0.094	4.994	<0.01	[0.245, 0.613]
	RP → SC	0.364	0.097	4.070	<0.01	[0.180,0.556]
Indirect effect	RP →SK →SC	0.227	0.064	N/A	<0.01	[0.114,0.380]
Total effect		0.591	N/A	N/A	<0.01	N/A
VAF		0.38%				

β = Beta coefficient. S.E= Standard Error. C.R. Critical Ratio. *p*-value<0.01. 95% CI= Confidence Interval. N/A= Not Applicable. VAF = variance accounted for.

Total effect: the sum of the direct effect and the indirect effect.

Likewise, the direct effect of safety knowledge on safety compliance was also statistically significant (β = 0.436). This beta value confirms the positive correlation between the two constructs (r=0.565) as shown in Table 4.27. This finding suggests that higher levels of safety knowledge can lead to better compliance with safety measures. The value of this effect reinforces the critical role that safety knowledge plays in ensuring compliance with safety protocols and procedures.

Furthermore, the direct effect of risk perception on safety compliance was statistically significant (β= 0.364), demonstrating that risk perception still has a direct influences safety compliance in the presence of a mediator. This direct effect supports the positive correlation coefficient of these two constructs (r= 0.496) in Table 4.27. This statistically significant direct path between risk perception and safety compliance indicates the partial mediation effect of safety knowledge in this model.

Moreover, the analysis revealed an indirect effect of risk perception on safety compliance mediated by safety knowledge (β = 0.227). This mediation effect indicates that safety knowledge partially mediates the relationship between risk perception and safety compliance, thereby supporting the first hypothesis of this study.

The total effect of risk perception on safety compliance was statistically significant, β =0.591. This overall effect includes both indirect and direct impacts, underscoring a significant influence of risk perception on safety compliance.

To measure the extent of partial mediation, the variance accounted for (VAF) was calculated. The VAF for safety knowledge was 38% of the total effect (0.591). This indicates that more than a third of the relationship between risk perception and safety compliance is mediated through the safety knowledge pathway. In other words, safety knowledge explains over one-third of the total relationship between risk perception and safety compliance. This result represents a theoretically and practically significant finding that confirms safety knowledge as an important, but not singular, mechanism through which risk perception translates to safety compliance behaviours in the chemical process industries. The magnitude provides concrete evidence for prioritising knowledge-based interventions while acknowledging the necessity of complementary approaches targeting other mediators.

4.6.2 Hypothesis 2: Safety Culture mediates the relationship between risk perception and safety compliance.

SEM was employed to test the hypothesis, and the mediation model fit indices are expressed using confirmatory factor analysis (CFA) indices. The CFA indices describe the validity of the model, which should be examined before interpreting structural paths and mediation results. As shown in Table 4.30 below, the model demonstrated a good fit with all indices meeting the minimum cut-off values.

Table 4.30: Mediation model fit indices for Hypothesis 2

Model fit indices	χ^2	df	P <0.05	χ^2/df <3.0	CFI >0.90	TLI >0.90	RMSEA <0.080	SRMR <0.060
Initial model	921.42	589	<0.01	1.823	0.91	0.91	0.049	0.0569
χ^2: Chi-square. df: Degrees of freedom. p: p-value. χ^2/df: Chi-square divided by degrees of freedom. CFI: Comparative Fit Index. TLI: Tucker-Lewis Index. RMSEA: Root Mean Square Error of Approximation. SRMR: Standardised Root Mean Square Residual								

The mediation analysis was conducted to investigate the direct and indirect effects of risk perception on safety compliance, with safety culture serving as the mediator. The direct and indirect effects are illustrated in Figure 4.3, which shows the value and the direction of the relationships.

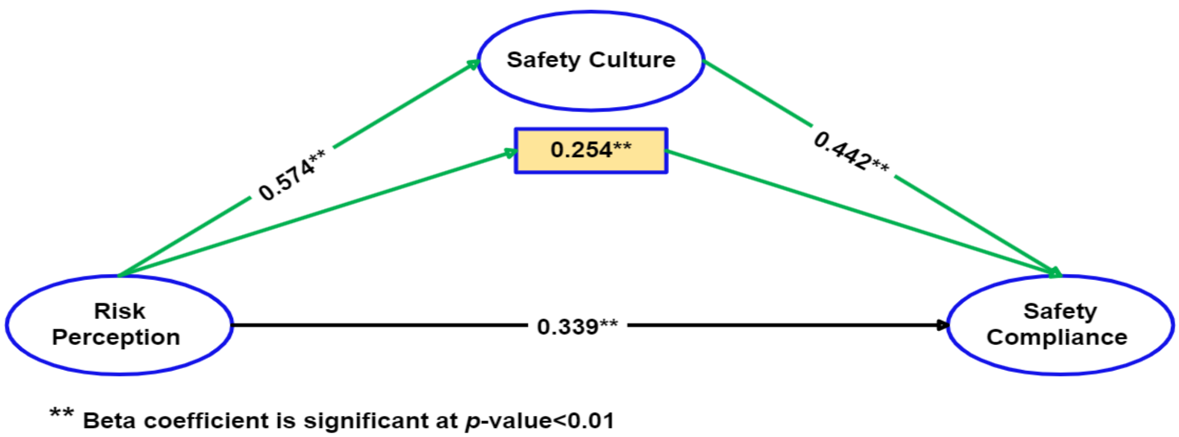

Figure 4.3: Hypothesised Model 2 with the direct and indirect effects of risk perception on safety compliance through safety culture.

The results of this mediation analysis are presented in Table 4.31. The direct effect of risk perception on safety culture was statistically significant (β = 0.574). This beta value supports the correlation coefficient value of (r=0.543) in Table 4.27, which shows a moderate relationship between risk perception and safety culture.

The direct effect of safety culture on safety compliance was also positive and statistically significant (β = 0.442). This beta coefficient also supports the correlation coefficient value (r= 0.543) in Table 4.27. This finding suggests that a safety culture is correlated and can lead to better compliance with safety measures. This highlights the importance of safety culture in promoting safety compliance behaviours.

Table 4.31: Standardised direct and indirect effects of hypothetical model 2

	Path	β	S.E	C.R. (t-value)	p	95% CI [Lower, Upper]
Direct effect	RP → SCR	0.574	0.075	5.848	<0.001	[0.421,0.717]
	SCR → SC	0.442	0.101	4.801	<0.001	[0.230,0.644]
	RP→ SC	0.339	0.105	3.722	<0.001	[0.141,0.548)
Indirect effect	RP → SCR→SC	0.254	0.072	N/A	<0.001	[0.118,0.329]
Total effect		0.593	-	-	-	[0.335,0.610]
VAF		0.43				
β = Beta coefficient. S.E.= Standard Error. C.R. Critical Ratio. *p*-value<0.01 CI= Confidence Interval. VAF= variance accounted for. Total effect: the sum of the direct effect and the indirect effect.						

Additionally, the direct effect of risk perception on safety compliance was statistically significant (β = 0.339). This result demonstrates that risk perception continues to have a direct, positive impact on safety compliance, even in the presence of a mediator. This indicates that safety culture partially mediates the relationship between risk perception and safety compliance.

Notably, the analysis revealed a statistically significant indirect effect of risk perception on safety compliance mediated by safety culture (β = 0.254). This statistically significant mediation effect suggests that safety culture mediates the relationship between risk perception and safety compliance, thereby supporting the second hypothesis of this study. This pattern suggests that while safety culture serves as an important mechanism through which risk perception translates to safety compliance, risk perception also influences compliance through additional pathways not captured in this specific mediation model.

The total effect of risk perception on safety compliance was significant, β = 0.593. This overall effect encompasses both indirect and direct impacts, underscoring the significant influence of risk perception on safety compliance. These results support the hypothesised mediation model, demonstrating that risk perception influences safety compliance through direct and indirect pathways involving safety culture. The statistically significant direct and indirect effects underscore the importance of considering both risk perception and safety culture when developing interventions to improve safety compliance. The VAF for safety culture is about 0.43. This indicates that safety culture, as a mediator, accounts for 43% of the total effect (0.593) of risk perception on safety compliance.

4.6.3 Hypothesis 3: Situational Awareness mediates the relationship between risk perception and safety compliance.

The mediation analysis investigated the direct and indirect effects of risk perception on safety compliance, with situational awareness serving as the mediator. The direct and indirect effects are illustrated in Figure 4.4, which shows the values and the directions of the relationships.

The results of this analysis are detailed in Table 4.32. The direct effect of risk perception on situational awareness was statistically significant ($\beta = 0.32$), indicating that an increase in risk perception is associated with an increase in situational awareness. This statistically significant direct effect suggests that individuals who perceive higher levels of risk are likely to have enhanced situational awareness. This coefficient mirrors the correlation of 0.323 found in Table 4.27.

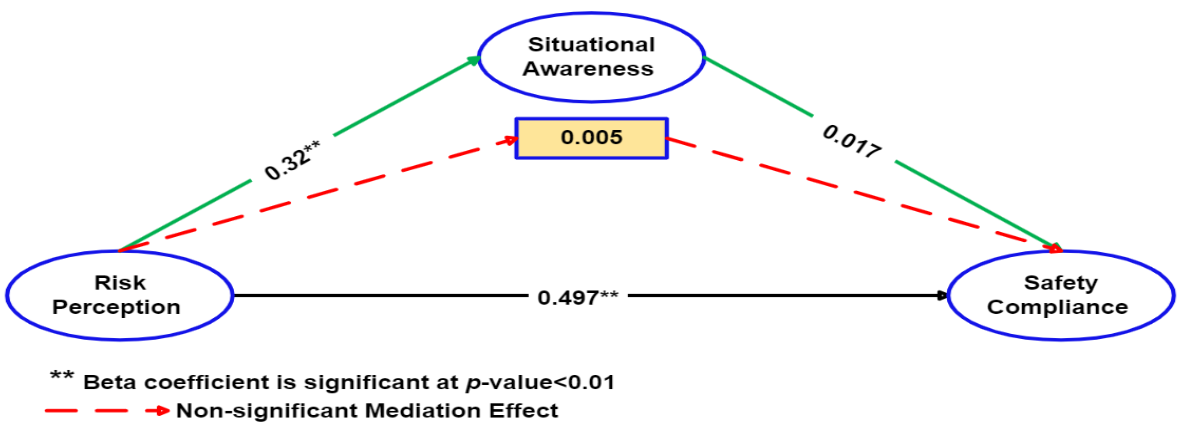

Figure 4.4: Hypothesised Model 3 with the direct and indirect effects of risk perception on safety compliance through situational awareness.

However, the direct effect of situational awareness on safety compliance was statistically insignificant ($\beta = 0.017$). This non-significant path indicates that situational awareness is unlikely to have a direct impact on safety compliance in this model. The p-value is greater than 0.05, and the confidence interval includes zero, further confirming the lack of statistical significance.

Table 4.32: Standardised direct and indirect effects of hypothetical model 3

	Path	β	S.E	C.R. (t-value)	p	95% CI [Lower, Upper]
Direct effect	RP → SA	0.32	0.061	5.254	<0.01	[0.193,0.447]
	SA → SC	0.017	0.061	0.278	0.781	[-0.102,0.145]
	RP → SC	0.497	0.060	8.238	<0.01	[0.344,0.617]
Indirect effect	RP→SA→SC	0.005	0.021	N/A	0.768	[-0.029,0.055]
β = Beta coefficient. S.E. = Standard Error. C.R. = Critical Ratio. p-value <0.01 CI= Confidence Interval.						

The direct influence of risk perception on safety compliance was statistically significant (β = 0.497). This strong direct influence indicates that higher levels of risk perception directly lead to improved safety compliance. This result indicates that individuals who better perceive risks are more likely to adhere to safety standards and protocols.

The indirect effect of risk perception on safety compliance, mediated by situational awareness, was statistically insignificant (β = 0.005). This non-significant mediation effect appears to indicate that situational awareness does not mediate the relationship between risk perception and safety compliance, leading to the rejection of hypothesis three. The confidence interval for the indirect effect includes zero, suggesting that the indirect pathway is not statistically significant.

The mediation analysis demonstrates that situational awareness does not mediate the relationship between risk perception and safety compliance in this model. This result led to the rejection of the third hypothesis. The direct effect of risk perception on situational awareness is statistically significant, indicating a positive influence. However, the impact of situational awareness on safety compliance is statistically insignificant, indicating that situational awareness does not have a direct influence on safety compliance. Consequently, the indirect effect of risk perception on safety compliance, mediated by situational awareness, is also insignificant.

Sneddon *et al.* (2013) found that reduced levels of situational awareness were significantly associated with heightened unsafe behaviour in the workplace. Despite the non-significant effect of situational awareness on safety compliance in the current study, it is important to consider that the role of situational awareness in influencing safety compliance could be more complex than is captured in the current model. The non-significant result suggests that situational awareness does not directly impact safety compliance; however, this does not necessarily mean that situational awareness is irrelevant to safety outcomes.

Further discussion of the results from this quantitative phase will be provided in Chapter 6. The subsequent chapter, Chapter Five, will detail the qualitative findings from the qualitative phase.

4.7 Chapter summary

The current chapter concentrates on analysing quantitative data. It starts with an initial evaluation of response homogeneity. Levene's test for all constructs indicates no significant mean differences, but H&S participants were excluded to prevent response bias. The two-stage factor analysis (EFA and CFA) confirms the theoretical dimensionality of each construct, with the factor structure identified in EFA, each explaining between 60% and 67% of the variance in the construct. CFA verifies the structure of each construct with good fit indices. All constructs demonstrate excellent validity and reliability, with AVE values exceeding 0.60, composite reliability above 0.70, and Cronbach's alpha ranging from 0.764 to 0.96. The Pearson correlation analysis reveals statistically significant positive relationships between all constructs, with a notably strong correlation between safety knowledge and safety culture ($r = 0.823$) and a weak correlation between situational awareness and safety compliance ($r = 0.175$). Safety knowledge partially mediates the relationship between risk perception and safety compliance, with statistically significant direct and mediating paths ($\beta = 0.227$), confirming Hypothesis 1. Safety culture exhibits stronger partial mediation than safety knowledge ($\beta = 0.254$), with statistically significant direct and mediating paths, thereby confirming Hypothesis 2. Situational awareness shows no significant mediation effect ($\beta = 0.005$); therefore, Hypothesis 3 is rejected.

Chapter 5: Qualitative Data Analysis

This chapter presents the findings of the qualitative phase, derived through Thematic Analysis (TA) of the interviews, in line with the methodology outlined in Section 3.4.5. The analysis combined both deductive and inductive approaches. Deductive coding, based on the study's identified relationships in the quantitative phase, produced five overarching themes. In contrast, inductive coding, grounded in participants' accounts, generated three additional factor groups. The use of both approaches enhances the credibility of the analysis, allowing theoretical expectations to be tested while also capturing unexpected insights that emerge directly from the data. This dual strategy enhances the robustness of the findings by integrating a theory-driven structure with participant-driven nuance, thereby ensuring both analytical rigour and contextual richness. The chapter is organised into five sections. Section 5.1 evaluates the relationships between the constructs identified in the quantitative phase. Sections 5.2, 5.3, and 5.4 present the workplace, individual, and organisational factors, respectively, comprising four, five, and six factors. Finally, Section 5.5 summarises the key insights from the qualitative analysis.

Following Braun and Clarke (2006) in the inductive coding approach, which aimed to investigate the relationship between situational awareness and safety compliance, the initial coding process generated 24 codes (see Table J1). These codes were then grouped into broader themes after related codes were identified. This involved reviewing the codes to identify patterns, similarities, and differences, and then organising them into overarching themes that capture the essence of the data. Finally, themes were refined by reviewing and adjusting them to ensure they accurately represent the data and effectively answer the research questions. The final deductive and inductive themes are illustrated in Figure 5.1.

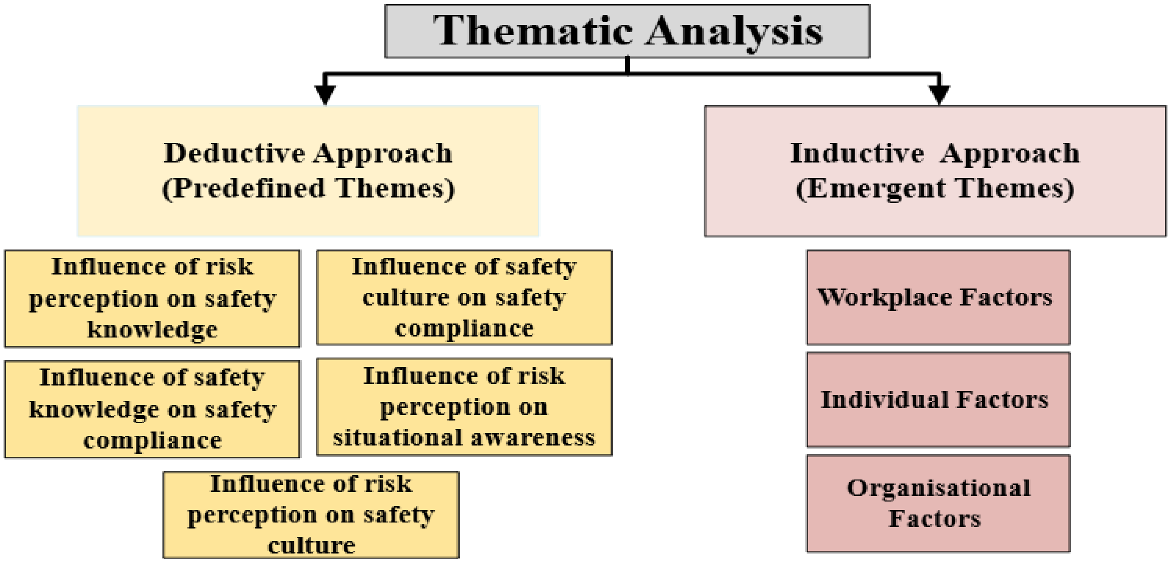

Figure 5.1: Thematic Analysis Map

5.1 Confirmatory study on relationships between study constructs

As the research progressed to conducting interviews, the researcher took the opportunity to validate the Person correlations in Table 4.27, which were predefined in Chapter 4. This aims to provide qualitative support for the relationships between constructs as shown in Table 5.1.

A methodological decision was made to present the confirmatory analysis before the explanatory findings, despite the chronological sequence of interview questions. This presentation order aligns with the study's mixed-methods design, where the qualitative component served to support the quantitative results (Creswell and Clark, 2017). By foregrounding the confirmatory analysis, the research narrative better demonstrates how the qualitative insights strengthen the quantitative findings.

Table 5.1: Summary of relationships, numbers of participants and quotes captured in the confirmatory study

Relationship	No. Participants	No. Quotes
Risk perception influence on safety knowledge	20	20
Safety knowledge influence on safety compliance		19
Risk perception influence on safety culture		17
Safety culture influence on safety compliance		18
Risk perception influence on situational awareness		18

5.1.1 Relationship between risk perception and safety knowledge

This subtheme identifies a bidirectional, mutually reinforcing relationship between individuals’ risk perception and safety knowledge. This theme was highlighted prominently in all 20 interviews (Table 5.1), highlighting a consistent and significant relationship between individuals' perceptions of risk and their acquisition of safety knowledge. Participants consistently reported that the level of safety knowledge they possessed had a positive impact on their mindfulness and understanding of risks. One participant explicitly stated:

> *“I would say positively. Training is the means of building knowledge and increasing the level of risk perception. When we perceive high risks, we are keen to know more about how to control them” (P5).*

This quote underscores the importance of training programs in enhancing both knowledge and risk awareness, suggesting that a well-structured training program can effectively heighten employees' risk perception. Furthermore, the influence of safety training and safety information was consistently mentioned as a critical factor in shaping risk perception. Another participant noted:

> *“For sure, positively. Because how we perceive risks is significantly influenced by safety training and the information we receive. These programs help us to have a more accurate and well-informed perception of potential risks in the workplace by providing education and practical skills” (P18).*

Participants also highlighted their curiosity and proactive attitude towards learning more about safety measures. One interviewee expressed:

> *“Yeah, high levels of risk perception made me curious to have as much safety knowledge as I can because I appreciate its importance. This makes me more prepared and able to deal with risks and mitigate them” (P20).*

This participant links high levels of risk perception to curiosity about safety knowledge, suggesting that risk perception may act as a driver for proactive learning.

In summary, all interviews consistently acknowledge a positive relationship between risk perception and safety knowledge. Risk perception motivates the proactive pursuit of safety knowledge, and this knowledge, in turn, refines and heightens risk perception.

5.1.2 Relationship between safety knowledge and safety compliance

This relationship was strongly highlighted in 19 out of 20 interviews, as illustrated in Table 5.1. Participants consistently indicated that the extent of their safety knowledge significantly impacts their adherence to safety rules and protocols. Participants emphasised that possessing comprehensive safety knowledge directly influences their confidence to work safely. This knowledge not only increases their confidence but also enhances their ability to perform tasks safely. For instance, one participant highlighted:

> *"Knowledge of safety rules and procedures plays a crucial role in encouraging a safe working environment. When I am familiar with safety rules and procedures, I feel more confident to work in a safe manner." (P14)*

Furthermore, participants underscored the perceived significance of safety knowledge in promoting safe work practices. One participant asserted that possessing knowledge of safety regulations and protocols not only promotes safer work but also encourages them to implement these regulations. The participant expressed this:

> *"Being knowledgeable of safety rules and procedures makes it easy for you to work safely. You know procedures and how they help you to take control over risks and execute your job, this understanding encourages me to implement them and work safely." (P7)*

Another key point raised by the participants is the relationship between safety knowledge and obedience to safety rules. A lack of knowledge about safety procedures can lead to dangerous situations, putting individuals at risk. As one participant pointed out:

> *"If you don't know the safety procedures or safety rules, you will be at risk and endanger your life. The more safety knowledge you possess, the more obedient you are to safety rules and procedures." (P3)*

In conclusion, interviews suggest that safety knowledge is an important factor in influencing safety compliance. Employees who are well-informed about safety rules, procedures, and risks exhibit higher levels of compliance.

