The Effects of Safety Training as a Moderator for the Relationship between Safety Climate and Process Safety: The Case of Abu Dhabi National Oil Company (ADNOC) Refining Company (TAKREER)

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ABSTRACT

Process safety has acquired global attention in the 21st century due to its association with workplace accidents and injuries. Employers and occupational health and safety (OHS) specialists have expressed increasing interest in enhancing process safety due to the link between poor process safety and adverse incidents such as explosions, fires, and chemical spills. Such catastrophes can cause severe damage, such as fatalities, injuries, property destruction, environmental degradation, and loss of productivity, putting a significant and long-term financial strain on organizations.

Several events have been reported in the United Arab Emirates (UAE) over the last decade. Some of the unfortunate occurrences include the Shah Oil Field release of toxic hydrogen sulphide in 2009, in which three employees died, another accident in Borouge with a boiler explosion in which one employee died, and the 2017 explosion at ADNOC Refinery (TAKREER) facility, which resulted in the loss of millions of dollars in assets. Many occurrences went unreported due to internal policy, fear of negative publicity, litigation, and the need to protect secret information.

Understanding the elements that influence process safety is critical for improving process safety and reducing occupational accidents and injuries. As a result, it is critical to investigate the process safety parameters in the context of the ADNOC refinery. It is also critical to assess the impact of safety climate variables on process safety and employee perception of safety training, strengthening the relationship between safety climate elements and process safety.

Data triangulation was used in the study, which involved combining data from focus group discussions, interviews, and quantitative analysis. The hypotheses developed on the research model were tested concurrently using SEM-AMOS path modelling. The findings revealed the significant and robust impact of reported top management safety commitment, management safety practices, and supervisory safety behaviour on process safety, validating all the hypotheses. The study, however, found little support for the safety training construct as a moderator between safety climate characteristics and process safety relationships. The consequences of this study are significant for process safety practices, the process industry and the oil and gas sector in general. According to the findings, medium and lower-level employees evaluate process safety on an overall and dimensional level (employee safety engagement, employees' safety performance and safe working environment). These findings increase a manager's and an organization's management level's comprehension of how employees perceive process safety and tie this aspect to safety climate in particular and safety culture in the general workplace environment

Keywords: *Process safety, safety climate, top management commitment towards safety, top management safety practices, supervisory safety behaviour, safety training, process industry, United Arab Emirates.*

LIST OF ABBREVIATIONS

ADNOC	:	Abu Dhabi National Oil Company
AMOS	:	Analysis of Moment Structure software package
CFA	:	Confirmatory factor analysis
CFI	:	Comparative Fit Index
Df	:	degree of freedom
EFA	:	Exploratory factor analysis
GCC	:	Gulf Countries Cooperation
GFI	:	Goodness-of-Fit Index
ILO	:	International Labour Organisation
OSHA	:	Occupational Safety and Health Administration
PSM	:	Process Safety Management
RMSEA	:	Root Mean Square Error of Approximation
SA	:	Safety attitude
SB	:	Safety behaviour
SC	:	Safety climate
SEM	:	Structural equation modelling
SK	:	Safety knowledge
SM	:	Safety motivation
TLI	:	Tucker Lewis index
UAE	:	United Arab Emirates

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Catastrophic incidents caused by human factors in process safety have lately been debated. In December 2017, an Austrian Baumgarten natural gas hub explosion injured 18 persons and left one dead. In 2018, an explosion injured two and killed six people at the Czech Republic's Unipetrol. In contrast, the explosion at a Wisconsin refiner wounded 11 people and caused the noxious release of smoke that led to evacuation from a hospital, schools, and homes. A fire in a pumping station at Poland's Gdańsk Refinery was reported in May 2018 (Process Safety Engineering, n.d.). As for the United Arab Emirates (UAE), several incidents have been reported for the past decade or so. Some of the misfortunate occurrences include the Shah Oil Field release of toxic hydrogen sulphide in the year 2009, mineral oil release at the Al Ruwais facilities in the year 2011 (Abu Dhabi National Oil Company [ADNOC] Sustainability Report, 2011), and the 2017 explosion that occurred at ADNOC Refinery in Takreer facility (Takreer Incident, 2017).