5.1.3 Relationship between risk perception and safety culture

The connection between the two constructs emerged clearly across 17 out of 20 interviews (Table 5.1). Participants highlighted the intertwined relationship between risk perception and safety culture. A recurrent point made by the participants was the critical role of risk communication in shaping risk perception. As one participant stated:

> *"In my experience, the way people perceive risks strongly shapes the safety culture around them. When workers genuinely believe the hazards in chemical plants are serious, they tend to follow procedures more carefully and encourage others to do the same, which reinforces a culture of safety. On the other hand, if risks are underestimated or seen as unlikely, you often see a more relaxed attitude where shortcuts become acceptable. Over time, these perceptions influence how teams talk about safety, whether they raise concerns, and how seriously they take management's initiatives. In that sense, risk perception doesn't just affect individual behaviour, it sets the tone for the entire safety culture, which then determines how consistently safety rules are followed." (P6)*

This participant articulates risk perception as the cultural foundation of the CPI safety systems, where authentic hazard recognition triggers collective vigilance and adherence to procedures. At the same time, underestimation normalises deviance in high-consequence environments. Another participant highlighted:

> *"As an operator, I can say that how we view risks directly affects the way we act and the culture we build on the floor. When we recognise that even small deviations can escalate into serious incidents, we stay alert and remind each other to stick to the rules. However, if people believe the risks are exaggerated or unlikely, they tend to cut corners, which gradually weakens the group's overall attitude toward safety. I've noticed that when management highlights real examples of accidents, it sharpens our*

perception of risk and makes us more committed. In the end, our shared perception of danger is what creates a strong or weak safety culture here." (P19)

This statement emphasises how risk perception operates as a collective driver of safety culture in chemical and process industries. By linking heightened awareness of hazards to vigilance, peer reinforcement, and compliance, the response demonstrates that risk perception is not merely an individual construct, but a shared one that strengthens or erodes cultural norms surrounding safety.

The implementation of safe systems of work was also identified as a key influencer of risk perception. These systems provide structured procedures and guidelines that help employees navigate and mitigate risks effectively. By having clear and practical measures in place, employees can better understand how to avoid or manage potential hazards. A participant noted:

> *"Effective risk communication and the implementation of safe working procedures can contribute to raising the level of risk perception, enabling employees to avoid underestimating risks and hazards." (P17)*

This quote suggests that safe working procedures are an important factor for improving risk perception. When employees are aware of and adhere to these procedures, they are less likely to underestimate risks, thereby enhancing the overall safety culture.

The interviews collectively reveal a positive relationship between risk perception and safety culture (e.g. communication and safe systems of work). This relationship is symbiotic; it suggests that as risk perception increases (Namian *et al.*, 2016; Rogers and Pearce, 2013), the safety culture within the organisation is potentially further strengthened (Dasgupta *et al.*, 2024).

5.1.4 Relationship between safety culture and safety compliance

The theme was a prominent topic in 18 out of 20 interviews conducted for this study (Table 5.1). Participants consistently emphasised that a strong safety culture is vital for achieving higher levels of safety compliance. They argued that when an organisation maintains a positive safety culture, it naturally leads to improved adherence to safety protocols and procedures.

Participants emphasised that the commitment of leadership and management to safety is important in fostering a safety culture. When leaders prioritise safety and demonstrate their commitment through actions and policies, it encourages employees to follow suit. One participant explained:

> *"Of course. The commitment of leadership and management to safety encourages us to work safely. When we are motivated and rewarded for our commitment to safety, we are happy to carry on. Communication with us and involving us in safety tasks also motivates us to work safely; this can cover any gap between the management level and the frontline workers and build up trust." (P1)*

This quote underscores the importance of leadership in fostering a safety culture. By actively engaging with employees, recognising their efforts, and ensuring open communication, leaders can bridge the gap between management and frontline workers, fostering a sense of trust and mutual commitment to safety.

Moreover, participants noted that a positive safety culture can improve attitudes and behaviours towards safety. Effective leadership and management commitment can embed safety as a core value within the organisation. One participant elaborated:

> *"Yes, indeed. Because I think these elements or constructs can contribute to a good safety culture and improve attitudes and behaviours towards safety. Better leadership and management commitment to safety can instil a culture of safety within the company. Communicating with employees and motivating them can result in a continuous improvement of compliance. Moreover, it can create an environment where employees do not see safety as just a set of rules, but an essential part of how work is done." (P20)*

This insight highlights that when safety becomes an integral part of the organisational culture, employees are more likely to view it as a fundamental aspect of their work rather than a mere compliance requirement (Amirah *et al.*, 2024). This shift in perspective can lead to ongoing improvements in safety practices and compliance (Kalteh *et al.*, 2021).

Additionally, participants emphasised that a robust safety culture is built on several key aspects, including efficient leadership, open communication, and motivation. These elements work together to create an environment where safety is prioritised and practised consistently. Another participant noted:

> *"I think so. These aspects all contribute to cultivating a robust safety culture, which, in turn, improves safety compliance. Efficient leadership establishes the framework for giving priority to safety, while open communication guarantees that employees understand and adhere to safety protocols. Motivation encourages a proactive attitude towards safety, and an organisation's determined commitment establishes the basis for a culture where safety is a fundamental principle." (P19)*

This statement reinforces the notion that a comprehensive approach to establishing a safety culture is important. Effective leadership provides direction, open communication ensures clarity and understanding, and motivation drives proactive engagement with safety practices. Together, these factors create a strong foundation for a culture where safety is deeply ingrained and compliance is routinely achieved.

In conclusion, the interviews clearly demonstrate that safety culture influences safety compliance, which aligns with the findings of Ayi and Hon (2018). Organisations that foster a positive safety culture through strong leadership, open communication, and motivation are more likely to achieve high levels of safety compliance. Employees in such environments view safety as an integral part of their work, leading to improved attitudes and behaviours towards safety practices. Therefore, investing in and nurturing a positive safety culture is essential for achieving sustained safety compliance and ensuring a safe working environment.

5.1.5 Relationship between risk perception and situational awareness

This correlation is confirmed in 18 out of 20 interviews in this study (Table 5.1). Most participants reported that their situational awareness is enhanced by their heightened perception of risks in the workplace. The high level of risk perception cultivates a vigilant and attentive attitude towards their surroundings, contributing to a safer working environment.

Participants consistently highlighted that the perception of workplace risks sharpens their focus on critical information and details in their environment. This enhanced focus helps them identify potential hazards and respond appropriately. For example, one participant succinctly stated:

> *"Short answer, yes. Simply because my perception of workplace risks encourages me to pay more attention to critical information and details in the working environment." (P1)*

This quote underscores the direct relationship between risk perception and heightened situational awareness. Workers who are keenly aware of risks are more likely to notice important details that others might overlook, thereby preventing accidents and promoting a safer environment.

Moreover, participants emphasised that a good level of risk perception prevents them from underestimating potential dangers. This awareness makes them more alert to ongoing activities and changes in their environment, which is crucial for maintaining safety. One participant explained:

> *"Yes, I think so. When you have a good level of risk perception you will never underestimate risks and become more alert to all activities ongoing around you." (P16)*

This insight reveals that a well-developed sense of risk perception not only enhances situational awareness but also fosters a proactive attitude towards safety. Workers who recognise the significance of risks are more vigilant and prepared to address potential threats. As assured by another participant:

> *"Yes, indeed, an increased risk perception can improve situational awareness by motivating individuals to be more attentive to their surroundings, potential risks, and changing aspects of the environment. Being able to identify and comprehend risks*

> *enhances individuals' general knowledge of the situation, promoting a proactive and safety-conscious mindset.” (P19)*

On the contrary, one participant noted that understanding risks does not always lead to increased awareness of their surroundings. P9 stated:

> *“Honestly, I think risk perception does not always trigger situational awareness because just knowing something is risky doesn’t mean you stay alert all the time. You might know that a chemical is dangerous, but after doing the job every day, you can get used to it and stop paying as much attention. Staying aware needs more than just seeing risk, it comes from training, working with the team, and keeping your focus on the job. That’s why risk perception gives you the right mindset, but it doesn’t always keep you sharp in the moment.”(P9)*

The participant stated that identifying an activity or situation as perilous does not inherently maintain alertness. Risk perception establishes a foundational mentality that promotes caution; yet, elements such as training, teamwork, and active attention function as mechanisms that maintain awareness in practice, necessitating ongoing vigilance.

In conclusion, risk perception enhances situational awareness by fostering alertness (Endsley, 1995), yet it does not always maintain attention independently. It is suggested that awareness can decline without proper training, effective teamwork, and sustained focus. This indicates that individual perceptions and supportive organisational mechanisms contribute to maintaining situational awareness.

5.2 Workplace factors affecting the correlation between situational awareness and safety compliance

In sophisticated work environments, impaired situational awareness can have severe consequences, including the incurring of risks and unsafe behaviours(Nazir *et al.*, 2012). Situational awareness and safety compliance are crucial for ensuring the safety and efficiency of operations (Sandhåland *et al.*, 2015). However, they can be influenced by various workplace factors. This analysis identifies four factors that affect the relationship between situational awareness and safety compliance: workload and fatigue, work pressure and deadlines, complex work tasks and procedures, and long working hours. Table 5.2 summarises the frequency of the factor mentioned in the interviews (as participant numbers and the associated quotations).

Table 5.2: Summary of factors, number of participants and quotes of workplace factors

Main theme	**Factors**	**No. Participants out of 20**	**No. Quotes**
Workplace factors	Workload and Fatigue	10	22
	Work pressure and Meeting deadlines	5	9
	Complicated Work tasks and procedures	6	6
	Long working hours	6	14

5.2.1 Workload, Stress, and Fatigue

This factor emerged in 10 out of 20 interviews, with 22 quotations (Table 5.2). Workload and fatigue in the chemical and process industries have adverse effects on situational awareness and safety compliance, often influenced by production demands and operational complexities (Murray and Thimgan, 2016). An excessive workload can overwhelm employees, leading to stress and a decline in performance (Basit and Hassan, 2017). From the interviews, it was evident that workload affects situational awareness and safety compliance. For instance, P11 highlighted that situational awareness diminishes when tasks need to be completed within a short timeframe. The urgency and the demands of the tasks can lead to shortcuts and omissions in safety procedures. P11 noted:

> *"Actually, when I have to finish a task in a short time, this will make me lose awareness. When the task itself is exhausting and requires lots of effort, I skip some of the safety procedures in order to get it done on time. And dealing with a workload that exceeds our ability to cope with. This makes me try to do the job with less effort and sometimes violate safety procedures." (P11)*

This statement underscores the impact that workload has on safety compliance. Workers under excessive workloads may experience difficulty focusing on their tasks and prioritise task completion over adhering to safety protocols, leading to errors and lapses in safety compliance.

Fatigue, resulting from prolonged exertion or lack of rest (Caldwell *et al.*, 2019; Van Cutsem *et al.*, 2017), impairs cognitive functions like alertness and decision-making (Zahra *et al.*, 2015). This reduces situational awareness and increases the likelihood of errors, which is critically dangerous in high-risk environments (Mohammadfam *et al.*, 2021). For example:

> *"Being free from workload or stress also helps to comply with safety. Yeah, maybe fatigue and stress are the main factors. Maintaining situational awareness is challenging when someone is stressed or fatigued."(P8)*

This quote from P8 aligned with the previous literature, highlighting that the absence of stress and fatigue is important for safety compliance (Alroomi and Mohamed, 2021; Linda *et al.*, 2018). Understanding the impact of workload and fatigue on employees' situational awareness and safety compliance is essential for developing effective safety management strategies.

5.2.2 Work Pressure and Meeting Deadlines

This factor emerged from five participants out of 20, with nine quotations (Table 5.2), who highlighted the influence of work pressure and meeting deadlines (related to the urgency, time constraints, and consequences of failure) on situational awareness and safety compliance. Work pressure is often due to tight deadlines, which create a sense of urgency and stress among employees. Work pressure from multiple tasks within limited timeframes creates stress, which compromises situational awareness and leads to reduced safety compliance (Guo *et al.*, 2016; Kronenwett and Rigotti, 2019; Pooladvand *et al.*, 2022). Work pressure has a direct impact on concentration, as described by a participant:

> *"Non-compliance can result from working under pressure. Employees would be more likely to make errors. When working under very tight deadlines, I feel under pressure and lose concentration on the surrounding environment sometimes."(P10)*

This statement suggests that excessive work pressure can lead to errors and loss of concentration, which may, in turn, compromise situational awareness. It can also result in mistakes and non-compliance with safety protocols. Additionally, P8 described how the pressure from tight deadlines affects their awareness and compliance:

> *"Work pressure causes stress and anxiety, which can cause me to lose situational awareness of my surroundings. Tight deadlines can cause pressure on me, and the easy way to get the job done on time is to violate work and safety procedures when possible."(P8)*

This quote illustrates the detrimental effects of tight deadlines on employees' mental state and their consequent behaviour. The pressure to meet deadlines can lead to anxiety and reduced situational awareness, prompting employees to take shortcuts that compromise safety.

5.2.3 Complexity of Work Tasks and Procedures

This factor was mentioned by 6 participants out of 20 (Table 5.2). The chemical and process industries require accurate attention to detail and strict adherence to safety protocols. Complex work tasks demand extra concentration and mental energy, which can overwhelm employees and lead to mental exhaustion (Gaillard, 2018). This mental overload can significantly diminish situational awareness, making it challenging for employees to understand their environment and potential hazards clearly (Vidulich and Tsang, 2012).

Task complexity and procedural intricacy consistently impair situational awareness and safety compliance across high-risk industries, a pattern corroborated in the nuclear (Naderpour and Lu, 2013; Zhang *et al.*, 2013), construction (Hussain *et al.*, 2024), and transportation (Wang *et al.*, 2023) sectors. For instance, P17 highlighted how difficult tasks require heightened concentration, negatively impacting situational awareness:

> *"Situational awareness can be negatively impacted when there are tasks that are difficult to execute and require extra concentration. In such situations, the focus is on getting the job done regardless of the minor safety violations."(P17)*

This statement aligns with Wang *et al.* (2023), which shows that the complexity of tasks can consume an employee's cognitive resources, thereby diminishing their ability to maintain situational awareness. Participants in the interviews provided insights into how complex work procedures impact their situational awareness and safety compliance:

> *"Sometimes, work procedures are complicated due to some sensitive tasks. This requires more concentration on these tasks. This may burden the cognitive abilities and compromise situational awareness. The loss of situational awareness may lead to errors or lapses, ultimately compromising compliance with safety regulations." (P12)*

This statement highlights that sensitive task within procedures require high levels of concentration, which can be mentally exhausting and lead to lapses in situational awareness, thereby hindering compliance. Similarly, P18 emphasised the increased mental energy required for complex tasks, which impacts the ability to focus and complete tasks efficiently:

> *"Complex tasks require extra mental energy to complete. This increases the workload, which impacts the ability to focus and accomplish tasks. This could also affect the ability to ensure compliance with safety procedures, which increases the demand for concentration."(P18)*

The need for additional mental energy to handle complex tasks means that employees may struggle to maintain focus, which can potentially increase the likelihood of procedural non-compliance.

Likewise, safety procedures are critical in the chemical and process industries, but their complexity can sometimes lead employees to skip or manipulate them. This non-compliance can be attributed to the mental strain caused by these procedures, particularly when employees are already dealing with complex tasks (Santiago and Campus, 2007). P16 described how the complexity of tasks and safety procedures can lead to fatigue and reduced compliance:

> *"I think when the work task is very complex, it requires much attention and concentration. Sometimes, safety procedures are very hard to implement and require a great deal of concentration. I think paying close attention to details is important for maintaining accurate situational awareness."(P16)*

This quote highlights the challenges employees encounter when attempting to follow complex safety procedures while managing demanding tasks. The cognitive load from these tasks and procedures can lead to mental overload, which reduces situational awareness and increases the likelihood of safety violations.

The complexity of work tasks and procedures in the chemical and process industries impacts situational awareness and safety compliance (Naderpour and Lu, 2013; Zhang *et al.*, 2013). The need for extra concentration and mental energy to execute these tasks and procedures can overwhelm employees, leading to mental fatigue and a reduction in situational awareness (Silva Gomes and Cardoso Júnior, 2023). The evidence from the interviews suggests that complex tasks and intricate safety procedures contribute to mental overload, making it challenging for employees to maintain awareness and adhere to safety protocols.

5.2.4 Working Long Hours

This factor was identified in 6 out of 20 interviews with 14 quotations, as illustrated in Table 5.2. Due to the demanding nature of the tasks involved in the chemical and process industries, long working hours are a common feature. However, extended work periods significantly affect situational awareness and safety compliance. This analysis examines the impact of prolonged working hours on employees' cognitive functions, situational awareness, and adherence to safety rules and procedures. Participants indicated different elements which can impair their awareness, such as concentration and focus.

Working for long hours continuously can lead to cognitive fatigue, which impairs various mental functions essential for maintaining situational awareness (Johnston *et al.*, 2019; Williamson *et al.*, 2011). Cognitive fatigue manifests as reduced concentration, slower information processing, and impaired decision-making abilities (Brazaitis and Satas, 2023). For instance, P19 emphasised how continuous work decreases concentration and awareness:

> *"Yes. I believe that working continuously for long hours can decrease my concentration and awareness. My brain cannot stay focused for a long time. Breaking work tasks into sub-tasks so I can have breaks, and do not need to work for long hours, and can comply with safety."(P19)*

This statement highlights the need for breaks to prevent cognitive fatigue and maintain situational awareness. Therefore, employees' ability to concentrate may decline without sufficient rest, raising the risk of errors.

Extended work periods lead to reduced alertness, which is crucial for identifying and reacting to dangers in the work environment (Lerman *et al.*, 2012; Williamson *et al.*, 2011). Employees’ fatigue leads to a decline in situational awareness and their capacity to perceive, comprehend, and react to their surroundings (Endsley, 2015; Kuparinen-Koho, 2020). Participant P3 described the effects of working for long hours on concentration on what is happening around, and safety compliance:

> *"Yes, working for long hours can reduce the ability to focus and apply work and safety procedures appropriately. Long hours of working at sea and fatigue can cause loss of concentration on what is happening around you."(P3)*

This quote illustrates that long working hours, particularly in demanding environments such as offshore facilities, lead to a loss of concentration and a decreased awareness of one's surroundings. This reduction in vigilance can result in missed safety protocols and increased risks. Long working hours in the chemical and process industries impact situational awareness and safety compliance. The interviews highlight that long work periods may lead to cognitive fatigue, decreased concentration, and awareness, which can, in turn, reduce compliance.

These workplace factors have a negative impact on situational awareness and safety compliance. High workloads and fatigue can reduce alertness, leading to lapses in compliance with safety protocols (Bayounis and Basahel, 2020; Sneddon *et al.*, 2013; Zeytinoglu *et al.*, 2007). Similarly, intense work pressure and tight deadlines may push employees to prioritise speed over caution, compromising safety (Ghasemi *et al.*, 2018). Complex tasks require heightened attention and vigilance; if situational awareness is lacking, errors and protocol breaches are more likely (Naderpour and Lu, 2013; Zhang *et al.*, 2013). Additionally, long working hours contribute to fatigue, further diminishing situational awareness and increasing the tendency to skip safety steps (Macky and Boxall, 2008). This suggests that addressing these factors can improve safety outcomes by enhancing employees' ability to stay alert and comply with necessary safety measures.

5.3 Individual factors affecting the relationship between situational awareness and safety compliance

In the chemical and process industries, individual factors significantly influence the relationship between situational awareness and safety compliance. This directly affects the ability to identify potential hazards, maintain situational awareness, and respond to safety threats more effectively (Stubbings *et al.*, 2012). These factors, including safety knowledge, training, experience, overconfidence, and self-awareness, are important and should be taken into account to ensure accurate situational awareness and safety compliance. This analysis examines how these factors influence the relationship between situational awareness and safety compliance. Table 5.3 summarises the individual factors, the number of participants who mentioned these factors and the number of quotes.

Table 5.3: Summary of factors, number of participants and quotes of individual factors

Main theme	Factors	No. Participants out of 20	No. Quotes
Individual factors	Safety Knowledge	11	22
	Training	13	43
	Experience	6	10
	Overconfidence	4	6
	Self-Awareness	6	14

5.3.1 The influence of safety knowledge

This factor emerged in 11 out of 20 interviews with 22 quotations (Table 5.3). Participants argue that their level of safety knowledge has a direct impact on their situational awareness and compliance with safety protocols. Safety knowledge can shape the relationship between situational awareness and safety compliance in the chemical and process industries (Vinodkumar and Bhasi, 2010; Wang *et al.*, 2021). These industries inherently involve complex processes and hazardous materials, demanding a robust understanding of safety rules and technical procedures to maintain a safe working environment. The interplay between an individual's safety knowledge and ability to maintain situational awareness directly influences their compliance with safety regulations, enabling proactive hazard identification and informed decision-making, thereby mitigating risks and preventing accidents (Feller *et al.*, 2023; Haidegger, 2019; Irwin *et al.*, 2019; Orikpete and Ewim, 2024).

One significant aspect of safety knowledge is its role in enhancing an individual's ability to recognise and respond to unsafe behaviours and potential hazards (Ramdaniati *et al.*, 2023). As highlighted by one participant:

> *"Safety knowledge makes it easier to spot unsafe behaviour, potential dangers, and changes from standard safety procedures. When you use what you've learned about safety in the real world, you are more likely to spot cases where safety rules aren't being followed." (P20).*

This quote emphasises the importance of practical safety knowledge in real-world applications. It suggests that employees who are knowledgeable in safety procedures can be more effective in identifying deviations from safe practices, enabling them to take corrective actions promptly.

Moreover, safety knowledge empowers individuals to apply appropriate safety measures and avoid unsafe practices as suggested by Ramdaniati *et al.* (2023). As one participant articulated:

> *"Safety knowledge and understanding of work safety procedures empower me to identify risks and hazards and apply appropriate safety measures. Thus, avoiding unsafe practices and behaviours and working in a safe manner" (P2).*

This statement highlights how a thorough understanding of safety procedures not only facilitates hazard identification but also instils a sense of responsibility and confidence in employees to adhere to these procedures, ultimately fostering a safer work environment.

The confidence derived from safety knowledge is another critical factor that enhances situational awareness. As noted by another participant:

> *"People with more safety knowledge, I guess, are more confident and able to recognise unsafe actions or situations. Knowledge of safety rules and procedures makes it easy to work safely". (P8).*

This quote suggests that knowledge contributes to a worker's confidence in recognising and mitigating risks. Confidence in one's knowledge and abilities enable more accurate and timely situational assessments, which can lead to safer working practices. Furthermore, understanding the procedures and their importance in risk management encourages proactive safety behaviours:

> *"You know procedures and how they help you to take control over risks and execute your job, this understanding encourages me to implement them and work safely" (P8).*

This insight highlights that awareness of the rationale behind safety procedures motivates employees to follow them.

In conclusion, safety knowledge is integral to the relationship between situational awareness and safety compliance in the chemical and process industries. This knowledge enhances the ability to identify and respond to potential hazards, boosts confidence in recognising unsafe conditions, and encourages the diligent application of safety procedures.

5.3.2 The Influence of Training

This factor was identified in 13 out of 20 interviews, with 43 quotations (Table 5.3). Participants argue that training is an important factor influencing their situational awareness and safety compliance. Training and competence play a fundamental role in bridging situational awareness with safety compliance in the chemical and process industries (Hofmann and Stetzer, 1996; Wang *et al.*, 2021). Given the high-risk nature of these industries, it is essential that employees are not only aware of potential hazards but also possess the necessary skills and knowledge through training to manage and mitigate these risks effectively (Blair and Seo, 2007). Training programs are instrumental in fostering recognition competence, ultimately enhancing situational awareness and promoting strict adherence to safety protocols (O’Hare and Beer, 2020; Sutton, 2015).

Safety training is a cornerstone for developing the required safety knowledge that enables workers to effectively recognise and address potential hazards (Sanfilippo, 2016). As one participant noted:

"Safety training provides staff with the required safety knowledge to effectively recognise potential hazards and implement appropriate procedures. Situational awareness can be increased through safety training. Safety training provides the knowledge about potential risks and safe practices, which enables you to be more observant, recognise risks and respond to them effectively. Safety training also highlights the importance of recognising risks and reporting them" (P17).

This highlights the role of safety training in improved situational awareness. Training programs enhance employees' ability to observe, identify, and respond to hazards promptly by equipping them with knowledge about potential risks and safe practices. Furthermore, safety training can help recognise and report risks, which potentially can result in proactive safety practices. This underscores the dual role of training in both hazard identification and safety practices. Effective training ensures that employees are not only able to spot dangers but also understand the critical importance of reporting these risks.

The skills gained through training programs is suggested to further strengthen the relationship between situational awareness and safety compliance. As highlighted by one participant:

"I will say sessions of training because situation awareness is a skill, and the skill needs to be sharpened. Training helps us remain vigilant and responsive to changes in the environment, which is important for implementing safety procedures. It allows us to recognise early warning signs of potential dangers and respond appropriately to ensure continuous compliance with safety. Training is crucial for ensuring safety compliance as it equips individuals with essential skills and conveys knowledge about existing risks. Regular safety training provides me with the safety information I need to know to work safely" (P5).

This emphasises the role of training in maintaining high levels of situational awareness, which is crucial for timely and effective risk identification. This suggests that regular training keeps safety knowledge current and relevant, ensuring that employees are always prepared to handle evolving risks and challenges in the workplace. This ongoing education is important for maintaining a competent workforce prioritising safety, as reported by Ford and Tetrick (2008).

In conclusion, training is an important factors that impact the relationship between situational awareness and safety compliance (O'Hare and Beer, 2020). Regular safety training can equip employees with the necessary skills to recognise and respond to potential hazards, therefore enhancing their situational awareness (Bęś and Strzałkowski, 2024; Namian *et al.*, 2016). This, in turn, can promote an environment of safety compliance, where employees proactively mitigate risks and adhere to safety procedures.

5.3.3 The Influence of Experience

This factor was identified in 6 out of 20 interviews, with 10 quotations (see Table 5.3). Experience is important to maintaining situational awareness, adhering to safety procedures, and preventing accidents in high-risk environments (Massimiliano *et al.*, 2023). Experience has been identified as an important factor in maintaining situational awareness (Li *et al.*, 2020; Salmon *et al.*, 2008). By bringing knowledge and a nuanced understanding of their work environment, employees significantly enhance their ability to apply safety procedures and comply with safety regulations (Ahmed and Haque, 2023; Li *et al.*, 2021). For example, one participant reported:

> *"Experience I would say, makes me more mindful of risks and hazards in the workplace and how to cope with them on a daily basis. This experience can give the advantage to act appropriately in critical situations and ensure safety compliance." (P7)*

This statement illustrates that experience shapes situational awareness and promotes compliance. Likewise, P17 noted that experienced workers' heightened situational awareness naturally extends to more consistent application of safety procedures:

> *"Experience. If I were to say something, I would say that it can make you more aware of risks and hazards associated with my job, as well as how to deal with them on a daily basis. This level of situational awareness is reflected in applying safety rules and procedures and being compliant all the time." (P17).*

Another participant emphasises the significance of experience in cultivating the understanding of the work environment, allowing workers to anticipate potential hazards and take proactive action to ensure safety compliance:

> *"I think my own experience. With experience, I have deeper understanding of workplace operations and can identify potential hazards. The familiarity with procedures and knowledge of past incidents allows me to anticipate risks and implement preventative measures more effectively to ensure safer work environment. Sometimes I am in charge of doing a job and presides over other team workers. I have to pay attention to everyone to protect him and to save his life and to make sure that the job is done in the right way" (P3).*

This underscores the importance of experiential learning in developing an intuitive grasp of the work environment, enabling workers to foresee potential dangers and respond proactively. Experience not only aids in recognising risks but also in applying preventative measures derived from an understanding of historical incidents and established procedures.

5.3.4 The Influence of Overconfidence

This factor was identified in 4 out of 20 interviews, with six quotations (Table 5.3). Individual factors, such as overconfidence, can negatively impact the relationship between maintaining high situational awareness levels and safety adherence (Price *et al.*, 2016; Price and LaFiandra, 2017). Broihanne *et al.* (2014) and Mearns (2017) argue that overconfidence can lead to a false sense of security, causing workers to underestimate risks and neglect safety procedures. Raza *et al.* (2019) also reported that overconfidence can impair situational awareness by creating a false belief that one fully understands and can manage all aspects of a situation without remaining vigilant, leading to complacency and causing one to skip or inadequately perform safety measures. One participant stated:

> *"Yes. I believe that overconfidence can significantly impact situational awareness, as it may lead us to pay less attention to risks or overestimate our abilities, thereby narrowing our attentional focus and increasing the likelihood of procedural violations. When employees think they know everything about a situation without*

> *thinking about what might still be unknown, they become lenient in implementing safety procedures" (P20).*

This underscores the danger of assuming sufficient knowledge, which can result in neglecting unknown risks, compromising situational awareness, and undermining safety compliance. When workers believe they have mastered their environment, they may neglect the continuous assessment required to identify new or evolving hazards. For instance, a worker who has successfully managed similar tasks repeatedly might overlook small but significant changes in their surroundings that could pose new risks. One participant stated:

> *"When I do the routine tasks, I feel more confident that I do not need to care much about safety, as I have done this for many years and it has gone well. I think doing routine tasks reduces concentration because people are experienced and overqualified in doing it" (P5).*

This illustrates that when performing repetitive tasks, individuals may become mentally disengaged due to overconfidence in their ability to complete the tasks correctly. This will lead to an underestimation of risks, as workers may believe they are more capable than they actually are, reducing their alertness to potential hazards. When workers become overly confident in their abilities, they may begin to view safety protocols as unnecessary or burdensome.

5.3.5 The Influence of Self-Awareness

This theme was highlighted in six out of 20 interviews, with 14 quotations (Table 5.3). Self-awareness encompasses an individual's recognition of their responsibilities, the ability to monitor their actions, and the commitment to adhering to safety procedures for their own safety and the safety of others (Bourgeon *et al.*, 2019; Saetrevik and Hystad, 2017). One participant describes a scenario where self-awareness played a crucial role in preventing a catastrophe:

> *"To save someone else, you have to ensure your safety first to be able to help others. A live example of that, a few years ago, a newly hired contractor was trying to*

overhaul a pump containing H_2S dissolving in the main system. He started to open valves to drain the H_2S into the atmosphere. I spotted him, kicked him out of the area to be away from the gas, asked a colleague to close the valve, isolated the area and evacuated the plant. This incident was reported and his contract was terminated due to unsafe operation" (P8).

This incident highlights how P8's self-awareness allowed him to recognise the immediate danger and take decisive action to protect himself and others. This suggests that self-awareness can lead to immediate and appropriate responses to potential hazards. This example underscores the importance of self-awareness in maintaining a high level of situational awareness and promoting compliance with safety, which is a shared responsibility where everyone is accountable for maintaining a safe work environment.

In addition, when working with people who do not prioritise safety, self-awareness can trigger better situational awareness for some people and can lead them to be more compliant. As stated by P5:

"I have worked on different company sites. I tend to be more alert and keep an eye on things when I feel people around me do not care about safety. Working in locations where a minimum of 1 fatality a year is usual triggers my awareness to the maximum level. I think self-awareness is critical in this case to have accurate situational awareness and comply with safety." (P5)

This quote suggests that an individual's self-awareness makes them more alert and attentive to potential hazards when the environment feels unsafe, thereby ensuring compliance.

Another participant demonstrated that they prioritise safety and commit to it mentally. This mental commitment was described as important in assessing the situation and compliance with safety. The participant stated:

"When I think about safety, I make it a priority in my mind. Being committed to safety is important to identify and assess the situation around and be able to comply with safety."(P15)

This quote suggests that self-awareness is an active mental process that aids in continuously assessing and responding to situations, always prioritising safety.

In summary, self-awareness is important for maintaining situational awareness and improving safety compliance. Participants indicated that self-awareness enables individuals to make informed decisions that safeguard themselves and others. The provided example of P8's intervention in averting a dangerous incident illustrates the role of self-awareness in promoting a safe workplace.

5.4 Organisational factors affecting the correlation between situational awareness and safety compliance

Organisational factors pertain to the systemic and structural operation of the company or organisation. Organisational factors can affect the relationship between situational awareness and safety compliance. Managing such factors can strengthen the link, ensuring a safer workplace (Saetrevik and Hystad, 2017; Sandoval, 2005). Six factors emerged from the interviews. A summary of the factors, the number of quotes, and the number of participants is provided in Table 5.4.

Table 5.4: Summary of factors, number of participants and quotes of organisational factors

Main theme	Factor	No. Participants out of 20	No. Quotes
Organisational factors	Safety culture	10	16
	Management commitment and leadership	4	8
	Communication of risks and safety information	12	12
	Employee involvement	5	8
	Reporting system	5	9
	Safety rules and procedures	13	22

5.4.1 The influence of safety culture

This sub-theme was identified in 10 out of 20 interviews, with 16 quotations (Table 5.4). From the interviews, participants argue that safety culture is a critical factor that affects their situational awareness and safety compliance.

Safety culture, as defined in the quantitative phase, fosters an environment where safety rules and procedures are not merely guidelines but are deeply ingrained in the daily practices of every employee (Kabiesz and Tutak, 2024). This culture may encourage the observance of the environment, potentially leading to heightened situational awareness and more compliant behaviour. One participant has noted:

> *"Having a strong safety culture helps employees stay more aware of their surroundings, which in turn improves their ability to recognise risks and follow safety protocols. A colleague of mine once pointed out that a valve was slightly misaligned. He reported it immediately, and it turned out there was a pressure build-up. If people were not so careful about safety, this might not have been seen. By being alert and acting quickly, he stopped something that could have been disastrous. When safety culture is deeply established, workers not only recognise and perceive risks but feel obligated to address them" (P9).*

This highlights the importance of a safety culture in encouraging workers to remain consistently vigilant and aware of their surroundings, and to report unsafe conditions.

Moreover, a positive safety culture fosters a culture of shared responsibility, meaning that safety is seen as a collective effort rather than an individual task (Simpson, 2000). This collaborative approach ensures that unsafe acts are more likely to be observed and corrected by colleagues, creating a safer working environment. A participant noted this:

> *"A culture of shared responsibility regarding safety makes employees collaborative in observing unsafe acts. Predominant safety culture in the workplace and practising safety from top management to the bottom. A positive safety culture helps to be aware of workplace risks and hazards and maintain situational awareness. I think safety culture serves as a gear in the workplace as it motivates being observant and aware of surroundings, as well as driving the organisation towards safety compliance" (P10).*

Highlighting the top-down influence of safety culture underscores the importance of leadership in setting the tone for safety practices. When safety is consistently practised from management to frontline workers, it fosters a culture where safety protocols are taken seriously at all organisational levels. Describing safety culture as a "gear" in the workplace highlights its fundamental role in driving the organisation towards safety compliance.

5.4.2 The influence of management commitment and leadership

This factor emerged in four interviews out of 20 with eight quotations (Table 5.4). The participants argue that management commitment to work and safety procedures is important in the workplace. Leaders who practice and encourage safety set a positive example for their teams (Dannenberg, 2015; Gächter *et al.*, 2012). Such leaders develop a sense of responsibility and vigilance among employees, ensuring that situational awareness is a continuous and collective effort (Willmer, 2017). For example:

> *"Management is pushing to emphasise that boosting safety is everybody's responsibility. Good leadership practices safety and encourages employees to do so. Management commitment to safety also motivates us always to identify risks and hazards in the workplace and never underestimate them to maintain a high level of situational awareness at all times" (P7).*

Conversely, when management neglects safety and prioritises operational goals over safety protocols, they not only compromise situational awareness but also put lives and equipment at risk by underestimating risks and ignoring safety procedures.

> *"Some members of the management were pushing to proceed with the job at any cost. That was a job on a natural flow gas-producing well, and the well wasn't connected to the main station with the flow line. So, it's a new well, and the idea is to do a 24-hour test. They decided to collect and transport the produced liquid associated with the gas into an open-to-the-atmosphere tank, which is very dangerous. I wasn't there. But later on, I realised what happened there. The liquid associated with the gas usually contains condensates. In some way, there was a spark, and the tank caught fire as the atmosphere was saturated with gas. The accident happened and caused loss of lives and loss of equipment because decision-makers underestimated the situation and ignored safety procedures" (P2).*

This quote highlights that the catastrophic consequences underscore the critical need for management to assess situations accurately and never underestimate risks. In addition, it must prioritise safety and enforce strict adherence to safety procedures.

Leadership and management commitment play an important role in setting the tone for safety and establishing an environment where situational awareness is prioritised. P5 stated:

> *"Effective leadership ensures that employees have the necessary resources, like training and support, to maintain high levels of situational awareness. Employees who observe management's commitment to safety are more likely to adopt a similar focus on staying alert to potential hazards in their environment. On the other hand, failing to uphold a commitment to safety rules is like giving the green light to employees to take shortcuts. The enforcement of these rules is critical, as people tend to ignore safety rules if rules are not enforced and monitored." (P5)*

This quote suggests that when employees observe management's strong commitment to safety, it sets a behavioural standard. If leaders consistently prioritise safety, employees are more likely to mirror these behaviours, staying vigilant and aware of their surroundings. In contrast, failing to uphold safety rules can lead to employees becoming complacent, reducing their alertness to potential hazards, and ultimately compromising safety in the workplace.

In conclusion, management commitment and leadership are important to enhancing situational awareness and ensuring safety compliance in the workplace. The interviews highlighted that leaders who actively promote safety set positive examples and provide necessary resources to motivate employees to stay vigilant and continuously assess risks. However, when management neglects safety or fails to enforce safety rules, it undermines employees' awareness and compliance, leading to dangerous outcomes.

5.4.3 The influence of the communication of safety information

This factor was identified in 12 out of 20 interviews, with 12 quotations (Table 5.4), during which participants highlighted how communication of risk and safety information influences situational awareness and safety compliance. The participants argue that communication is very important for enhancing situational awareness and safety compliance. Communication is an important component in the chemical and process industries, directly influencing situational awareness and safety compliance. Effective communication ensures that employees are well-informed about potential hazards, safety protocols, and necessary precautions, thereby fostering a safer working environment (Massimiliano *et al.*, 2023).

Clear and consistent communication helps in building trust in management, encouraging employees to follow safety rules and procedures (Allert and Chatterjee, 1997). Sharing information regarding risks and hazards ensures that all employees are aware of them (Roth *et al.*, 2006). This, in turn, helps maintain situational awareness and apply safety measures. One participant stated:

> *"Good communication between departments regarding safety issues. This communication fosters an environment that prioritises safety for everyone. This communication channel can build trust in management and encourage them to follow the rules. Poor communication can lead to misunderstandings or ambiguity, making it more difficult to assess the situation and make informed decisions accurately. Regular safety meetings ensure that information about risks and hazards is effectively conveyed to employees" (P16).*

This quote underscores that regular and clear communication not only ensures that safety information is disseminated effectively but also builds trust in management and inspires compliance within the organisation. On the other hand, through sharing information about accidents, near misses, and potential dangers, organisations can enhance situational awareness among their employees and improve safety compliance (Gnoni and Saleh, 2017). For example:

> *"Reporting such unsafe acts allows us and the company as a whole to exchange information regarding accidents and near misses to avoid them being repeated awfully. Yes, I think clear communication of risks can ensure that all employees are well aware of potential hazards in their workplace. This communication enables employees to anticipate potential risks and respond promptly. Safety signs are visual reminders that enhance situational awareness by conveying critical information about*

hazards, mandatory actions, and prohibited activities. Safety signs are tools to reinforce awareness in all areas of the workplace" (P20).

This statement highlights the importance of clear communication in ensuring employees are well-informed about potential hazards. It also emphasises the role of communication through safety signs in enabling employees to anticipate risks and take timely action to mitigate them.

Conveying information about risks and safety measures can improve situational awareness and encourage workers to adhere to safety rules (Isreal, 2025). However, communication is not dependent on active verbal communication alone (Timmermans and Oudhoff, 2011). Safety signs serve as constant reminders of the risks and the measures in place to mitigate them as part of a broader communication strategy to help maintain situational awareness and encourage compliance with safety rules (Isreal, 2025). As stated by P6:

"Effective communication of risks and control measures in place to protect employees can raise situational awareness and encourage them to follow safety rules. Using safety signs in the workplace is a non-verbal method of communication. Safety signs inform and remind me of risks and hazards in every part of the site." (P6)

This quote emphasises the significance of effective communication and the importance of nonverbal communication methods, such as safety signs, in keeping employees informed about their surroundings and encouraging them to follow safety rules.

In conclusion, communicating safety information through safety signs is important for maintaining situational awareness and promoting safety compliance within organisations. By sharing information about risks and safety measures, employees are more likely to recognise hazards and follow safety rules. Nonverbal communication, such as safety signs, serves as a constant reminder of risks and control measures, helping to reinforce situational awareness throughout the workplace.

5.4.4 The influence of employee involvement

This factor was identified through five interviews out of 20, resulting in 8 quotations (Table 5.4). The participants argue that employee involvement in all aspects of developing workplace activities, procedures, and safety protocols improves their situational awareness of risk recognition and compliance with safety standards.

Identifying and assessing risks plays an important role in enhancing situational awareness (Dai *et al.*, 2016). When employees actively participate in risk assessments, they develop a deeper understanding of the hazards in their work environment, improving their ability to recognise and respond to potential risks (Zou *et al.*, 2010). For example, one participant noted:

> *"We are encouraged to contribute to looking for solutions to problems we face and share them with management. Employee involvement in risk assessment helps improve their ability to identify risks and hazards, thereby contributing to better situational awareness. This also motivates them to apply safety procedures and work safely" (P18).*

This quote highlights that involving employees in risk assessments not only enhances their ability to identify hazards but also fosters a proactive approach to safety. By being part of the solution, employees become more vigilant and situationally aware.