These appalling incidences highly stress the need to implement effective approaches, strategies, and tools that are less technical and more user-friendly to prevent such disastrous recurrences and effectively mitigate their impacts. Past process safety incidences had characteristically involved releasing toxic materials, injuries, massive losses, adverse environmental effects, and death (Amin, Khan, & Amyotte, 2019). These incidences catapulted the essence of safety across the process safety industry into the limelight for both industry actors and governments (European Commission, 2015). Numerous countries, particularly the West, have developed regulations to enhance their process safety, especially industrial plants. The most popular rules are contained in the Occupational Safety and Health Administration (OSHA) that initiated the 29 CFR 1910.119 Process Safety Management of Highly Hazardous Chemicals Standard to prevent accidental releases within the process industry. It is meant to protect employees from being exposed to the release of hazardous chemicals and toxins (OSHA, 2000). Despite the execution of comprehensive and technical regulations and guidelines, devastating episodes linked with process safety have continued to occur worldwide. These episodes have led to the need for identifying vital human factors and their impacts on process safety. Moreover, many studies show that safety training can positively influence the safety climate and improve workers' unsafe behaviours, thus reducing the process safety incident (Cooper & Phillips, 2004). In research done by Jafari (2014), the impact of safety training on safety climate was assessed in two construction sites, which revealed that the safety training resulted in a significant impact on employee safety climate, leading to fewer process accidents.

1.2 STATEMENT OF PROBLEM

Process safety has acquired global attention due to its association with workplace accidents and injuries in the twenty-first century. (de Almeida & Vinnem, 2020). Escalating interest was noted among employers and occupational health and safety (OHS) professionals in improving process safety due to the association between ineffective process safety and adverse incidences, such as explosions, fires, and toxic spills. Such incidents can inflict severe damages, including fatalities, injuries, property destruction, environmental degradation, and loss of production (Swuste et al., 2020), which place a substantial and long-term financial burden on organisations.

In the past 30 years, many disastrous accidents have caught the attention of the public. Companies cannot last long without practical and good process safety programs. Venkatasubramanian (2010) emphasises a systematic approach to process safety programs and listed many functional challenges for the system, such as scientific and industrial, employees, systems and procedures, management, culture, regulation, and theoretical challenges. Process safety accidents continue to happen, although there is a progression in the knowledge and understanding of the fundamental causes over the past years (Swuste et al., 2020). Process safety management tries on eliminating these accidents by focusing on engineering science, culture and climate, lift-cycle approach and risk assessment (Mannan et al., 2015).

Many efforts had been made to eliminate process safety accidents. However, accidents still occur despite the efforts done by top-level organisations, researchers and artificial intelligence to stop these accidents (Khan & Hashemi, 2017). To improve process safety and mitigate occupational accidents and injuries, it is integral to understand the factors that influence process safety. Many studies have examined critical antecedents such as safety culture, safety climate, and engineering and technical challenges. (see Anwar, Mustafa, & Ali, 2019; Behari, 2019; Hendershot, Herber, & King, 2011; Keren, West, Rogers, Gupta, & Mannan, 2003; Mearns, 2017; Olive, O'Connor, & Mannan, 2006; Ostroff, Kinicki, & Muhammad, 2012; Ramos, Droguett, Mosleh, & Moura, 2020). Mearns (2017) advocated that integrating human factors with additional contextual factors will likely influence process safety.

Process industries, up to the present moment, have recorded significant process safety progress. However, various authors have decried the continued occurrences of major process incidents, although many research and efforts by industries had been made to understand the underline causes to minimize the events of process safety accidents. (Amyotte et al., 2016; Bhandari et al., 2019; Khan & Hashemi, 2017; Qi et al., 2012; Reniers & Khakzad, 2017; de Almeida & Vinnem, 2020). Unambiguous inferences have been drawn from the extant literature about reducing or increasing accident counts – process safety and workplace – within the process and chemical industries in the past decades.