Additionally, involving employees in the development and review of safety procedures and policies can significantly motivate them to adhere to these protocols (French and Geller, 2008). When employees feel that their input is valued and that they have a say in the safety measures that affect them, they are more likely to follow these procedures diligently (Wilson and Nottrodt, 2009). They will develop better situational awareness and a stronger commitment to maintaining a safe work environment. For example, participant 4 commented:

> *"They encourage us to take part in assessing work conditions, risks that exist and any problems we face at work. Taking part in assessing work conditions, risks, and hazards also increases our ability to have accurate situational awareness. I think that providing employees with opportunities to participate in the creation or review of safety policies and procedures is an effective way to motivate them to identify potential risks and hazards, in addition to complying with them" (P4).*

This statement underscores the motivational aspect of employee involvement. Participation in creating safety policies makes employees feel responsible and accountable, and improves hazard recognition, which in turn enhances their commitment to maintaining a safe work environment (Ricci *et al.*, 2016).

Additionally, employee involvement can foster a sense of ownership and accountability. As stated by P6:

> *"I think that involving employees in any development or review of work procedures, safety procedures, and policies motivates them to have accurate situational awareness of workplace risks and hazards and apply safety precautions to mitigate these risks and comply with safety. This involvement can make employees feel that they are an important stakeholder in the workplace." (P6)*

The quote suggests that employee involvement in the development and review of safety procedures enhances situational awareness and safety compliance by increasing employees' understanding of risks and motivating them to follow safety protocols. It also suggests that this involvement fosters a sense of ownership and responsibility, potentially making employees more vigilant towards hazards and proactive in maintaining safety.

In conclusion, employee involvement in developing and reviewing safety procedures significantly enhances situational awareness and safety compliance. By participating in the development of safety procedures and policies, employees can gain a deeper understanding of workplace hazards and become more effective at identifying and responding to risks.

5.4.5 The influence of the reporting system

This factor was identified in 5 out of 20 interviews with nine quotations (Table 5.4). The five participants highlighted the influence of reporting on situational awareness and safety compliance. From interviews, participants argue that reporting unsafe acts and conditions makes them more attentive to their work environment and encourages them to apply safety rules and procedures. When a robust reporting system is in place, everyone will feel comfortable reporting unsafe practices and conditions (Probst and Estrada, 2010). Sharing reports helps employees learn from others' experiences, promoting widespread situational awareness and safety compliance.

> *"Additionally, the reporting mechanism that is in place encourages employees to be more vigilant about any unsafe acts. This gives us the courage to speak up and report unsafe acts. …… Sure, I will stop them immediately. This action must be reported to the HSE and the immediate supervisor. (P19).*

This underscores the importance of reporting systems in the workplace. Effective reporting systems encourage vigilance and prompt immediate action, promote situational awareness, and encourage the application of safety procedures (de Brito and Boy, 1999). Because the focus is on correcting the actions and improving conditions rather than imposing punishments, this strategy can encourage all employees to report unsafe conditions and acts without fear of retribution, even in extreme cases. Similarly, another participant said:

> *"We have a strict reporting system, and everyone is expected to report unsafe actions and conditions. Additionally, the reporting system encourages employees to stay alert for any unsafe behaviours or situations. Any unsafe act must be stopped immediately and reported as an unsafe act to the HSE for appropriate action. Sharing reports helps us learn from other employees' experiences," (P6).*

This also highlights the importance of reporting systems in enhancing situational awareness and ensuring adherence to safety procedures. Sharing reports helps employees learn from others' experiences, promoting widespread situational awareness and safety compliance.

5.4.6 The influence of safety rules and procedures

This factor was identified in 13 out of 20 interviews, with 22 quotations (Table 5.4). The participants argue that safety rules and procedures influence their willingness to implement and apply them. Quotes highlight the significance of simple and effective safety procedures in promoting adherence. For example,

> *"Work procedures, like the rule to always use a safety belt when taking readings, are designed to keep us safe. But in reality, the design of offshore platforms makes it difficult to apply that rule every time. In some cases, we end up using ladders instead, which is technically a deviation from the procedure. Since the layout of pipelines can't*

be changed, we have to adapt to get the job done. We're always conscious of the risks, so we take extra care when we use alternative methods. Still, when procedures are written clearly and reflect the actual work conditions, people are much more likely to comply with them. That's why regular updates and improvements to procedures are essential, they make it easier for our awareness to translate into safe actions." (P10).

The quote highlights the practical challenges workers face when safety procedures are difficult to follow due to design constraints. This necessitates adaptation and often results in deviations from standard procedures.

Although following safety rules is generally straightforward, people may choose to skip them for various reasons, resulting in reduced situational awareness and control over potential hazards. One participant highlighted:

"Actually, following safety rules and procedures is easy, however, people choose to skip them. When people deviate from procedures, they become less aware of the risks and hazards that may arise and less able to control the situation. Yes, knowing safety rules and procedures is fundamental to working safely. I always apply safe working procedures to ensure compliance with safety" (P13).

This quote highlights that when individuals choose to deviate from safety procedures, their situational awareness tends to diminish, making it more difficult to anticipate hazards or control adverse situations, which may lead to non-compliance. Another participant stated:

"From my experience, the safety rules and procedures are what tie situational awareness and compliance together. If I'm just "aware" of what's happening around me but there are no clear rules, that awareness doesn't always translate into safe action. For example, I might notice a pressure gauge climbing, but without a defined procedure, I might delay or handle it the wrong way. The rules give me the step-by-step response, so my awareness turns into proper compliance."(P4)

This suggests that even if the situational awareness identifies the problem, without procedural guidance, the operator may act inconsistently or even dangerously. This suggests that safety rules and procedures are important for translating situational awareness into safety compliance actions.

5.5 Chapter summary

The thematic analysis was presented, which identified four main themes from interviews (confirmatory study of relationships between study constructs, workplace factors, individual factors, and organisational factors). The confirmatory study of relationships between study constructs revealed that risk perception influences safety knowledge, which has a direct impact on safety compliance. It also showed that risk perception has a direct influence on safety culture, which in turn influences safety compliance. The results also exhibited that risk perception directly influences situational awareness in the workplace.

The workplace factors are workload, stress, and fatigue; work pressures and deadlines; complex tasks and procedures; and long working hours. These factors negatively impact situational awareness, which in turn reduces safety compliance. Conversely, individual factors such as safety knowledge, training, experience, and self-awareness positively influence situational awareness, which in turn likely leads to improved safety compliance. However, overconfidence can undermine situational awareness, leading to lower adherence to safety protocols. The organisational factors are safety culture, management commitment, communication, employee involvement, reporting systems, and safety rules and procedures. The presence and effectiveness of these six organisational factors facilitate vigilance and enhance situational awareness; conversely, if these factors are ineffective, even aware workers may resort to violations that undermine both situational awareness and safety compliance. Further discussion on these findings of Chapter 5: will be presented in Chapter 6:.

Chapter 6: Discussion of Quantitative and Qualitative Findings

This chapter interprets the study findings by synthesising quantitative and qualitative evidence to explain the mechanisms through which risk perception translates into safety compliance in the Chemical Process Industries (CPI). Specifically, the chapter examines how safety knowledge, safety culture, and situational awareness operate as mediating mechanisms that shape workers' safety behaviour in high-risk process environments. By integrating statistical mediation analysis with qualitative thematic insights, this chapter provides a deeper understanding of how these constructs interact to influence safety practices within complex industrial systems.

The discussion is organised into seven sections. Section 6.1 discusses the mediating role of safety knowledge, followed by Section 6.2, which examines the mediating role of safety culture. Section 6.3 compares the mediating roles of safety knowledge and safety culture. Section 6.4 then discusses the mediating role of situational awareness. Section 6.5 outlines the limitations of the study, while Section 6.6 presents an additional investigation of the quantitative data informed by factors identified in the qualitative analysis. Finally, Section 6.7 summarises the key insights of the chapter.

6.1 The mediating role of safety knowledge between risk perception and safety compliance

The mediation analysis reveals that safety knowledge serves as a critical mechanism through which risk perception translates into safety compliance in the CPI context, supporting Hypothesis 1. As detailed in Table 4.29, the significant indirect effect ($\beta = 0.227$) confirms that risk perception operates both directly and indirectly through knowledge acquisition to shape compliance behaviours.

Safety knowledge is important for converting risk perception into safety compliance. From a theoretical perspective, this relationship reflects the mechanisms proposed by Protection Motivation Theory (PMT), which suggests that perceived threats motivate individuals to seek coping strategies, including the acquisition of knowledge that enables protective behaviour (Rogers, 1983). Similarly, the Health Belief Model emphasises that perceived susceptibility and severity can stimulate behavioural readiness when individuals believe they possess the knowledge required to act (Rosenstock, 1974).

The statistically significant direct influence of risk perception on safety knowledge ($\beta = 0.521$) (section 4.6.1, Table 4.29) indicates that individuals with heightened risk perception and awareness can be more likely to actively pursue and retain safety-related information. This effect of risk perception found in our study is stronger than those reported in previous literature, suggesting that the relationship between risk perception and safety knowledge acquisition operates more powerfully in the CPI context than in other industrial settings. While Zhao *et al.* (2021), reported a weak effect ($\beta = 0.27$) in their chemical industry study, the current finding nearly doubles that magnitude, indicating that risk perception serves as a substantially more potent driver of safety knowledge acquisition.

The qualitative findings converge with these statistical results by illustrating how workers themselves perceive and enact this relationship in practice. As P20 articulated, "*high levels of risk perception made me curious to have as much safety knowledge because I appreciate its importance. This makes me more prepared and able to deal with risks and mitigate them"*, illustrating how perceived vulnerability triggers proactive learning as a preparatory strategy. This statement reflects the threat appraisal mechanism described in the PMT. According to PMT, individuals who perceive higher levels of threat become motivated to engage in protective cognitive behaviours, such as acquiring knowledge that enables them to manage potential hazards. In the CPI context, heightened awareness of operational risks appears to stimulate proactive knowledge-seeking behaviour as workers attempt to reduce perceived vulnerability and increase their ability to respond effectively to hazardous situations (Rogers, 1983).

Similarly, P5 framed safety training as the conduit for this process, stating training "is the means of building knowledge and increasing the level of risk perception. When we perceive high risks, we are keen to know more about how to control them," underscoring risk perception's role as a motivational driver for knowledge engagement. This observation reflects the coping appraisal component of PMT, where individuals evaluate whether they possess the resources or knowledge required to manage perceived threats. When risk perception increases, workers become more motivated to seek training and safety information to improve their ability to control hazards.

This convergence between statistical relationships and experiential accounts strengthens the validity of the proposed behavioural sequence and confirms that risk perception functions not merely as a cognitive assessment of danger but as an important driver of knowledge-seeking behaviour in hazardous operational environments. This mechanism may be particularly pronounced in the Chemical and Process Industries, where workers routinely operate within tightly coupled systems involving hazardous substances and complex process controls, making the acquisition of accurate safety knowledge essential for effective risk management.

This finding builds on and extends Jahangiri *et al*. (2008) positive correlation (r= 0.609) by establishing a directional causal pathway rather than merely a correlational relationship in the CPI. The current finding also aligns with that of Namian *et al.* (2016) regarding the role of risk perception and recognition in the effectiveness of training interventions in high-risk contexts. The CPI's inherent hazards, where severe consequences are ever-present, appear to intensify this relationship, as workers recognise knowledge as non-negotiable for risk mitigation (Basahel, 2021; Christian *et al.*, 2009). Consequently, organisations can leverage risk awareness as a pedagogical tool, designing training that explicitly connects hazard recognition to knowledge application, thereby sustaining preparedness.

Likewise, the direct effect of safety knowledge on safety compliance was also statistically significant (β = 0.436) (Table 4.29). This finding suggests that higher levels of safety knowledge are associated with greater adherence to safety compliance measures. The relatively large effect size suggests that procedural knowledge becomes a decisive behavioural determinant in high-risk environments such as the CPI, where operational errors can rapidly escalate into catastrophic incidents. This result aligns strongly with the foundational theoretical work by Griffin and Neal (2000). They argued that safety knowledge allows workers to understand the risks associated with non-compliance, thereby increasing adherence to safety rules. This finding demonstrates remarkable consistency with Chung's (2018) healthcare study (β = 0.431), suggesting model stability in high-risk sectors where consequences are heightened. The effect observed in this study (β = 0.436) exceeds that reported by Kwon and Kim (2013) in manufacturing (β = 0.266), suggesting that safety knowledge may play a more critical role in the CPI due to the highly technical nature of chemical processes and the severe consequences of errors.

The qualitative findings complement this statistical evidence by illustrating how workers interpret and apply safety knowledge in their daily activities and translating it into safety compliance. P19 exemplified this notion: *"a strong base in safety knowledge and a clear understanding of safety rules and procedures make employees more likely to work in a safe manner... [due to] heightened adherence to established protocols, which contribute to minimising workplace risks*". This statement highlights how safety knowledge supports consistent rule adherence and enables workers to correctly interpret and apply operational procedures. In the chemical and process industries, where tasks involve complex systems and hazardous materials, such procedural understanding is essential for informed operational decision making and maintaining safety compliance (Clarke, 2006; Griffin and Neal, 2000). This interpretation reinforces the mediating role identified in the quantitative model, illustrating how safety knowledge transforms abstract awareness of hazards into concrete behavioural responses during routine operations.

Taken together, the quantitative and qualitative findings demonstrate that safety knowledge functions as the cognitive bridge translating risk perception into consistent safety compliance. Statistical effect sizes demonstrate the strength of this relationship across the sample, while participant accounts illuminate the cognitive processes through which knowledge enables workers to understand the rationale behind procedures, recognise situations requiring adaptation, and maintain compliance

Additionally, the direct effect of risk perception on safety compliance in the mediation model (Figure 4.2) was statistically significant ($\beta = 0.364$) (Table 4.29), demonstrating that risk perception still has a direct influence on safety compliance. This direct path assures the partial mediating effect of safety knowledge. In the CPI context, where workers are frequently exposed to high-consequence hazards, heightened risk perception may independently motivate precautionary behaviour even before knowledge-based responses are activated. It suggests that individuals who perceive higher risks are more likely to engage in behaviours that comply with safety standards, regardless of their level of safety knowledge. While the persistence of this direct pathway aligns with previous literature, its magnitude reveals important contextual nuances of the risk perception-compliance relationship. The current effect size (0.364) falls within but refines the range established by prior research, such as Ji *et al.* (2011) finding in aviation ($\beta = 0.26$) and Xia *et al.* (2016) in construction ($\beta = 0.432$), Xia *et al.* (2017) in construction ($\beta = 0.25$). The current study's intermediate effect size ($\beta = 0.364$) contributes to this body of evidence by suggesting that contextual variation is theoretically significant. It suggests that the strength of the direct risk perception-compliance relationship is contingent upon industry-specific characteristics, particularly the nature of hazards and operational complexity.

The statistically significant indirect effect of risk perception on safety compliance mediated by safety knowledge ($\beta = 0.227$) confirms the mediating role of safety knowledge in the CPI (Table 4.29). This finding suggests that risk perception has an indirect influence on safety compliance through safety knowledge. The total effect (direct and indirect) is ($\beta = 0.591$), so other factors not captured in this model, such as safety culture, could complement this relationship. The mediation proportion implies that safety knowledge accounts for 38% of the total effect (0.591) of risk perception on safety compliance, thereby supporting an interpretation of it being essential.

The qualitative findings provided a coherent narrative that illuminates the statistical mediation identified in the quantitative analysis. While the quantitative model establishes the relationships among risk perception, safety knowledge, and safety compliance, the qualitative data explain the mechanisms underlying these links. The sequence of risk perception → safety knowledge → safety compliance emerged consistently across interviews, with workers explicitly describing how knowledge informs procedural decisions and operational actions. This dual evidence validates the statistical mediation model while adding temporal and explanatory depth that numbers alone cannot capture. By empirically demonstrating this mediation pathway, the study extends existing safety behaviour models by showing how safety knowledge operates as the mechanism through which risk perception translates into compliance within the CPI context, positioning knowledge acquisition as a crucial driver of safe work behaviour.

The practical significance of this mediation is underscored by historical CPI incidents. Major industrial accidents illustrate how deficiencies in safety knowledge can prevent workers from translating risk awareness into safe action. Investigations of the Texas City Refinery explosion revealed that operators recognised process hazards but lacked the procedural knowledge required to apply appropriate control measures during unit start-up, demonstrating a gap between perceived risk and operational capability (CSB, 2007). Similar patterns are evident in the Bhopal disaster of 1984 and the Piper Alpha disaster of 1988, where investigations identified knowledge gaps, procedural misunderstandings, and inadequate comprehension of safety systems as critical contributors to catastrophic outcomes. In these events, workers were not entirely unaware of the risks; rather, they lacked the detailed operational knowledge needed to interpret warning signals, implement protective procedures, and respond effectively during abnormal conditions. These cases, therefore, demonstrate that risk perception alone does not ensure safe behaviour; without sufficient safety knowledge, awareness of hazards may fail to translate into appropriate compliance actions within complex industrial environments.

These case studies collectively reinforce the argument that while risk perception is necessary, it is insufficient on its own to ensure safety compliance. Safety knowledge is the critical mediator that translates risk awareness into effective safety compliance practices (Clarke, 2006). In practical terms, the findings of this study suggest that to improve safety knowledge, organisations must invest in safety training programs beyond simply informing workers of the risks (Burke *et al.*, 2011; Namian *et al.*, 2016). Improving safety knowledge through continuous scenario-based training is essential for enhancing compliance in such high-risk industries (Haslam *et al.*, 2005). This training keeps employees updated on changing hazards and protocols, and customising it for particular roles enhances the applicability of safety knowledge (Burke *et al.*, 2006; Geller, 2005; Geller, 2001; Zohar, 2002). However, restrictive schedules and engagement challenges diminish training efficacy since traditional forms of training frequently do not capture employee interest (Burke *et al.*, 2011; Wilkins, 2011). Incorporating training into standard workflows, utilising interactive scenarios, and providing flexible formats enhances accessibility and retention (Neal and Griffin, 2006).

Incorporating this safety knowledge gained from training into daily operations via briefings and checklists cultivates consistent safety practices, diminishing the likelihood of errors (Neal and Griffin, 2006; Reason, 1990). Nevertheless, integrating safety briefings and checklists into routine operations may encounter opposition, as staff members might perceive them as superfluous disruptions (Hepner *et al.*, 2017). Engaging employees in the development process and obtaining continuous feedback can enhance acceptance and ensure that these tools correspond with the requirements of their workflows (Neal and Griffin, 2006; Reason, 1990).

Simulation-based training enhances risk perception, enabling workers to internalise the repercussions of non-compliance, thereby improving long-term safety behaviour (Wang *et al.*, 2010). Although simulation-based training effectively enhances risk perception, high costs and doubts about practicality limit its adoption (Elendu *et al.*, 2024). Implementing pilot programs, securing external funding, and showing return on investment data can demonstrate value and justify investment (Wang *et al.*, 2010). By focusing on the continuous development and reinforcement of safety knowledge, organisations can promote safety and ensure that risk perception can lead to safe compliance practices, thus preventing future incidents and ensuring a safer working environment.

Overall, this study provides important theoretical and empirical contributions to safety research. Theoretically, it clarifies the cognitive mechanism through which risk perception translates into safety compliance by identifying safety knowledge as a key mediating factor. Methodologically, the integration of quantitative mediation analysis with qualitative worker narratives offers robust mixed-methods evidence explaining how this behavioural pathway operates in practice. From an industry perspective, the findings highlight the critical importance of developing and sustaining safety knowledge within the Chemical and Process Industries, where complex operational environments and high-consequence hazards make informed decision-making essential for preventing catastrophic accidents.

6.2 The mediating role of safety culture between risk perception and safety compliance

The present study demonstrates that safety culture serves as a critical mediator in translating risk perception into safety compliance within the chemical and process industries. As outlined in Section 4.6.2, the mediation analysis results robustly support hypothesis 2, which states that safety culture mediates the relationship between risk perception and safety compliance in the chemical process industries (CPI).

Quantitatively, risk perception exhibited a moderate positive correlation with safety culture (β = 0.574) (Table 4.31) in the CPI, implying that employees' increased awareness and perception of workplace risks can contribute to the development of workplace safety culture. The path coefficient (β = 0.574) exceeds the bivariate correlation (r= 0.543) reported in Table 4.27. The risk perception-safety culture relationship in the CPI is approximately 2.5 times stronger than the (r= 0.227) relationship observed by Colim *et al.* (2021) in a furniture manufacturing. This difference likely reflects the fundamentally lower hazard severity, simpler operational complexity, and less tightly coupled processes in furniture manufacturing compared with the high-risk CPIs.

Qualitative insights corroborate this pattern, showing that risk perception functions not only at the individual level but as a "cultural substrate" shaping organisational norms. As P6 explained, "*risk perception doesn't just affect individual behaviour, it sets the tone for the entire safety culture*," illustrating how accurate hazard recognition drives procedural adherence and peer reinforcement. When employees recognise and communicate risks collectively, they model safe behaviours for one another, reinforcing adherence to procedures and safety protocols. This shared understanding shapes organisational norms, as workers internalise risk-aware practices not only for individual protection but as expected standards within the group. This suggests that risk perception drives organisational mechanisms through peer reinforcement and normative influence that strengthen safety culture and support consistent compliance behaviour.