Despite the significant progress noted in process safety and general safety tools and approaches, numerous considerable accidents have been reported at an average of above three annually (Song & Suh, 2019; Reniers & Khakzad, 2017). While acknowledging the speedy development that the process industry has registered, Khan and Hashemi (2017) lamented on the continued occurrences of significant accidents at an alarming rate, hence warning that "if the future is similar to the past, unfortunately, we should expect more accidents". Despite several quotas, such as the International Association of Oil and Gas Producers (IOGP) (2017) showing declining rates in fatal accidents and fatalities over the years (see Figure 1), many incidents were unreported due to issues, such as internal procedure, fear of adversative publicity, litigation, and safeguarding confidential information (Shamim et al., 2019).

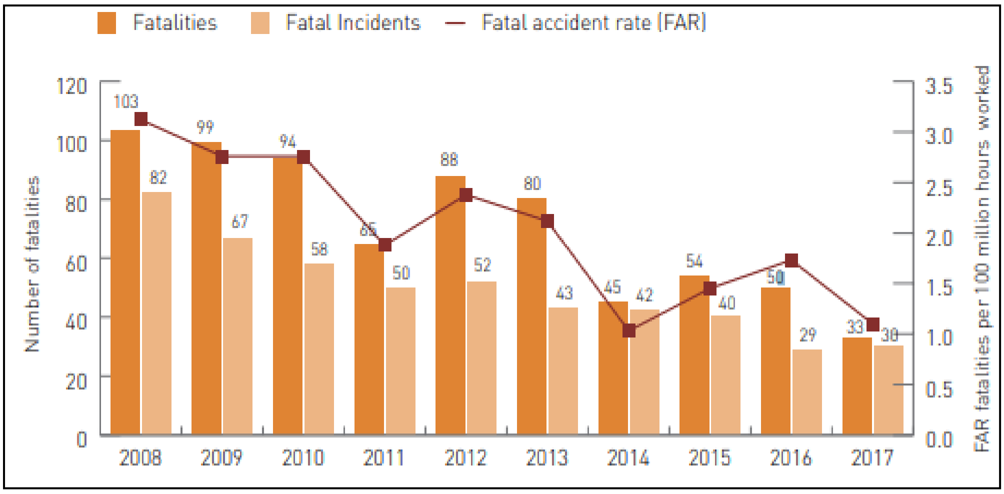


Figure 1. Count of fatal accidents and fatalities (2008-2017)

The shared impressions of rules, procedures and practices related to workplace safety are the safety climate. (Zohar, 1980). This concept denotes the extent to which safety is a workplace priority and merits more attention within process safety. (Zohar & Luria, 2005). Examining safety climate at the site level is crucial because, as Ostroff and colleagues (2012) asserted, safety climate is rooted in individual employees' perceptions. Hunter and Wolf (2016) found that some safety climate factors (e.g., supervisor safety behaviour) are more crucial to process safety than the rest (e.g., top management commitment to safety and top management safety practices). Reniers et al. (2006) asserted that process plants are becoming difficult to control due to the sudden increase in the scale and complexity of modern process industries, making the effects on safety climate factors inevitable (Kidam & Hurme, 2012). According to many hypotheses, the impact on safety climate may be troublesome for occupational accidents and injuries in general and process safety in particular. (von Wehrden et al., 2012).

Studies that have assessed the relationships between safety climate factors and process safety are scarce, including their dimensions (Lingard et al., 2012). Lingard et al., 2012, showed that the relationship between safety climate and process safety accidents behaviours is well established in safety research, and its significance is acknowledged as process safety incidents. The scarcity safety climate, on the other hand, influences behaviours and subsequent incidents. More research work has probed into system maintenance and technical issues, while less on human factors and management system issues, in general. Xie and Guo (2018) found that human factors are the leading cause of incidents in industries.

Nonetheless, past studies and meta-analyses have concluded that the relationships between safety climate factors and process safety are unclear, thus requiring further investigation (Hendershot, 2012). Many reasons have been outlined to justify the mixed findings on the relationships between safety climate and process safety. Some have argued that safety climate factors may exert different effects on specific dimensions of process safety (see Mearns, Hope, Ford, & Tetrick, 2010; Pousette, Larsman, Eklöf, & Törner, 2017).

The UAE has been a significant player in the oil and gas (O&G) industry, serving as the backbone of its economy since the late 1950s (Butt, 2001). With estimated O&G reserves amounting to 81,135.9 MMb (million barrels), the UAE is the eighth largest oil-producing country (Yin, Bai, Gao, & Xu, 2018). The UAE Vision 2030 presents an agenda for diversifying from O&G to manufacturing, transportation, and hospitality and tourism (ADCED, 2008), while O&G will continue to play a significant role. A recent study on the UAE O&G industry suggested that human factors are controlled from the lens of process safety to optimise human performance and to minimise human failure using diverse safety management strategies (Harhara, Singh, & Hussain, 2015; Shqairat & Sundarakani, 2018). These studies elucidate that human factor elements have received limited attention in most studies concerning organisational safety and health (OSH) and process safety management (PSM). A study reported that both industry and Organisational Safety and Health Act (OSHA) regulators should focus more on human factors in managing hazards in process industries (Theophilus, Nwankwo, Acquah-Andoh, Bassey, & Umoren, 2018). A unique feature of process safety in the process industries is that the framework for managing the integrity of the operating systems and the processes involved for handling hazardous petrochemical substances are affected by human factors, such as workers' emotions, commitment, and cognitive biases, along with potentially adverse consequences from the resilience of safety systems and procedures. Human reliability determines agility in the process sector because it relies primarily on human variables such as workforce participation, employee performance, and work environment. This study adds to the existing process safety literature by adopting the recommendations of prior researchers (see Khan et al., 2016; Swuste, Theunissen, Schmitz, Reniers, & Blokland, 2016) assess the specific safety climate factors in process safety.

In January 2017, after the catastrophic accident at the ADNOC Refining facility, the management recognized the necessity for a systematic method that integrate the critical concepts of hazard identification, hazard assessment, and hazard controller throughout the process life cycle. In addition, more research is needed in the conception of dangerous portents; this was recognized as the first topic in the process safety research outline for the 21st century (Crowl, 2009) and will aid both as a precautionary effort and in the design of protective measures. Moreover, (re)thinking the scheme of process safety needs a concurrent opinion of technical and communal standpoints, and research to suggest frameworks and models is now continuing in this way. Systems engineers have many obstacles: technical, personnel, measures, management and culture, regulatory, and theoretical (Venkatasubramanian, 2010b).

A unified framework to uphold and advance process safety, which contains the environment, person, and behaviour, is described in Cooper (2000). According to data collected from 116 Italian businesses, companies that implemented process safety management systems outperformed others in the definition of process safety and its communication to employees, the updating of hazard examination, the identification of hazards, the description of corrective actions, and employee training. (Cooper PhD, 2000).

Process safety is of vital importance, and the viability of the Oil and Gas industry is exceptionally reliant on improving process safety behaviours. Supportable growth is a subject of central concern in different industry sectors. Its standing has been documented by industry and academic communities. As a result, sustainable-development-related content has begun to appear universally in engineering programs in universities in the last two decades. Many improvements in terms of viability evolution in guidelines, business tools, and automation have been made. However, industrial accidents continue to happen. Understanding the dimension of process safety and it influences sustainable growth is, therefore, of supreme significance. To achieve the improvements needed to advance the process safety act, it is commanding that we hold inventive methods, such as studying the human factor, the application of training and its effect on the employee traits to avoid process safety accidents.