While the current study found a moderate positive correlation between risk perception and safety culture (r= 0.543), Kao *et al.* (2008) reported a weak but negative correlation (r= -0.206) in their investigation of five petrochemical plants in Taiwan. This difference (positive in the current CPI context versus negative in the petrochemical setting) likely reflects contextual and organisational variations rather than contradictory findings. In highly regulated chemical process environments, where operations involve tightly coupled processes and hazardous substances, risk perception tends to reinforce collective vigilance and strengthen procedural adherence, thereby contributing positively to safety culture. A pertinent example of the positive correlation between risk perception and safety culture is the Bhopal disaster of 1984, where inadequate risk perception and a weak safety culture led to one of the worst industrial accidents in history, resulting in thousands of casualties (Dhara and Dhara, 2002).

The findings also revealed that safety culture has a modest direct correlation to safety compliance ($\beta = 0.442$) (Table 4.27) in the CPI, reflecting the influence of organisational norms on employees' adherence to safety procedures. This beta coefficient is supported by the bivariate correlation ($r = 0.543$) presented in Table 4.27. This relationship is well-documented in the literature, indicating that components of a strong safety culture, including management commitment, transparent communication, and ongoing safety training, are important for cultivating an environment where compliance is the standard. The finding of a direct link between safety culture and compliance was also found by Kuswara (2017) with ($\beta = 0.689$) in the oil and gas industry. This is also consistent with Kalteh *et al.* (2022), who found a significant direct relationship between safety culture and safety compliance ($\beta = 0.783$) in oil and gas refineries. Hafeez *et al.* (2022) also found that safety culture has a positive impact on safety compliance ($\beta = 0.53$) in healthcare.

Qualitative evidence illuminates the mechanisms underpinning this effect. The mechanism for this influence was shown to be management commitment and open communication, which transform safety from a set of rules into an intrinsic value. As P20 articulated, effective leadership and communication *"can create an environment where employees do not see safety as just a set of rules, but an essential part of how work is done."* This demonstrates that management commitment and open communication serve as the mechanisms through which safety culture influences behaviour, transforming formal rules into shared organisational norms that promote consistent adherence. This finding is consistent with a body of literature, including Zohar (2002) and Dannenberg (2015), which posits that a positive safety culture leads to higher compliance.

Despite the finding of the current study being notably lower than findings from other high-risk sectors, this contextual variation suggests that the strength of the safety culture-compliance relationship could be contingent upon industry-specific characteristics, particularly the nature of operational complexity and technical demands. The chemical process industries (CPI) context examined in this study involves unique technical challenges that likely attenuate the safety culture-compliance relationship compared to other sectors. This finding of safety culture-compliance relationship highlights the importance of organisational safety culture in influencing individual behaviours, illustrating that a proactive safety culture not only mitigates risks but also fosters robust compliance with safety protocols among employees (Stosic *et al.*, 2023).

A statistically significant indirect effect of risk perception on safety compliance mediated by safety culture was identified ($\beta = 0.254$) (Table 4.29), confirming the mediating role of safety culture within the CPI context. This finding suggests that risk perception indirectly influences safety compliance through safety culture. The total effect of risk perception on safety compliance ($\beta = 0.593$) suggests that additional mechanisms beyond safety culture also contribute to this relationship. The mediation proportion implies that safety culture accounts for 43% of the total effect (0.593) of risk perception on safety compliance, thereby supporting the interpretation that it is essential. The partial mediation reflects the complexity of CPI operations, where tightly coupled processes, hazardous substances, and varying organisational norms mean that cultural mechanisms alone cannot fully translate risk perception into compliance.

This finding is unique in that it is the first research to use safety culture as a mediator between risk perception and safety compliance. The model of risk perception → safety culture → safety compliance is supported by the qualitative insights, which highlighted the role of risk perception in shaping safety culture and how safety culture leads to safety compliance. These findings validate the hypothesised mediation pathway (Hypothesis 2) while revealing its cultural mechanics. Risk perception initiates the chain by establishing the collective hazard awareness necessary for cultural formation, which culture then operationalises into habitual compliance

The finding of partial mediation, rather than full mediation, points to the existence of other factors and potential obstacles that can impede the translation of risk perception into compliance, even when a safety culture is present. These include resistance to change, which is a well-documented obstacle that can impede the development of safety culture, as employees may perceive safety practices as disruptive to their established routines (Probst and Graso, 2013). Involving employees in safety planning and effectively communicating the advantages of safety practices can cultivate ownership and alignment with organisational and individual objectives (Kath *et al.*, 2010). Leadership commitment is essential for surmounting these obstacles, as engagement in safety initiatives, strategic allocation of resources, and exemplifying safe behaviours indicate that safety is a priority throughout the organisation (Michael *et al.*, 2005). Furthermore, systematic evaluations of safety incidents and near-misses facilitate ongoing enhancement, ensuring that safety protocols remain pertinent and efficient, particularly in dynamic risk contexts (Wu *et al.*, 2008; Zohar and Luria, 2003).

These insights are reflected in numerous historical industrial disasters where deficiencies in safety culture and risk perception resulted in catastrophic consequences. Major industrial accidents illustrate how deficiencies in risk perception and safety culture can prevent organisations from translating hazard awareness into effective compliance behaviour. Investigations of the Bhopal disaster, the Piper Alpha disaster, and the Texas City Refinery explosion consistently identified similar mechanisms: inadequate hazard recognition, procedural misunderstandings, and failures to convert risk awareness into safe operational action. These incidents demonstrate the particular vulnerability of the CPI environments, where tightly coupled process systems, hazardous substances, and complex operational procedures require accurate risk interpretation and strong cultural reinforcement to ensure safe performance. In such settings, awareness of risk alone is insufficient; it must be embedded within organisational norms and supported by leadership, communication, and procedural discipline. These cases therefore reinforce the mediation pathway identified in the present study by illustrating how safety culture functions as the organisational mechanism that translates risk perception into consistent safety compliance within high-risk process environments.

From a theoretical perspective, this finding clarifies the behavioural pathway through which risk perception is translated into compliant safety behaviour within organisational settings. Methodologically, the integration of quantitative mediation analysis with qualitative insights strengthens the robustness of this conclusion by demonstrating not only the statistical existence of this pathway but also the organisational mechanisms through which it operates. Within the chemical and process industries, where complex processes and tightly coupled operational systems require consistent adherence to safety procedures, the findings highlight the critical role of safety culture in converting risk perception into sustained safety compliance.

6.3 Comparison of the mediating roles of safety knowledge and safety culture

The analysis of safety culture and safety knowledge as mediators reveals important nuances in how risk perception translates to safety compliance in the chemical process industries (CPI). Both mediators demonstrate statistically significant indirect effects, but with differences in magnitude and explanatory power. Safety culture exhibits a stronger mediating effect (β= 0.254) compared to safety knowledge (β= 0.227), accounting for 43% of the total effect (β= 0.593), versus 38% for safety knowledge of the total effect (β= 0.591). This 5%-point difference represents a 13.2% relative increase in explanatory power. This finding suggests that in the CPI context, organisational safety culture serves as a slightly more potent mechanism for converting risk perception into safety-compliant behaviour than individual safety knowledge. The total effects are nearly identical (0.593 vs 0.591), confirming the robustness of the overall risk perception-safety compliance relationship while highlighting the differential contribution of each mediator. The 57% of the relationship unexplained by safety culture (compared to 62% for safety knowledge) indicates that safety culture operates more comprehensively within the safety system. In practice, this suggests that while both knowledge development and culture building are essential, safety culture interventions may yield slightly greater returns in translating risk perception into compliance in the CPI.

The exceptionally high correlation between safety knowledge and safety culture ($r = 0.823$) has important implications for interpreting their mediating effects. While single-mediator models indicate statistically significant indirect effects for both constructs, the strong association between them suggests that these effects may partially reflect shared underlying variance rather than fully independent mechanisms (Beckstead, 2012). Consequently, the modest difference in variance explained (38% vs. 43%) should be interpreted with caution, as it may represent conceptual overlap rather than distinct explanatory power.

This finding resonates with organisational learning theory (Argyris and Schön, 1997), which posits that individual knowledge acquisition and organisational norms co-evolve within a reciprocal reinforcement cycle: safety culture shapes what knowledge is valued and disseminated, while collective knowledge enactment reproduces cultural norms. Consequently, the apparent marginal advantage of safety culture as a mediator should not be interpreted as evidence of hierarchical primacy. Rather, these constructs likely represent intertwined manifestations of a broader safety system (Bisbey *et al.*, 2021) through which risk perception is translated into safety compliance. This interpretation suggests that in high-hazard contexts such as the CPI, knowledge and culture function as mutually constitutive rather than competing pathways.

In real-world incidents, in Bhopal, a lack of safety knowledge left workers unequipped to manage the risks associated with toxic methyl isocyanate, resulting in catastrophic fatalities (Fortun, 2009). Similarly, the Texas City explosion revealed how a weak safety culture, characterised by inconsistent safety protocols and budget constraints, can deprioritise compliance and exacerbate risks (CSB, 2007). These cases highlight the importance of integrating safety knowledge and safety culture to develop a comprehensive approach to compliance. By empowering individuals with practical knowledge and reinforcing safety norms at the organisational level, industries can create a synergistic framework that transforms risk perception into effective and consistent safety compliance practices, thereby reducing hazards and preventing future incidents.

6.4 The mediating role of situational awareness between risk perception and safety compliance

As outlined in Section 4.6.3, the analysis results did not support Hypothesis 3, which posited that situational awareness mediates the relationship between risk perception and safety compliance. The hypothesised mediating role of situational awareness was not supported (β = 0.005) (Table 4.32) due to the low and non-significant beta coefficient, leading to the rejection of hypothesis 3.

The analysis reveals a moderate direct effect of risk perception on situational awareness (β = 0.32) (Table 4.32). This suggests that when employees have an accurate perception of risk, they are more likely to possess precise situational awareness. This result is supported by the bivariate correlation (r= 0.323) in (Table 4.27). This indicates that within the context of the chemical process industries (CPI), an employee's accurate perception of potential hazards is a tangible, though not overwhelmingly dominant, contributor to their development of a precise and dynamic understanding of their operational environment. This finding aligns cohesively with and strengthens the existing body of literature. It converges with the work of Xie *et al.*

(2025), who demonstrated a similar positive relationship ($\beta = 0.264$) among airline pilots, and Ji *et al.* (2018), who reported a comparatively stronger effect ($\beta = 0.39$) among Chinese civil flying cadets.

The position of the present CPI finding within the range of effects reported in aviation studies highlights the cross-domain relevance of the relationship between risk perception and situational awareness. However, the moderate magnitude of the effect observed in this study likely reflects contextual differences between operational environments. While aviation systems operate within highly standardised and simulation-intensive training structures, CPI operations frequently involve less visible hazards, complex process interactions, and dynamic human–machine interfaces. Consequently, risk perception functions not as the sole determinant of situational awareness but as a critical enabling factor within a broader constellation of influences. This interpretation is consistent with Situational Awareness Theory (Endsley, 1995), which conceptualises situational awareness as emerging from the perception of environmental elements, their comprehension, and the projection of their future states. Within this framework, accurate perception of hazards represents the initial cognitive step that enables workers to interpret operational cues and anticipate potential safety threats.

Qualitative insights from the present study further illuminate this cognitive mechanism. Participant 5 explained, “Yes, I think so, because high levels of risk perception can enhance vigilance and make people more attentive to their surroundings.” This statement illustrates how heightened risk awareness encourages workers to actively monitor their operational environment and remain attentive to subtle changes that may indicate emerging hazards. In practice, this heightened attentional focus strengthens the perceptual stage of situational awareness by directing attention toward critical environmental cues. Through this mechanism, risk perception enhances vigilance and supports the early identification and anticipation of potential dangers, thereby enabling workers in CPI settings to respond more effectively to dynamic and potentially hazardous operational conditions.

Surprisingly, situational awareness does not affect safety compliance in CPI with ($\beta = 0.017$, $p = 0.781$) (Table 4.32), while the bivariate correlation is ($r= 0.175$) Table 4.27, which contradicts the previous research. Endsley (1988) asserts that situational awareness is the paramount and immediate indicator of individuals' safety compliance and safe performance in safety-critical sectors. Sneddon *et al.* (2013) found that reduced levels of situational awareness were significantly associated with heightened unsafe behaviour in the workplace. Other studies also argue that safety performance is predominantly linked to individuals' situational awareness (Caponecchia *et al.*, 2018; Endsley and Robertson, 2000). Gheisari *et al.* (2010) also emphasise that when safety managers have heightened situational awareness, they are better equipped to make faster and more precise decisions, which helps to reduce errors and promote overall safety on construction sites. This non-significant relationship (β = 0.017) may be attributed to individuals who report lower situational awareness also being those who acknowledge non-compliance. One possible reason is the heavy dependence on automated systems in chemical industry plants, such as alarm systems, Distributed Control Systems (DCS), and other technologies, which can divert the need for workers to rely on their situational awareness (Endsley, 2018). This reliance on technology can also lead to complacency, where workers assume the systems will catch any potential issues, reducing their need to remain highly aware of their surroundings (Bainbridge, 1983; Elish, 2019). In addition, this result may suggest that the relationship is more nuanced than the current model captures.

The statistically significant direct effect of risk perception on safety compliance (β = 0.497) (Table 4.32), nearly identical to the bivariate correlation (r= 0.496, Table 4.27), reveals a robust and direct pathway between these constructs in the chemical process industries (CPI). This finding confirms that heightened risk perception directly drives improved safety compliance, a relationship well-established in the literature by Rundmo (1996) and supported by Thepaksorn *et al.* (2018) (β = 0.36) and Arezes and Miguel (2005) (β = 0.419) in the context of personal protective equipment use. However, the current study's effect size is notably stronger than findings in other high-risk sectors, exceeding Wang and Xu (2022) construction industry result (β = 0.148) and Xia *et al.* (2017) finding among Chinese construction workers (β = 0.25). This contextual difference is theoretically significant, suggesting that the direct influence of risk perception on compliance is particularly potent in the CPI, where managing complex processes in a high-risk work environment is critical and the consequences of non-compliance are more salient. The near-equivalence of the direct effect and the bivariate correlation is a crucial finding, as it indicates that the proposed mediator, situational awareness, accounts for virtually none of the relationship between risk perception and safety compliance.

Interestingly, the indirect effect of risk perception on safety compliance mediated by situational awareness was statistically insignificant ($\beta = 0.005$, $p= 0.768$) (Table 4.32) in the chemical process industries, leading to the rejection of hypothesis 3. While the direct influence of risk perception on situational awareness was statistically significant ($\beta = 0.32$), the direct relationship between situational awareness and safety compliance was statistically insignificant ($\beta = 0.017$, $p = 0.781$) (Table 4.32). The insignificant relationship between situational awareness and safety compliance has led to a weakening of the mediation role of situational awareness.

The apparent contradiction between the significant effect of risk perception on situational awareness and the non-significant effect of situational awareness on safety compliance can be partly explained by contextual characteristics of the chemical process industries which involve complex procedures and hazardous materials, pose unique challenges that may disrupt the usual SA-SC pathway seen in other sectors. Unlike other sectors such as aviation or construction, where situational awareness is closely linked to immediate manual action, CPI operations are highly automated and governed by system-level controls. The extensive use of control systems, alarm management, and procedural safeguards may reduce the extent to which individual situational awareness directly translates into observable compliance behaviour. In such environments, compliance is often driven by standard operating procedures and technological enforcement rather than moment-to-moment cognitive appraisal, potentially weakening the direct situational awareness–compliance pathway despite adequate levels of awareness among personnel.

Sampling and measurement considerations further contribute to this discrepancy. Situational awareness is a dynamic, cognitive state, whereas safety compliance was measured as a relatively stable behavioural tendency. Capturing both constructs through a cross-sectional self-report survey may therefore attenuate their observed relationship, as the temporal alignment required for situational awareness to exert an immediate behavioural effect is not preserved. Methodologically, prior studies demonstrating strong links between SA and safety compliance have often relied on task-based simulations (Naderpour *et al.*, 2014a; Wright *et* *al.*, 2004), observational measures (Patrick *et al.*, 2006), or real-time assessments (Harper *et al.*, 2023), which are better suited to detecting situational awareness effects than retrospective self-report instruments.

Thus, the non-significant mediation effect for situational awareness indicates that the hypothesised indirect pathway, where risk perception translates to safety compliance through situational awareness, lacks empirical support in this cross-sectional sample. This null finding does not negate situational awareness's theoretical relevance to CPI safety (Endsley, 1995; Sneddon et al., 2013); rather, it signals that the relationship may be contingent upon contextual boundary conditions unmeasured quantitatively. To elucidate these contingencies and uncover the process mechanisms through which situational awareness may operate under specific CPI conditions, the qualitative findings interrogate frontline workers' lived experiences. The following sections discuss the thematic analysis findings that reveal why and under what conditions situational awareness influences (or fails to influence) safety compliance in chemical process industries.

6.4.1 Identified themes through thematic analysis of interviews

This section thoroughly analyses themes identified through interviews in Chapter 5. The discussion is structured around key themes, including the confirmation of relationships theme, the workplace factors theme, the individual factors theme, and the organisational factors theme.

Section 6.2.1 presents the findings from the confirmatory study, which examined the relationships between the study's five constructs: risk perception, safety knowledge, safety culture, situational awareness, and safety compliance. Section 6.2.2 discusses the impact of workplace factors, followed by Sections 6.2.3 and 6.2.4, which examine individual factors and organisational factors, respectively.

6.4.1.1 Workplace factors that influence the relationship between situational awareness and safety compliance

This study further explored the finding that situational awareness (SA) has no significant direct impact on safety compliance in the quantitative phase of the chemical and process industries. Thematic analysis identified four key workplace factors that actively interfere with this relationship: (1) the effects of workload, stress, and fatigue; (2) the influence of work pressures and deadlines; (3) the challenges posed by complex tasks and procedures; and (4) the long working hours.

The first factor, the influence of workload, stress, and fatigue, emerged as a challenge that affects situational awareness, as highlighted by 10 out of 20 participants. For instance, P8 identified this influence: "*Maintaining situational awareness is challenging when someone is stressed or fatigued.*" (Section 5.2). This finding aligns with previous literature, as earlier studies have shown that individual workload can adversely affect situational awareness. As workload stress or fatigue escalates, situational awareness diminishes, leading to a decline in safe performance (Berggren *et al.*, 2011; Caldwell *et al.*, 2019; Nählinder *et al.*, 2004). In the chemical process industries, these stressors may not operate in isolation, but rather collectively through interconnected pathways that likely overwhelm workers' cognitive resources, forcing trade-offs between task completion and safety compliance.

The second factor, Work Pressure and Tight Deadlines, similarly undermined SA, with 5 participants describing how time constraints directly compromise safety practices. Work pressure can create an environment where SA is deliberately deprioritised, leading to a decision to violate safety protocols. P10 observed that *"Working under pressure increases the likelihood of making errors,"* while P8 explicitly connected deadlines to safety violations: *"The easy way to get the job done on time is to violate work and safety procedures."* (Section 5.2). This finding is consistent with research by Kronenwett and Rigotti (2019), who found that task urgency leads to stress and reduced focus, and Pooladvand *et al.* (2022), who identified similar patterns in high-pressure environments.

The third factor, complex work tasks and procedures, represented another significant barrier to SA maintenance, with 6 participants describing how cognitive overload from intricate processes diminishes safety compliance. P12 articulated this challenge: *"Work procedures are complicated due to some sensitive tasks... this may burden the cognitive abilities and compromise situational awareness."* Similarly, P18 noted how complexity increases workload: *"Complex tasks require extra mental energy... this could also affect the ability to ensure compliance with safety procedures."* This finding is consistent with Wickens (2002) cognitive load framework, which explains how competing task demands reduce attentional capacity and performance in high-stakes environments.Loukopoulos *et al.* (2001) also highlighted that task complexity creates practical challenges in safety-critical settings. Additionally, Loukopoulos *et al.* (2016) also argue that complex work tasks often require employees to focus narrowly on procedural steps, leaving them with less cognitive capacity for monitoring their surroundings. This tension is particularly evident in the chemical and process industries, where intricate safety protocols are essential for managing hazardous materials but can also overwhelm employees. These findings resonate with Vidulich and Tsang (2012) assertion that cognitive overload narrows attention, reducing awareness of environmental hazards and increasing the risk of errors and noncompliance. This factor demonstrates that the system itself can impose a load that cripples the situational awareness necessary for its own safe operation.

The fourth factor, long working hours, further compounded these challenges, with 6 out of 20 participants reporting that prolonged shifts directly impaired their situational awareness. Folkard and Tucker (2003) study found that the likelihood of error escalates when shifts exceed 8 hours. P19 explained: *"Working continuously for long hours decreases my concentration and awareness. My brain cannot stay focused for a long time."* Similarly, P3 noted that *"Long hours of working... cause loss of concentration on what is happening around you."* This finding is consistent with Brazaitis and Satas (2023), who found that prolonged shifts lead to cognitive fatigue, which manifests as reduced concentration and slower information processing, thereby compromising situational awareness. Similarly, Dawson and Reid (1997) and Williamson *et al.* (2011) found that extended shifts impair vigilance and decision-making, critical components of situational awareness. Similarly, Folkard and Tucker (2003) emphasised the cumulative risks associated with long working hours in high-risk environments, echoing the participants’ experiences in this study. This convergence of evidence strengthens the argument that fatigue significantly compromises workers’ ability to maintain situational awareness, negatively affecting safety compliance.

In conclusion, the discussion examined how the aforementioned workplace factors negatively impact situational awareness and safety compliance in the chemical and process industries. Participants’ experiences, such as skipping safety steps under pressure or struggling with task complexity, corroborate findings in existing literature, which link these factors to diminished performance and increased errors. The study highlights the importance of practical interventions in sustaining situational awareness and compliance. These findings emphasised the need to balance operational demands with safety considerations and recommended future research using objective measures to validate and expand on these results.

These findings have wider implications. They suggest that organisations should adopt strategies to mitigate negative workplace factors. This involves managing workloads to lessen cognitive strain (Hedge *et al.*, 2006), ensuring adequate rest periods to combat fatigue, providing sufficient rest to prevent fatigue, setting realistic deadlines to lessen pressure, simplifying tasks and procedures where possible (Salas *et al.*, 1995; Stanton *et al.*, 2017), and monitoring work hours to minimise the risks associated with long shifts (Folkard and Tucker, 2003). By addressing these issues, organisations can amplify the positive impact of situational awareness on safety compliance, ultimately fostering safer work environments in high-risk sectors.

6.4.1.2 Individual factors that influence the relationship between Situational Awareness and Safety Compliance

The results outlined in Section 5.3 revealed several individual factors that impact the influence of situational awareness on safety compliance within the chemical and process industries. These factors are Safety Knowledge, Training, Experience, Overconfidence, and Self-Awareness. These factors influence this relationship, with safety knowledge and safety training emerging as two complementary pillars that collectively enable the translation of awareness into action.

Safety knowledge and training represent two sides of the same coin in influencing the relationship between situational awareness and safety compliance. Insights from 11 out of 20 participants revealed that participants consistently emphasised how their level of safety knowledge directly influenced their ability to maintain situational awareness and adhere to safety procedures. On the other hand, 13 participants out of 20 highlighted that safety training enhances their ability to recognise and respond to hazards effectively, promoting a safe performance. This perspective highlights the practical importance of safety knowledge and training in recognising and addressing deviations from safe practices. These findings align with prior studies, such as those by Khaleghinejad and Ziaaldini (2015), which assert that safety knowledge influences employees' comprehension of rules and regulations, risk recognition, and avoidance of occupational hazards. Safety knowledge serves as a key safeguard, enabling workers to understand their environment (situational awareness) and follow safety procedures effectively. For example, participants noted that knowing safety rules makes it easier to identify risks and take the appropriate actions. This directly reflects Reason's (1990) framework, which suggests that, without solid knowledge, even awareness of the situation may not be enough to act appropriately and comply with safety. Therefore, by building and reinforcing safety knowledge, organisations can create a stronger line of defence against human error, as Reason's framework suggests.

Complementing safety knowledge, training provides essential information about potential risks and safe practices, reinforcing the importance of recognising hazards. P17 emphasised that safety training increases situational awareness by fostering observant behaviour and encouraging the identification and reporting of risks. They stated, "*Safety training provides the knowledge on potential risks, safe practices, which enables you to be more observant".* This factor was reinforced by P5, who explained that training sharpens situational awareness, allowing employees to be more attentive and alert to any changes. They stated: "*Training helps us remain vigilant and responsive to changes in the environment, which is important for implementing safety procedures".* These insights align with previous literature, such as Hofmann and Stetzer (1996) and Wang *et al.* (2021), which underscores the importance of training in high-risk industries to ensure employees can effectively manage and mitigate risks. Additionally, this finding is consistent with the work of O'Hare and Beer (2020), who argue that regular training programs play a critical role in equipping employees with the knowledge and skills necessary to navigate the complexities of high-risk environments. Similarly, Sutton *et al.* (2015) and Sanfilippo (2016) emphasise that safety training provides employees with the tools needed to recognise potential hazards and implement appropriate procedures, fostering a safer workplace. In addition, Kowalewski *et al.* (2023), found that Video-based training has the capacity to enhance situational awareness in surgical environments, thereby enhancing performance and minimising errors. Research indicates that structured training, encompassing pre- and post-assessments, can markedly enhance situational awareness scores among participants, as evidenced in pilot cadets (Hariri *et al.*, 2022). Salas and Cannon-

Bowers (2001) recommend implementing role-specific training modules to enhance both engagement and effectiveness. Tailored training interventions can ensure that employees are equipped to handle the unique challenges of their roles, further strengthening the link between situational awareness and safety compliance.

The other three individual factors, experience, overconfidence, and self-awareness, could be interconnected as internal, cognitive, and psychological factors that shape an individual's mindset. These three reside within the worker, governing how they process information, assess risk, and ultimately decide to act. Experience is the accumulation of knowledge that forms mental schemas; overconfidence is a bias in self-assessment, and self-awareness is a metacognitive skill that involves introspection. This common psychological foundation means they directly influence behaviour from the inside out. A central and powerful commonality is their dual or paradoxical nature. Each factor is presented not as purely good or bad, but as a double-edged sword that can either significantly enhance or dangerously degrade safety performance. Experience can lead to expertise and proactive risk anticipation, but can also breed complacency in routine tasks, as P10 expressed. Overconfidence, which often stems from experience, can directly lead to underestimating risks and disregarding established procedures, as P5 and P20 stated in Section 5.3. While self-awareness is largely positive, its dual nature is implied through its absence; a lack of self-awareness is the dangerous counterpart that prevents a worker from self-correcting, as articulated by P5.

The findings align with prior research. For example, regarding experience, Li *et al.* (2020) and Salmon *et al.* (2008) linked expertise to improved hazard recognition, which enables workers to navigate complex environments with greater confidence and foresight. At the same time, Ahmed and Haque (2023) emphasise the role of experiential knowledge in procedural adherence. This finding demonstrates how experience can both strengthen and weaken the SA-compliance relationship depending on context. In terms of overconfidence, Broihanne *et al.* (2014) and Mearns (2017) emphasise how overconfidence erodes SA by fostering complacency and reducing vigilance, ultimately compromising safety compliance. Similarly, Weinstein (1980) and Slovic *et al.* (2004) caution that overconfidence in risk assessment can result in safety oversights, especially among experienced workers who may perceive safety protocols as unnecessary.

Conversely, self-awareness heightens vigilance. This finding resonates with Saetrevik and Hystad (2017) assertion that self-aware individuals act as “safety buffers,” utilising self-awareness to mitigate ignorant safety cultures. Such observations may expand traditional SA models, such as Endsley (1995) three-level hierarchy, which primarily focuses on external environmental scanning. The data suggest that self-awareness bridges internal cognitive states with external situational factors, enabling workers to recalibrate their SA in response to personal motivations and environmental conditions. The reflexive nature of self-awareness also facilitates collective resilience by embedding individual cognition into broader safety cultures. As demonstrated by P8’s decisive actions in isolating a hazardous area, self-awareness transforms tacit knowledge into proactive interventions that benefit the entire organisation. This aligns with Geller (2001) assertion that safety is an “inside-out” process, where personal accountability drives systemic safety improvements.

Finally, because of their dual nature (experience, overconfidence, and self-awareness), it can be argued that all three factors require proactive organisational management. Practically, organisations cannot assume these traits will naturally lead to positive outcomes; they require active intervention to harness their benefits and mitigate their risks. In essence, the common thread is that experience, overconfidence, and self-awareness are interconnected psychological forces that act as critical moderators between a worker's awareness and their actual safety behaviour. Their dual nature makes them powerful tools for safety when managed correctly, but significant liabilities when ignored.

The practical implications of these findings indicate that a paradigm shift in chemical industry safety management is required, recognising that situational awareness alone cannot lead to compliance without the positive influence of individual factors. Organisations must implement theoretically grounded interventions specifically targeting safety knowledge functions, consistent with Reason's (1990) human error model, requiring contextualised knowledge reinforcement beyond rote learning. Training should be conceptualised as continuous cognitive skill development rather than periodic compliance activity. Crucially, organisations must address the dual nature of experience, leveraging Salmon *et al.* (2008) schema development while mitigating Geller's (2001) habituation through structured reflection protocols.

6.4.1.3 Organisational factors that influence the relationship between Situational Awareness and Safety Compliance

The thematic analysis identified six organisational factors that influence this relationship. These factors are safety culture, communication, employee involvement, management commitment, reporting systems, and safety rules and procedures. These factors do not operate in isolation but rather interact dynamically to influence both situational awareness and safety compliance.

At the most fundamental level, safety culture and management commitment provide the cultural bedrock on which all other mechanisms rest. Without clear leadership signals and embedded norms, situational awareness remains individual and fragmented, rather than shared and actionable. Participants consistently emphasised that management commitment shaped their motivation to maintain vigilance. P7, for instance, noted that leadership commitment encouraged workers *"to always identify risks and hazards… and never underestimate them,"* while P9 observed that a strong safety culture helped employees remain attentive to their surroundings. These accounts reveal how cultural signals influence whether SA is prioritised and whether compliance is considered a collective responsibility. This finding is consistent with Zohar (2002) and Dannenberg (2015), who argued that management behaviours and cultural norms are the primary drivers of workplace safety practices.

Conversely, P5 pointed out, *"failing to uphold a commitment to safety rules is like giving the green light to employees to take shortcuts"*. This implies that management should demonstrate commitment to safety and support employees in staying alert and vigilant. This is supported by Ukato *et al.* (2024), who assert that leaders enable employees to take responsibility for their own safety and that of their peers by offering training, resources, and support for safety-related efforts and initiatives. Therefore, when management commitment is weak or cultural norms devalue safety, awareness fails to translate into compliance because workers perceive that vigilance is neither supported nor rewarded.

However, a strong safety culture legitimises communication, encourages employee participation, and sustains trust in reporting systems (Mirbaha *et al.*, 2015; Yazdi, 2025) as they operate as interactive channels that maintain and enact situational awareness in daily life practice. These mechanisms translate cultural values into tangible behaviours by keeping awareness alive through dialogue, participation, and vigilance. P16 described how open communication *"builds trust in management and encourages following the rules,"* while P18 emphasised that involvement in risk assessments improves workers' ability to *"identify risks and hazards"*. Similarly, P12 highlighted that reporting systems foster attentiveness by motivating employees *"to be more vigilant to any unsafe acts"*. These perspectives suggest that awareness is not static; it must be continually reinforced through interaction to prevent it from degrading into complacency.

These findings align with Massimiliano *et al.* (2023), who argue that effective communication tools, including visual aids, enhance employees' ability to navigate complex work environments safely. It also aligns with Vredenburgh (2002) findings, which emphasise that involving employees fosters cognitive engagement. Additionally, Haas *et al.* (2020) and Zou (2011) identified effective reporting systems as key to maintaining situational awareness and improving safety compliance. Similarly, Probst *et al.* (2008) and Dekker (2007) highlighted how non-punitive reporting cultures foster trust, encouraging employees to report hazards and unsafe behaviours without fear of retribution. These studies align with participant insights, stressing the importance of correcting unsafe acts rather than punishing individuals (Goulart, 2016). Moreover, the results align with Conchie (2013) research, which demonstrates that trust in management is crucial for encouraging active reporting and fostering a safety-oriented organisational culture. The shared reports improve situational awareness and create opportunities for continuous safety improvements, reinforcing the connection between situational awareness and compliance.

Safety rules and procedures provide concrete guidance for safe conduct in specific situations (Hale and Borys, 2013). Participants recognised that well-designed rules and procedures reduce cognitive load and steer behaviour. However, they also noted that impractical rules, such as mandatory safety belts in poorly designed offshore environments (P10), could lead to deviations. This suggests that awareness and compliance can become disconnected when organisational systems (e.g., plant design) fail to support work procedures and rules. This finding challenges a purely procedural view of compliance and instead highlights the adaptive, and often risky, behaviours workers adopt to reconcile awareness with operational realities.

The results align with previous research, which suggests that clear and effective safety procedures standardise safe practices, reduce errors, and enhance situational awareness (Hollnagel, 2014; Leveson, 2011; Naveh *et al.*, 2005). Well-designed procedures minimise cognitive load, enabling workers to focus on hazard identification and compliance rather than procedural ambiguity (Dekker, 2011). However, when procedures are overly complex or impractical, they can lead to deviations that compromise safety compliance (Dekker, 2004; Hollnagel, 2014). Furthermore, risk assessments play a crucial role in mitigating these challenges. Hale and Hovden (1998) argue that regular and systematic risk evaluations enhance hazard identification and reinforce a culture of compliance, findings that are consistent with the perspectives shared by study participants.

The practical implications of these findings suggest that these organisational factors do not operate in isolation but as part of an integrated system. This interdependence explains the central paradox of the research problem. In the CPI, this study establishes that a robust safety culture and unwavering management commitment form the indispensable, interdependent bedrock for effective safety management. This foundation can enable a based communication, which can activate employee involvement, transforming compliance into collective ownership, while non-punitive reporting systems convert frontline insights into actionable learning. Ultimately, safety rules and procedures derive their efficacy not from their existence but from their embeddedness within this living ecosystem. Structured procedures are indispensable for translating situational awareness into action, yet they become mere bureaucratic artefacts without the cultural, leadership, and participatory foundations described. By focusing on these organisational factors, industries can enhance both situational awareness and safety compliance, leading to improved safety outcomes in high-risk environments.

Section 6.2 revealed that three groups of factors influence the relationship between situational awareness (SA) and safety compliance in the chemical and process industries. Workplace factors, such as workload and deadlines, undermine SA by overloading cognitive resources and narrowing attentional capacity. Individual factors, including safety knowledge and training, serve as enablers of risk recognition and hazard response. In contrast, experience, overconfidence, and self-awareness function as double-edged variables, enhancing vigilance when managed but encouraging complacency when unchecked. Organisational factors, such as safety culture and management commitment, form the cultural bedrock for maintaining situational awareness. At the same time, communication, employee involvement, reporting systems, and effective procedures reinforce awareness through collective mechanisms. Importantly, these factors do not operate in isolation but interact dynamically, underscoring that the SA-compliance relationship is systemic and requires integrated interventions across workplace, individual, and organisational levels.

The implications of the results are limited to the specific context of the Chemical Process Industry from which the sample was taken. However, the transferability of these findings to other industries should be approached with caution due to differing risk profiles.

6.5 Limitations of the study

Notwithstanding its contribution to the current knowledge of risk perception and safety compliance in the CPI, this study is subject to several limitations. However, it is important to acknowledge the inherent limitations that must be addressed in future research.

First, the cross-sectional design to assess mediation roles presents a limitation, as it captures data at a single point in time of the mediation effects which is vulnerable to biases such as social desirability bias. As Levin (2006) and Sedgwick (2014) note, cross-sectional data provide only a snapshot, which may attenuate observed relationships. For instance, the temporal alignment necessary for situational awareness to exert an immediate effect on safety behaviour may not be preserved.

Second, the study also faces time constraints in its data collection process. Long surveys can lead to respondents' fatigue, where participants lose focus or become disengaged, providing less thoughtful or rushed responses, particularly toward the end of the survey. This is evident from the number (136) of incomplete responses to the survey (See Section 3.3.4).

Third, this study began data collection during the COVID-19 pandemic, which impacted the ability to have a specific group of employees from a particular company or work site.

Fourth, the study also faced time constraints during its data collection. Short interview durations may prevent a thorough exploration of complex issues, potentially leading to superficial data that do not fully reflect participants' experiences. These limitations may have reduced the overall quality of the data and limited the depth of insights, particularly regarding the relationship between situational awareness and safety compliance. The study may have inherent limitations. The sample of 20 participants might not represent the broader population due to its small size.

Fifth and finally, while interviews offer valuable insights, the sample size and the specific context of the chemical and process industries may limit the generalisability of the findings to other sectors. Therefore, the differences in risk profiles and operations in each sector must be considered when applying the findings to other sectors.

6.6 Further investigation of the quantitative data regarding specific factors identified in qualitative analysis

This is an additional statistical analysis conducted after the interviews were analysed, and factors influencing the relationship between situational awareness and safety compliance were identified. Building on the qualitative findings, an additional statistical investigation was undertaken to examine the mediating effects of specific individual and organisational factors that positively influence the relationship between situational awareness and safety compliance. Given that these factors were already represented in the survey data through corresponding item sets, they were extracted and modelled using Structural Equation Modelling (SEM), consistent with the procedures outlined in Section 3.3.5. The same estimation parameters (β, p-value, CI) and model fit indices (CFI, TLI, RMSEA, SRMR) were applied to ensure methodological comparability with the primary mediation models. The full results of this additional mediation analysis are provided in Appendix K.

Table 6.1 summarises the indirect effect (mediation effect) of each factor. These mediation effects are statistically significant and fully mediate the relationship between situational awareness and safety compliance. Only two individual and five organisational factors were tested as these were represented in the survey. As illustrated in the table, all factors mediate the relationship between situational awareness and safety compliance, varying in the magnitude of the mediation effect. Safety knowledge exhibited the smallest mediation effect among the other factors ($\beta = 0.09$). On the other hand, management commitment and communication exhibited the largest mediation effects ($\beta = 0.2723$, $\beta = 0.2204$), respectively. These preliminary results suggest that these specific factors have a positive influence on the relationship between situational awareness and safety compliance. These quantitative findings provide a snapshot of evidence and support for the positive influence of these factors identified in the qualitative phase.

Table 6.1: Summary of factors used in mediation analysis between SA and SC

Type of factor		Factor	Indirect Effect (β)
Individual factors	1	Safety knowledge	0.09
	2	Training	0.148
Organisational factors	1	Safety culture	0.18
	2	Management commitment	0.2723
	3	Communication	0.2204
	4	Reporting system	0.1983
	5	Safety rules and procedures	0.1730

The limitations of this analysis are that it is limited to part of the factors which have a positive influence. Due to the limited time available for the research, it was not possible to examine the factors that have a negative effect. Additionally, the validity and reliability of all items in their respective constructs have been established in the quantitative phase. However, when items were reformulated to test the factors, they had not been retested (for validity and reliability) after being regrouped to construct the factor. Therefore, this represents an interesting research opportunity to build upon these preliminary findings.

6.7 Chapter summary

This research examines the complex relationships between risk perception, safety knowledge, safety culture, situational awareness, and safety compliance in high-risk industries, with a primary focus on the Chemical and Process Industries. Utilising both quantitative (survey) and qualitative (interview) approaches, the study provides a comprehensive analysis of how these factors interact to influence safety outcomes.

The findings from the quantitative and qualitative approaches underscore the roles of safety knowledge and safety culture as mediators in translating risk perception into actionable safety compliance behaviours. Structural Equation Modelling revealed that safety knowledge mediates the relationship between risk perception and safety compliance. In comparison, safety culture exhibited a higher mediation effect between risk perception and safety compliance. The statistically significant mediation roles of safety knowledge and safety culture suggest that educational and cultural interventions contribute to transforming risk perceptions into safety-compliant behaviours. Practical implications from this analysis emphasise the importance of continuous safety education and cultivating a strong safety culture. The qualitative findings consistently underpinned the quantitative results of the mediation roles of these constructs through the influence of risk perception on mediators, to safety compliance.

However, the quantitative results did not support the expected mediation role of situational awareness between risk perceptions and safety compliance, as evidenced by the non-significant correlation between situational awareness and safety compliance, which was investigated in the qualitative phase. The qualitative phase identified contextual factors that influence the relationship between situational awareness and safety compliance. The research identified multiple workplace factors, including workload, stress, fatigue, work pressure, tight deadlines, complicated tasks, and prolonged working hours, that diminish situational awareness, resulting in safety deficiencies in the chemical and process industries. The adverse effect of these factors lies in inducing cognitive overload, diminishing alertness, promoting shortcuts, and undermining compliance with safety protocols.

Nonetheless, the study revealed that individual factors, such as safety knowledge, training, experience, and self-awareness, have a positive influence on situational awareness and improve safety compliance. Moreover, organisational factors such as safety culture, management commitment, effective communication, employee involvement, reporting systems, and explicit rules and regulations significantly contribute to enhancing situational awareness and encouraging safety compliance.

Chapter 7: Conclusion and Future Work

7.1 Conclusion

This research aimed to assess the mediating roles of safety knowledge, safety culture and situational awareness on the relationship between risk perception and safety compliance in the chemical and processing industries. A mixed-methods approach combining quantitative and qualitative data collection and analysis was employed to conduct this research. The first phase (quantitative) employed an online survey to collect data from 238 participants in the chemical and process industries. The data were analysed using SEM to systematically evaluate the three mediation models and test their corresponding hypotheses.

The mediation analyses revealed that both safety knowledge ($\beta = 0.227$, $p < .001$) and safety culture ($\beta = 0.254$, $p < .001$) partially mediated the relationship between risk perception and safety compliance, supporting the first and second hypotheses. The analyses also revealed that the safety knowledge and safety culture explain 38% and 43% of the total effect of risk perception on safety compliance, respectively. These findings suggest that while heightened risk perception is associated with improved compliance, its influence is supported by the relevant safety knowledge and a supportive safety culture. Conversely, the analysis showed that situational awareness did not act as a mediator between risk perception and safety compliance ($\beta = 0.005$, $p = 0.768$). While risk perception has influenced situational awareness ($\beta = 0.32$), the direct effect of situational awareness on safety compliance was statistically insignificant ($\beta = 0.017$, $p = 0.781$), failing to support the third hypothesis.

The second phase (qualitative) employed an online interview to collect data from 20 participants from the survey sample and analysed it using thematic analysis. This phase aimed to evaluate the findings identified in the quantitative phase. The analysis of the interviews showed that risk perception has a positive influence on safety knowledge, which in turn influences safety compliance. Similarly, risk perception has a positive impact on safety culture, subsequently positively influencing safety compliance. Additionally, results revealed that risk perception has a positive effect on situational awareness. These findings support the quantitative results.

The qualitative findings have also identified three groups of factors, namely workplace, individual, and organisational factors, that influence the relationship between situational awareness and safety compliance. Workplace factors, such as workload, diminish workers' cognitive capacity, leading to lapses in vigilance, undermined situational awareness and reduced safety compliance. Additionally, overconfidence (individual factor) can have a detrimental effect. In contrast, individual factors such as safety knowledge and training, organisational factors such as a safety culture, and management commitment were identified as having a positive impact on enhancing situational awareness and ensuring that it translates into safety compliance through remaining vigilant and avoiding complacency. Therefore, all these factors may collectively counteract each other and result in the observed relationship.

Moreover, the additional mediation analysis suggested that all individual and organisational factors fully mediated the relationship between situational awareness and safety compliance. However, the strength of these mediating effects varied, with beta coefficients ranging from 0.09 ($p < 0.001$) for safety knowledge to 0.272 ($p < 0.001$) for management commitment.

To conclude, this research underscores the importance of safety knowledge and safety culture in bridging the gap between risk perception and safety compliance. Although situational awareness may not directly influence safety compliance, its influence is mediated by various factors, including workplace conditions, training, and leadership involvement. To cultivate a safer work environment, organisations should implement strategies that strengthen safety culture, promote safety knowledge, and reduce workplace stressors, ensuring that risk perception evolves into proactive and ongoing safety behaviours.

7.2 Suggestions for Future Research

The current study explored the mediating roles of safety knowledge, safety culture, and situational awareness in the relationship between risk perception and safety compliance in CPI. It also identified some workplace, individual, and organisational factors that influence the link between situational awareness and safety compliance. Several interesting areas exist that could offer future research opportunities.

It would be useful if further research could explore industry-specific differences in safety culture and compliance behaviours (e.g., CPI vs Construction). Although this study was performed in the chemical and process industries, its results may not be entirely applicable to other high-risk sectors, such as mining, construction, or healthcare. Comparative analyses across industries may reveal how varying safety knowledge levels, organisational safety culture and workplace hazards affect compliance behaviours. Furthermore, understanding regional and national differences in safety culture can help policymakers assess the effectiveness of specific regulatory frameworks in various contexts.

Furthermore, building on the present study's identification of workplace stressors as critical disruptors of the situational awareness-safety compliance relationship, future research can investigate targeted interventions to mitigate cognitive-eroding factors while simultaneously measuring their impact on behavioural compliance. For example, while this study highlights the detrimental role of these stressors, future work can provide more quantitative evidence on how targeted organisational strategies (e.g. fatigue management programmes) or behavioural interventions to counteract overconfidence translate into measurable compliance outcomes.

Future research can also aim to quantitatively model the combined influence of workplace, individual, and organisational factors on the relationship between situational awareness and safety compliance. While this study qualitatively identified their interdependence, the degree to which these factors interact, amplify, or mitigate one another remains unclear. This will link to the findings of the additional quantitative analysis presented in Section 6.3, as time constraints prevented us from further investigation. Future work can measure each of the factors identified and how they affect the relationship between situational awareness and safety compliance in the workplace (mediation or moderation).

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Appendices

Appendix A. Full Survey Items

Statements	Choices
Section 1: Demographics	
I identify myself as:	1. Male 2. Female. 3. Other 4. Prefer not to say
My age group is:	1. (18-26), 2. (27-34), 3. (35-42), 4. (43-50), 5. (51-58), 6. (59 or over)
My educational background is:	1. Secondary school, 2. Bachelor, 3. Msc, 4. PhD. 5. Other
My current job title description is:	1. Operator, 2. Engineer, 3. Senior Manager, 4. Area Manager, 5. Artisan, 6. Technician, 7. Specialist, 8. Practitioner, 9. Other.
I have been working in the Chemical and Process Industries for:	1.(Less than 5 years), 2. (6 - 10 years), 3. (11 - 15 years), 4. (16 - 20 years), 5. (More than 20 years).
In the last 5 years, I have worked in the sector of:	1. Chemical, 2. Oil and Gas. 3. Nuclear, 4. Food and drinks, 5. Energy, 6. Minerals, 7. Pharmaceutical, 8. Water treatment, 9. Other.
In the last 5 years, I have worked in the department of:	1. Health and safety, 2. Production, 3. Maintenance 4. Utilities, 5. Mechanical, 6. Electrical, 7. Instrumentation, 8. Production, 9. Other.
I have been working in this industry (my current job) for:	1.(Less than 1 Year), 2. (1-3 Years), 3. (4 - 9 Years), (10 Years or more)
I spend most of my time in my current job:	1. On the site. 2. At the office
I have experienced an accident or near miss in the last 5 years.	1. Yes. 2. No
I have been injured:	1. Yes. 2. No
Section 2: Risk perception	
1. Once exposed by to a hazard, my health will be severely affected.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
2. Even if a person recovers from an injury (from exposure to a hazard) there will be lasting effects.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know

3. If a risk is not well controlled, it will negatively impact employees and the company at large.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
4. I think hazards in my workplace are very sever.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
5. The risks in my workplace are likely to hurt somebody soon.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
6. I think risks in this industry are more serious than other industries.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
7. I think control measures in place are reducing risks to a considerable extent.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
8. I think there are some risks which are difficult to control.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
9. I think using safety measures can minimize the risk.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
10. I am very likely to be affected by hazards in my workplace.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
11. As long as I have been in contact with hazard, I may be affected.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
12. Work procedures do not protect me from hazards.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
Section 3: Safety compliance	
1.I use all necessary safety equipment to do my job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
2. I carry out my work in a safe manner.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
3. I follow correct safety rules and procedures while carrying out my job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
4. I ensure the highest levels of safety when I carry out my job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
Section 4: safety knowledge	
1.My company gives comprehensive training to the employees in workplace health and safety issues.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
2. Newly recruits are trained adequately to learn safety rules and procedures.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
3. Safety issues are given high priority in training programs.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know

4. Management encourages the workers to attend safety training programs.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
5. Safety training given to me is adequate to enable to me to assess hazards in workplace.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
6. I know how to perform my job in a safe manner.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
7. I know how to use safety equipment and standard work procedures.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
8.I know how to maintain or improve workplace health and safety.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
9.I know how to reduce the risk of accidents and incidents in the workplace.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
10. I know what the hazards are associated with my job and the necessary precautions to be taken while doing my job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
11. I seek out safety information regarding my job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
12. My line manager/supervisor always informs me of current concerns and issues.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
13. Safety information is always brought to my attention by my line manager/supervisor.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
14. It is easy to get safety information on this job.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
15. The organisation makes safety information available.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
16. There is good, reliable and useful safety information available in the organisation. `	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
17. The safety rules and procedures followed in my company are sufficient to prevent incidents from occurring.	1 = Never, 2 = Sometimes, 3 = Often, 4 = Always, 5 = I do not know.
18. My supervisors and managers always try to enforce safe working procedures.	1 = Never, 2 = Sometimes, 3 = Often, 4 = Always, 5 = I do not know.
19. Safety inspections are carried out regularly.	1 = Never, 2 = Sometimes, 3 = Often, 4 = Always, 5 = I do not know.
20. The safety procedures and practices in this organisation are useful and effective.	1 = Never, 2 = Sometimes, 3 = Often, 4 = Always, 5 = I do not know.
Section 5: safety culture	

1. Managers give feedback on safety performance.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
2. Managers are likely to notice unsafe acts.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
3. Managers always confront unsafe acts.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
4. Employees feel they can report unsafe acts.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
5. Discipline is applied to safety.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
6. People feel that this is a good place to work.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
7. People are proud of their company.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
8. Safety is given high priority by the management.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
9. Safety rules and procedures are strictly followed by the management.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
10. Corrective action is always taken when the management is told about unsafe practices.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
11. In my workplace managers/supervisors do not show interest in the safety of workers.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
12. Management considers safety to be equally important as production.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
13. I feel that management is willing to compromise on safety for increasing production.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
14. When near-miss accidents are reported, my management acts quickly to solve the problems.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
15. My company provides sufficient personal protective equipment for the workers.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
16.There is good communication here about safety issues which affect me.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
17. Safety information is always brought to my attention by my line manager/supervisor.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know

18. My line manager/supervisor does not always inform me of current concerns and issues.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
19. Management operates an open-door policy on safety issues.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
20. I do not receive praise for working safely.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
21. The company really learn from accident history, incident reporting etc.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
22. Employees feel confident in reporting incidents and/or unsafe conditions.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
23. Employees report incidents, near misses and/or unsafe conditions.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
24. Management acts upon reports of incidents and/or unsafe conditions.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
25. Employees get feedback on the actions of the management regarding incidents and/or unsafe conditions.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
Section 6: situational awareness	
1. I am not able to keep my mind focused on work and it has a tendency to 'wander'.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
2. I find it difficult to concentrate for long periods of time.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
3. I 'tune out' during routine work, or when work is boring.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
4. My work area is often cluttered or disorganised.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
5. I have trouble getting back into work after an interruption.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
6. I become bored with my work quickly.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
7. I am easily distracted by visual stimulation (i.e. movement).	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
8. I often find I have carried out work on 'auto-pilot', without being aware of it.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know
9. I find it difficult to pay attention to someone, even if I am being spoken to directly.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don't know

10. I ensure I know most activities that are ongoing so I can ‘keep an eye’ on things.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
11. I think ahead of my work to plan for different possible outcomes.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
12. I take note of objects/events on the even if they are not immediately related to my work.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
13. I find it easy to keep track of everything that is going on around me.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
14. I find it easy to remember work instructions.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
15. I often speak or act without thinking.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
16. I often have difficulty paying close attention to details, which often results in careless errors.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
17. When I finish reading or being told instructions, I often have to re-read them or ask for them to be repeated, as I don’t remember them.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
18. I am easily distracted by background noise.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
19. I often daydream during work.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know
20. I am easily distracted by my thoughts or feelings.	1= Strongly Disagree, 2= Disagree, 3= Agree, 4 = Strongly Agree, 5= I don’t know

Appendix B. Risk Perception items

Table B 1: Risk perception questions, the original and modified

Original items	Modified items
1. Once infected with COVID-19, my health will be severely affected.	1. Once exposed to a hazard, my health will be severely affected.
2. Even a person is cured of COVID-19, there will be sequelae.	2. Even if a person recovers from an injury, there will be lasting effects.
3. Once the COVID-19 breaks out again, it will negatively impact the society immediately.	3. If a risk is not well controlled, it will negatively impact employees and the company at large.
4. I think this COVID-19 epidemic is very widespread	4. I think hazards in my workplace are very severe.
5. The COVID-19 is easy to spread out.	5. The risks in my workplace are likely to hurt somebody soon.
6. I think the COVID-19 epidemic is more serious than previous infectious diseases (SARS, avian flu)	6. I think risks in this industry are more serious than in other industries.
7. I think the local status of COVID-19 is very serious.	7. I think control measures in place are reducing risks to a considerable extent.
8. I think the epidemic and spread of COVID-19 is difficult to control.	8. I think there are some risks which are difficult to control.
9. I think the COVID-19 is very difficult to treat	9. I think using safety measures can minimise the risk.
10. I am very likely to be infected with COVID-19.	10. I am very likely to be affected by hazards in my workplace.
11. As long as I have been in contact with the items of a COVID-19 patient, I may be infected.	11. As long as I have been in contact with hazards, I may be affected.
12. As long as I am in the same space with a COVID-19 patient, I may be infected by him.	12. Work procedures do not protect me from hazards.

Appendix C. Participants Information Sheet (PSI) of the survey

Participant Information Sheet

[FOR USE WITH STANDARD PRIVACY NOTICE FOR RESEARCH PARTICIPANTS]

Name of department: Chemical and Process Engineering

Introduction

My name is **Abdusalam Algalidi** and I am a PHD student at the University of Strathclyde studying advanced chemical and process engineering. I am conducting this research project, under the supervision of Dr Esther Ventura-Medina to investigate *Individual's risk perception and safety compliance* in chemical process industries.

What is the purpose of this research?

The purpose of this research is to investigate the influence of risk knowledge and situation awareness on the individual's risk perception and its relationship with safety compliance. In addition, this research explores whether organizational safety culture contributes to personnel safety compliance and therefore risk reduction.

What will you do in the project?

If you want to take part, you would be completing an online survey using your computer or smart device. This survey will take about less than 15 minutes. You will be asked to provide your email address if you wish to be contacted with study results when the study is finished, however, you do not have to provide it.

Do you have to take part?

No, you do not have to take part. It is entirely your decision to take part in the investigation and your participation is voluntary. Once you have submitted your answers it might not be possible to remove them from the study. If decide not to participate in this questionnaire, please select "*No, I do not consent*" button at the end of the informed consent.

Why have you been invited to take part?

You have been invited to take part as you are working in the chemical and process industry and will have experience in how safety management systems function in a workplace environment.

What are the potential risks to you in taking part?

There are no foreseeable risks to you in taking part in the project.

What information is being collected in the project?

The survey does not collect any information that will personally identify you such as your name, email address or IP.

Who will have access to the information?

Only the investigators involved in the project (myself and Dr Ventura-Medina) will have access to the raw data.

Where will the information be stored and how long will it be kept for?

All collected raw data will be securely stored centrally in the university servers, password-protected and encrypted university data storage facility (I:\ drive). The data will be kept for up to 5 years following the Good Practice Guidelines for the conduct of psychological research. Only the investigators involved in the project (myself and Dr Ventura-Medina) will have access to the raw data.

Appendix D. Privacy Notice of the Survey

University of Strathclyde Glasgow

Individual's risk perception and safety compliance in chemical process industries

Privacy Notice

1. Introduction

The University of Strathclyde is committed to transparency and to complying with its responsibilities under data protection legislation. This privacy notice sets out important information regarding how we will use your information and rights under the legislation. It is important that you read this notice prior to providing your information.

2. Data controller and the data protection officer

The University of Strathclyde is a data controller under protection legislation. Any enquiries regarding data protection should be made to the University's Data Protection Officer at dataprotection@strath.ac.uk

3. How we use your personal data

For the development of this research "Individual's risk perception and safety compliance in chemical process industries", no identifying data will be collected. For those who are interested to get back to them with study results will have to provide their email address at the end of the survey. This identity of participants will be kept until the end of the study to communicate study results but will never be disclosed. The raw data will be kept for up to 5 years following the Good Practice Guidelines for the conduct of research and then destroyed.

4. Legal basis for processing

The data that is going to be collected, as part of this study, will be used with research purposes.

The University of Strathclyde is committed to transparency and to complying with its responsibilities under data protection legislation. The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 2018. This consent form (privacy notice) has set out important information regarding how we will use your information and rights under the legislation. It is important that you read this notice prior to providing your information. The University of Strathclyde is a data controller under protection legislation.

5. Any recipient or categories of recipient of the personal data

The collected data is not to be shared with any outside organisation apart of the researching team based on the University of Strathclyde, as this project is sponsored by the University.

Appendix E. Interview framework

	Section 1: introduction		
	Steps	**Explanation**	**Notice**
1	**Introductions**	Introduces each other to build rapport with the interviewee, and explains how long the interview will probably last (1 hr).	To get to know each other, Build rapport and establish trust to encourage honest responses.
2	**Study purpose and applications:**	Explain the purpose of the interview and the study objectives, and the use of the findings, including how the findings will be reported and published.	Assure what has been said in the PIS.
3	**Consent forms, approvals:**	Informed consent forms were distributed to participants. Inform them that the interview will be recorded and obtain permission for that, as well.	Get the approval for conducting and recording the interview again before the start.
4	**Treatment of data**	Inform the participant on how recorded data will be managed, secured, stored and disposed of.	Assure the interviewee that the data will be kept safe and disposed of confidentially and anonymously.
5	**Other questions or concerns**	Any other issues are discussed before beginning the interview session	Answer any queries the participant may have?
	Section 2: Main questions		
	Question	**Dimension**	**Why ask it?**
1	Introductory Question: How is the concept of Situational Awareness known/termed in your workplace?	Open question	To ensure interviewees understand the concept of Situational Awareness and define it for them if needed.
2	In terms of your situational awareness in a given scenario at work, why do you think it might lead to compliance with safety or non-compliance?	Open question	To open up the interview and get the interviewee to talk about his/her views regarding situational awareness.
3	In a situational awareness context. Concerning the hazards you may encounter at your work, how do you	Open question	Try to determine how the interviewee perceives the current state of the workplace and how they would approach it in a safe manner.

	prepare yourself before you actually start work?		
	Probing question: ➢ To what extent are you interested in knowing about activities in the workplace that are ongoing around you? ➢ think ahead of your work to plan for different possible outcomes. ➢ Do you take note of objects/events even if they are not immediately related to your work? ➢ To what extent can you keep track of the things that are happening around you?		
4	What can make you lose situational awareness at work? How does that affect your safety compliance?	Open question	Try to find out what types of distractions may affect his/her awareness.
	Probing question: ➢ Do you get distracted by background noise? ➢ Do you think you are distracted by your thoughts or feelings?		
5	What factors may affect a person's situational awareness? yourself, for example.	Open question	Try to identify what can affect someone's awareness, potentially leading to a loss of situational awareness.
	Probing question: ➢ Do you think you can keep your mind focused on work? ➢ If someone is speaking directly to you, do you find it difficult to pay attention to them?		
	What might cause you to notice somebody doing something carelessly or not to notice that? Would you take any action?	Open question	Find out to what extent a worker is paying attention to what is going on around them.
	Probing question: To what extent do you think paying close attention to details is important?		
7	What are the circumstances or factors that might help you in following health and safety rules?	Open question	Determine if there are specific circumstances that encourage individuals to work safely.
8	In terms of situational awareness, what might be helpful for you in ensuring that you are aware of risks and hazards?	Open question	Determine to what extent the person is willing to maintain their situational awareness.
	Section 3 :Confirming questions?		
	Question	**Dimension**	**Why ask it?**
	Do you understand what is meant by risk perception?	Define risk perception for the participant	Agree on the meaning of risk perception

1	Do you think risk perception positively or negatively influences the acquisition of safety knowledge? Why?	RP → SK	Investigate the influence of risk perception on safety knowledge
2	Do you think the level of safety knowledge and adherence to safety rules and procedures affects employees' compliance with safety protocols? WHY?	SK → SC	Investigate the influence of safety knowledge on safety compliance.
3	Do you think the perception of risk associated with workplace hazards influences the safety culture? Why?	RP → SCR	Investigate the correlation between risk perception and safety culture.
4	In terms of workplace safety culture, do you think it affects the levels of safety compliance? Why?	SCR → SC	Investigate the influence of safety culture on safety compliance.
5	In terms of situational awareness, do you think risk perception affects it? Why?	RP → SA	Investigate the influence of risk perception on situational awareness.
	Finalise the interview: is there anything else you would like to tell me or share with me regarding today's topic? Thank you for the interview time and for taking part in the study		

Appendix F. Participants' Information sheet for interviews

Participant Information Sheet

[FOR USE WITH STANDARD PRIVACY NOTICE FOR RESEARCH PARTICIPANTS]

Name of department: Chemical and Process Engineering

Title of the study:
The influence of Situational Awareness on safety compliance in chemical process industries.
Introduction

My name is **Abdusalam Algalidi** and I am a PhD student at the University of Strathclyde investigating *Situational Awareness and safety compliance* in chemical process industries. I would like to invite you to participate in a study I am conducting to complete the research stage of my thesis. I am conducting this research project under the supervision of **Dr. Yi-Chieh Chen** and **Dr. John Morran**.

What is the purpose of this research?

The purpose of this research is to investigate the influence of individual's situation awareness on safety compliance.

What will you do in the project?

You will be asked to attend an online interview, which will last for approximately (30-45) minutes (maximum). The interview will occur between 16/10/2023 – 10/11/2023 . These interviews will be conducted using Zoom or Teams, and you can choose the date, time and location of the interview (can be during or out of work hours) to protect your confidentiality. No person should know, without your permission, that you have been interviewed for this study. You will be asked a series of questions and your responses will be audio-recorded for transcription. The recording will be deleted once it has been transcribed.

Do you have to take part?

Participation in this study is entirely voluntary. You can withdraw at any stage of the study before the end of the interview. Any data already collected will be deleted. However, after a participant's responses are transcribed and anonymised, it will no longer be possible to delete your data as it cannot be identified.
You do not need to answer all questions, and can ask for the response to any question NOT to be included in the analysis.

Why have you been invited to take part?

You have been invited to participate in this study as you have worked at least 5 years in chemical and process industries and your job role gives you the knowledge to help shed light on areas of interest in my research.

What are the potential risks to you in taking part?

The loss of confidentiality and anonymity in research could create a risk to participants, e.g., risks of career detriment, and there is a small risk of or potential some psychological trauma in from recalling a past n incident. To mitigate any risk to the participants all data will be anonymised and stored securely, accessible only to the Research team named above. You may take part using Zoom or Teams at a time, date and location of your choice. All outputs from the study will contain no information that could identify any individual – where necessary specific details of the incidents discussed during interview will be redacted.

What information is being collected in the project?

The project will collect information on the influence of situational awareness on safety compliance. This will include factors affecting situational awareness, and how risks and hazards are dealt with.

Appendix G. Privacy Notice of the Interviews

University of Strathclyde Glasgow

Individual's situational awareness and safety compliance in chemical process industries

Privacy Notice

1. Introduction

The University of Strathclyde is committed to transparency and to complying with its responsibilities under data protection legislation. This privacy notice sets out important information regarding how we will use your information and rights under the legislation. It is important that you read this notice prior to providing your information.

2. Data controller and the data protection officer

The University of Strathclyde is a data controller under protection legislation. Any enquiries regarding data protection should be made to the University's Data Protection Officer at dataprotection@strath.ac.uk

3. How we use the data

For the development of this research "Individual's situational awareness and safety compliance in chemical process industries", no personal or identifying data will be collected. All identifying information like (personal information, company names, location, dates, etc.) mentioned in the interview, will be deleted once transcription of the interviews has been completed. Only aggregated and anonymised data used for this research project will potentially be published in the research literature.

4. Legal basis for processing

The data collected as part of this study will be used with research purposes only.

The University of Strathclyde is committed to transparency and to complying with its responsibilities under data protection legislation. The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 2018. This consent form (privacy notice) has set out important information regarding how we will use your information and rights under the legislation. It is important that you read this notice prior to providing taking part in the interviews. The University of Strathclyde is a data controller under protection legislation.

5. Any recipient or categories of recipient of the personal data

The collected data is not to be shared with any outside organisation.

6. Retention period

Appendix H. Correlation matrix of EFA for study constructs

Table H 1: Correlation matrix of EFA for risk perception items

Correlation Matrix												
		1	2	3	4	5	6	7	8	9	10	11
Correlation	RP1											
	RP2	.677										
	RP3	.369	.595									
	RP4	.374	.419	.487								
	RP5	.304	.374	.385	.515							
	RP6	.424	.536	.521	.410	.521						
	RP7	.439	.343	.371	.305	.386	.428					
	RP8	.375	.403	.385	.387	.308	.358	.502				
	RP9	.401	.451	.455	.385	.360	.399	.537	.514			
	RP10	.361	.391	.315	.374	.426	.354	.500	.402	.536		
	RP11	.374	.379	.385	.362	.335	.378	.601	.570	.555	.544	
	RP12	.398	.297	.390	.397	.303	.307	.432	.407	.450	.342	.343
Sig.		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Table H 2: Correlation matrix of EFA for safety compliance items

Correlation Matrix				
		SC1	SC2	SC3
Correlation	SC1			
	SC2	.529		
	SC3	.434	.551	
	SC4	.338	.389	.470
Sig.		<.001	<.001	<.001

Table H 3: Correlation matrix of EFA for safety knowledge items

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Correlation	SK1																			
	SK2	.709																		
	SK3	.397	.464																	
	SK4	.467	.548	.569																
	SK5	.599	.578	.483	.456															
	SK6	.419	.490	.640	.627	.576														
	SK7	.372	.524	.429	.343	.412	.347													
	SK8	.512	.465	.450	.459	.509	.477	.650												
	SK9	.545	.585	.508	.569	.602	.506	.433	.519											
	SK10	.647	.603	.513	.514	.550	.473	.536	.558	.437										
	SK11	.464	.449	.467	.324	.596	.390	.447	.555	.613	.541									
	SK12	.510	.556	.535	.456	.564	.518	.483	.582	.557	.611	.649								
	SK13	.535	.532	.399	.470	.594	.415	.446	.568	.630	.600	.716	.671							
	SK14	.438	.419	.377	.322	.602	.369	.372	.423	.408	.441	.517	.493	.399						
	SK15	.492	.452	.392	.532	.533	.405	.424	.426	.610	.540	.523	.556	.566	.477					
	SK16	.526	.518	.464	.510	.518	.508	.404	.496	.588	.570	.485	.557	.514	.408	.665				
	SK17	.576	.552	.523	.532	.589	.513	.473	.492	.624	.676	.504	.641	.587	.511	.598	.792			
	SK18	.550	.521	.532	.599	.595	.494	.566	.586	.687	.630	.539	.587	.575	.459	.574	.566	.633		
	SK19	.482	.506	.493	.505	.576	.495	.397	.482	.592	.541	.479	.500	.538	.522	.511	.387	.495	.704	
	SK20	.361	.439	.448	.418	.461	.343	.477	.475	.526	.467	.422	.478	.464	.422	.396	.484	.534	.493	.451
Sig		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Table H 4: Correlation matrix of EFA for safety culture items

		CL1	CL2	CL3	CL4	CL5	CL6	CL7	CL8	CL9	CL10	Msc1	Msc2	Msc3	Msc4	Msc5	Msc6	Msc7	Msc8	Ab1	Ab2	Ab3	Ab4	Ab5	Ab6
Correlation	CL1																								
	CL2	.322																							
	CL3	.477	.532																						
	CL4	.408	.510	.665																					
	CL5	.511	.532	.598	.792																				
	CL6	.459	.599	.574	.566	.633																			
	CL7	.522	.505	.511	.387	.495	.704																		
	CL8	.322	.418	.396	.484	.534	.493	.451																	
	CL9	.602	.456	.533	.518	.589	.595	.576	.461																
	CL10	.377	.569	.392	.464	.523	.532	.493	.448	.483															
	Msc1	.540	.453	.401	.526	.581	.609	.534	.508	.642	.534														
	Msc2	.423	.459	.426	.496	.492	.586	.482	.475	.509	.450	.628													
	Msc3	.408	.569	.610	.588	.624	.687	.592	.526	.602	.508	.536	.519												
	Msc4	.441	.514	.540	.570	.676	.630	.541	.467	.550	.513	.629	.558	.641											
	Msc5	.517	.324	.523	.485	.504	.539	.479	.422	.596	.467	.529	.555	.613	.541										
	Msc6	.493	.456	.556	.557	.576	.587	.500	.478	.564	.535	.572	.582	.557	.611	.649									
	Msc7	.524	.470	.566	.514	.587	.575	.538	.464	.594	.399	.561	.568	.630	.600	.716	.671								
	Msc8	.198	.177	.042	.155	.143	.205	.276	.089	.244	.191	.266	.178	.243	.035	.225	.090	.215							
	Ab1	.372	.343	.384	.404	.473	.566	.397	.477	.412	.429	.571	.650	.433	.536	.447	.483	.446	.168						
	Ab2	.438	.467	.492	.526	.576	.550	.482	.361	.599	.397	.589	.512	.545	.647	.464	.510	.535	.315	.372					
	Ab3	.419	.548	.452	.518	.552	.521	.506	.439	.578	.464	.584	.465	.585	.603	.449	.556	.532	.198	.399	.709				
	Ab4	.345	.356	.401	.445	.442	.425	.355	.477	.315	.375	.366	.402	.347	.512	.319	.450	.321	-.002	.347	.430	.464			
	Ab5	.500	.410	.460	.481	.464	.609	.593	.473	.651	.361	.756	.580	.589	.558	.571	.586	.637	.347	.466	.588	.602	.351		
	Ab6	.369	.627	.405	.508	.513	.494	.495	.343	.437	.640	.437	.477	.506	.473	.390	.518	.415	.332	.347	.419	.490	.368	.378	
	Ab7	.182	.101	-.050	.224	.180	.096	.064	.079	.233	.158	.175	.175	.169	.056	.161	.077	.131	.663	.170	.183	.167	.008	.188	.209
Sig		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	.001	<.001	<.001	<.001	<.001	<.001	<.001
	Msc 8 and Ab7 were excluded from the final analysis because they have weak correlations with almost all of the items in this table.																								

Table H 5: Correlation matrix of EFA for situational awareness items

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Correlation	SA1																			
	SA2	.691																		
	SA3	.397	.464																	
	SA4	.589	.578	.483																
	SA5	.519	.490	.640	.437															
	SA6	.496	.314	.399	.380	.312														
	SA7	.372	.399	.429	.412	.347	.401													
	SA8	.512	.600	.450	.509	.477	.348	.650												
	SA9	.545	.441	.508	.602	.506	.325	.433	.519											
	SA10	.647	.540	.513	.550	.473	.329	.536	.558	.641										
	SA11	.464	.570	.467	.596	.390	.390	.447	.555	.613	.541									
	SA12	.619	.676	.535	.564	.518	.352	.483	.582	.557	.611	.649								
	SA13	.535	.630	.399	.594	.415	.302	.446	.568	.630	.600	.716	.465							
	SA14	.338	.419	.602	.377	.369	.594	.372	.423	.408	.441	.517	.585	.524						
	SA15	.429	.452	.477	.533	.405	.377	.384	.426	.610	.540	.523	.603	.566	.633					
	SA16	.526	.518	.464	.518	.508	.533	.404	.496	.588	.570	.485	.449	.514	.408	.665				
	SA17	.576	.552	.523	.589	.513	.518	.473	.492	.624	.676	.504	.576	.587	.511	.598	.792			
	SA18	.505	.521	.532	.595	.494	.309	.566	.586	.687	.630	.539	.587	.575	.459	.574	.566	.392		
	SA19	.462	.506	.493	.576	.495	.399	.397	.482	.592	.541	.479	.500	.538	.522	.511	.387	.495	.396	
	SA20	.381	.439	.419	.377	.322	.602	.419	.475	.526	.467	.422	.478	.464	.422	.704	.484	.534	.394	.451
Sig.		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Appendix I. Skewness and kurtosis statistic

Table I 1: Skewness and kurtosis statistics for risk perception items

Variables	Skewness Statistic	Kurtosis Statistic
RP1	-.897	.625
RP2	-.961	.894
RP3	-.864	1.891
RP4	-.767	.687
RP5	-.770	-.081
RP6	-.979	1.060
RP7	-.640	.466
RP8	-.759	-.080
RP9	-.814	.306
RP10	-.535	-.566
RP11	-.767	.218
RP12	-.605	-.412

Table I 2: Skewness and kurtosis statistics for safety compliance items

Variables	Skewness Statistic	Kurtosis Statistic
SC1	-0.859	1.536
SC2	-0.862	1.341
SC3	-0.786	1.257
SC4	-0.914	1.224

Table I 3: Skewness and kurtosis statistics for safety knowledge items

Variables	Skewness Statistic	Kurtosis Statistic
SK1	-.711	1.065
SK2	-.710	2.129
SK3	-.701	.937
SK4	-.699	.944
SK5	-.795	1.224
SK6	-.856	1.193
SK7	-.984	.973
SK8	-.832	.570
SK9	-.752	.374
SK10	-.911	1.188
SK11	-.581	.340
SK12	-.630	1.202
SK13	-.673	.821
SK14	-.753	.905
SK15	-.583	.676
SK16	-.907	.912
SK17	-.700	.674
SK18	-.589	.293
SK19	-.644	.106
SK20	-.683	.345

Table I 4: Skewness and kurtosis statistics for safety culture items

Variables	Skewness Statistic	Kurtosis Statistic
CL1	.663	-.371
CL2	.157	-.778
CL3	.192	-.378
CL4	.002	-.632
CL5	.040	-.684
CL6	.389	-.547
CL7	.150	-.452
CL8	.483	.344
CL9	.505	-.117
CL10	.541	.038
Msc1	.374	-.526
Msc2	.563	-.388
Msc3	.059	-.653
Msc4	.074	-.767
Msc5	.463	-.146
Msc6	.229	-.561
Msc7	.292	-.733
Ab1	.672	-.255
Ab2	.024	-.342
Ab3	.185	-.557
Ab4	.308	-.434
Ab5	.244	-.626
Ab6	-.006	-.486

Table I 5: Skewness and kurtosis statistics for situational awareness items

Variables	Skewness Statistic	Kurtosis Statistic
SA1	-.363	-.867
SA2	-.673	.435
SA3	-.605	.245
SA4	-.208	-.659
SA5	-.511	.096
SA6	-.366	-.411
SA7	-.651	.266
SA8	-.544	-.155
SA9	-.310	-.416
SA10	-.754	-.471
SA11	-.669	.190
SA12	-.538	.467
SA13	-.666	.582
SA14	-.919	1.401
SA15	-.169	-1.123
SA16	-.360	-.885
SA17	-.509	-.231
SA18	-.673	.435
SA19	-.206	-1.061
SA20	-.728	-.540

Appendix J. Initial codes identified from inductive coding

Table J 1: List of codes identified in interviews (generated from inductive coding)

No	Code	No	Code
1	Work pressure and Meeting deadlines	13	Experience
2	Workload and multiple tasks	14	Safety signs
3	Stress and fatigue	15	Safety knowledge
4	Long hours of work	16	Safety rules and procedures
5	Work tasks and procedures	17	Motivation
6	Overconfidence	18	Weather conditions
7	Supervision	19	Equipment issues
8	Self-awareness	20	Accidents experience
9	Communication of risks	21	Employee involvement
10	Risk assessment	22	Safety management commitment and leadership
11	Reporting	23	Training
12	Safety culture	24	communication

Appendix K. Further investigation of the quantitative data regarding specific factors identified in the qualitative analysis

1. Safety knowledge

For safety knowledge factor, 15 items from the safety knowledge construct data were used to conduct this additional mediation analysis. Results in Table K1 reveal that safety knowledge serves as a bridge between situational awareness and compliance. While situational awareness influences safety knowledge ($\beta = 0.207$, $p < 0.001$), its direct path to compliance is very weak and statistically insignificant ($\beta = 0.062$, $p = 0.294$). Critically, safety knowledge exerts the strongest influence in this model ($\beta = 0.436$, $p < 0.001$), with the indirect effect ($\beta = 0.090$), confirming that knowledge transmits awareness into compliance action. This suggests that safety knowledge can translate situational awareness into safety compliance.

Table K 1: Results of mediation analysis of safety knowledge between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	*p*-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Safety Knowledge	0.2072	0.056	3.680	<0.001	[0.096, 0.318]
Safety Knowledge → Safety Compliance	0.436	0.066	8.495	<0.001	[0.432, 0.694]
Situational Awareness → Safety Compliance	0.062	0.059	1.052	0.294	[-0.054, 0.178]
Indirect Effect Situational Awareness → Safety Knowledge → Safety Compliance	0.09	0.0458	N/A	<0.001	[0.033, 0.210]

2. Training

For the training factor, five items concerned with training from the safety knowledge construct data were used to conduct this additional mediation analysis. were used to conduct the mediation analysis. As outlined in Table K2, training acts as a motivator, transforming awareness into tangible compliance. Situational awareness has a direct impact on training ($\beta = 0.309$, $p < 0.01$), but does not have a direct influence on safety compliance ($\beta = 0.031$, $p = 0.630$). Instead, training independently has a statistically significant influence on compliance ($\beta = 0.479$, $p < 0.01$). The indirect effect of situational awareness on safety compliance through training is statistically significant ($\beta = 0.148$, $p < 0.01$). This indicates training activates awareness, transforming situational recognition into safety compliance execution.

Table K 2: Results of mediation analysis of training between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	p-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Training	0.309	0.055	5.566	<0.01	[0.199, 0.418]
Training → Safety Compliance	0.479	0.070	6.819	<0.01	[0.341, 0.618]
Situational Awareness → Safety Compliance	0.031	0.064	0.482	0.63	[-0.095, 0.156]
Indirect Effect Situational Awareness → Training → Safety Compliance	0.148	0.043	N/A	<0.01	[0.068, 0.235]

3. Safety culture

For the safety culture factor, the same 23 items from the safety culture construct data were used to conduct this additional mediation analysis. As presented in Table K3, situational awareness shapes culture ($\beta = 0.409$, $p < 0.001$), however, its path to compliance is negative (β = -0.159, p = 0.15) and statistically insignificant. The safety culture has a positive influence on compliance (β = 0.442, $p < 0.001$), and the indirect effect (β = 0.180, $p < 0.01$) outweighs the negativity of the direct path. This indirect effect suggests that the influence of situational awareness on safety compliance operates exclusively through its positive impact on safety culture.

Table K 3: Results of mediation analysis of safety culture between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	*p*-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Safety Culture	0.4093	0.043	9.587	<0.001	[0.325, 0.493]
Safety Culture → Safety Compliance	0.442	0.084	9.815	<0.001	[0.660, 0.992]
Situational Awareness → Safety Compliance	-0.1594	0.065	-2.451	0.015	[-0.288, -0.031]
Indirect Effect Situational Awareness → Safety Culture → Safety Compliance	0.18	0.0678	N/A	<0.001	[0.208, 0.471]

4. Management commitment

For the management commitment factor, seven items related to management commitment from the safety culture construct data were used to conduct this additional mediation analysis. Table K4 demonstrates that situational awareness influences management commitment (β = 0.418, $p < 0.001$), but commitment's influence on compliance is exceptional (β = 0.651, $p < 0.001$), nearly 50% stronger than the effect of safety culture. Management commitment acts as a strategic amplifier, with the strongest mediation effect (β = 0.272, $p<0.001$). The non-significant direct path (β = -0.094, p = 0.156) confirms that commitment does not fully channel awareness into compliance. This probably positions leadership not as a passive enabler, but as an active multiplier, suggesting that without visible commitment, awareness fails to translate into behavioural change, despite the cultural foundations.

Table K 4: Results of mediation analysis of management commitment between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	p-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Management commitment	0.4184	0.048	8.633	<0.001	[0.323, 0.514]
Management commitment → Safety Compliance	0.6509	0.077	8.442	<0.001	[0.499, 0.803]
Situational Awareness → Safety Compliance	-0.0937	0.066	-1.423	0.156	[-0.223, 0.036]
Indirect Effect Situational Awareness → Management commitment → Safety Compliance	0.2723	0.0603	N/A	<0.001	[0.160, 0.398]

5. Communication

For the communication factor, four items related to communication from the safety culture construct data were used to conduct this additional mediation analysis. Table K5 illustrates that situational awareness has a positive influence on communication ($\beta = 0.380$, $p < 0.001$), which in turn has the second-highest direct effect on compliance ($\beta = 0.580$, $p < 0.001$). Communication serves as the critical informational lifeline, with a mediating effect ($\beta = 0.220$, $p < 0.001$). The direct awareness-compliance path is insignificant ($\beta = -0.042$, $p = 0.509$), indicating communication transmits awareness through information flows. This suggests that communication's role is non-negotiable, even high awareness yields no compliance benefit without structured communication.

Table K 5: Results of mediation analysis of communication between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	p-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Communication	0.3799	0.054	6.991	<0.001	[0.273, 0.487]
Communication → Safety Compliance	0.5802	0.069	8.436	<0.001	[0.445, 0.716]
Situational Awareness → Safety Compliance	-0.0418	0.063	-0.662	0.509	[-0.166, 0.083]
Indirect Effect Situational Awareness → Communication → Safety Compliance	0.2204	0.0525	N/A	<0.001	[0.124, 0.330]

6. Reporting system

For the reporting systems factor, four items related to reporting systems from the safety culture construct data were used to conduct this additional mediation analysis. The results presented in Table K6 show that situational awareness has a positive impact on reporting (β = 0.401, p < 0.001), and reporting in turn, influences safety compliance (β = 0.494, p < 0.001). The indirect effect of situational awareness on safety compliance mediated by reporting is (β = 0.198, <0.001), revealing reporting's function, as it captures awareness and triggers corrective actions.

Table K 6: Results of mediation analysis of reporting between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	*p*-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Reporting	0.4013	0.057	6.989	<0.001	[0.288, 0.514]
Reporting → Safety Compliance	0.4942	0.067	7.384	<0.001	[0.362, 0.626]
Situational Awareness → Safety Compliance	-0.0197	0.065	-0.303	0.762	[-0.148, 0.108]
Indirect Effect Situational Awareness → Reporting → Safety Compliance	0.1983	0.0501	N/A	<0.001	[0.109, 0.301]

7. Safety rules and procedures

For the safety rules and procedures factor, two items related to safety rules and procedures from the safety culture construct data were used to conduct this additional mediation analysis. Safety rules function as the procedural keystone, exhibiting the cleanest full mediation pattern. Results presented in Table K7 reveal that situational awareness has a positive influence on safety rules and procedures (β = 0.338, p < 0.001). In contrast, safety rules and procedures have a stronger impact on safety compliance (β = 0.511, *p* < 0.001). The statistically significant indirect effect of situational awareness on safety compliance through safety rules and procedures (β= 0.1730, *p*<0.001) positions safety rules and procedures as dynamic frameworks that crystallise awareness into safety compliance actions.

Table K 7: Results of mediation analysis of safety rules and procedures between situational awareness and safety compliance

Path	β	S.E	C.R (t-value)	*p*-value	95% CI [Lower, Upper]
Direct Effect Situational Awareness → Safety Rules and Procedures	0.3384	0.065	5.232	<0.001	[0.211, 0.466]
Safety Rules and Procedures → Safety Compliance	0.5110	0.057	8.982	<0.001	[0.399, 0.623]
Situational Awareness → Safety Compliance	0.0057	0.060	0.095	0.924	[-0.112, 0.123]
Indirect Effect Situational Awareness → Safety Rules and Procedures → Safety Compliance	0.1730	0.0493	N/A	<0.001	[0.082, 0.277]