1.3 RESEARCH OBJECTIVES

The main objective of this study is to develop a process safety model that can reliably and validly measure the performance of the process industry, apart from assessing the effects of safety climate dimensions on the newly developed process safety model. The specific objectives are listed in the following:

1. To explore the process safety dimensions in the ADNOC refinery context.

2. To evaluate the impact of safety climate factors on process safety in the ADNOC refinery context.

3. To assess the moderating effect of safety training in the relationship between safety climate and process safety.

1.4 RESEARCH QUESTIONS

Previous catastrophic incidences have inspired the need to develop effective approaches, strategies, and tools to prevent the recurrence of such incidents or mitigate their impacts. These incidents, especially those involving high-risk industries, have catapulted safety within process safety industries into a priority area for industry actors and governments (European Commission, 2015). Although the OSHA (2000) regulations for enhancement of process safety, especially in industrial plants, have been developed for prevention within the process industry, human factors, and additional contextual factors, these regulations still demand assessment to ensure their viability in terms of protecting employees from being exposed to hazards linked with the release of hazardous chemicals and toxins (Amaya-Gómez et al., 2019; Lindhout, Kingston-Howlett, & Reniers, 2019; Ramos, Droguett, Mosleh, & Moura, 2020). There is ample evidence that human factors and additional contextual factors have a significant impact on both the conceptualisation and the measurement of process safety within the context of the process industry (Anwar, Mustafa, & Ali, 2019; Behari, 2019; Hendershot, Herber, & King, 2011; Keren, West, Rogers, Gupta, & Mannan, 2003; Mearns, 2017; Olive, O'Connor, & Mannan, 2006; Ostroff, Kinicki, & Muhammad, 2012; Ramos, Droguett, Mosleh, & Moura, 2020). An adequate process safety level offers greater safety fulfilment to employees, more significant return to the organisation through engagement, positive voluntary behaviour, and performance, as well as better societal returns to the safety culture of the organisation (Shamim et al., 2019; Song & Suh, 2019; Reniers & Khakzad, 2017). Although process safety in high-risk industries has received considerable attention, process plants are becoming more complex and challenging to manage the risk (Reniers et al., 2006), mainly due to the unavoidable effects of safety climate factors (Kidam & Hurme, 2012). The usefulness of safety climate as an analytical tool should reside in its capability to find specific and complex problems that can be well-thought-out important to enhance safety (von Wehrden et al., 2012). Only a few researchers have examined the relationships between safety climate elements and process safety to allow for a critical and impactful assessment. (Mearns, Hope, Ford, & Tetrick, 2010; Pousette, Larsman, Eklöf, & Törner, 2017). Thus, in exploring the dimensions of process safety and in measuring the impact of employee’s safety climate factors on process safety, this study has outlined the following:

1. What is the factor structure for process safety?

2. Do safety climate factors influence process safety?

3. Does safety training moderate the relationship between safety climate and process safety?

1.5 SIGNIFICANCE OF STUDY

1.5.1 THEORETICAL SIGNIFICANCE OF STUDY

Incorporating the assessments of multi-level safety climate practices and perceptions of safety training into the safety process can provide an integrated risk assessment, particularly in terms of the effectiveness of managing risk and hazards from the non-technical perspective. Multi-level safety climate strongly influences process safety, thus estimating risks related to process safety incidents. The study outcomes should convince the public that high-risk operations, such as nuclear power plants, could apply the strength of safety climate practices and the intervention of safety training to measure process safety and improve PSM. More importantly, this information can formulate process safety policy interventions by emphasising the most influential human factor that affects process safety. This study determines if safety climate awareness to mitigate risks in the refinery industry in the UAE are reasonably good, thus opening more opportunities for further research work in the process safety domain. These relationships contribute to the awareness and public acceptance strategy and policy development, which is believed to build public trust and acceptance despite the catastrophic incidents related to process safety across the world.

1.5.2 PRACTICAL SIGNIFICANCE

In rare circumstances, the validity and dependability of the linkages may reduce the impact of near-accidents and catastrophic catastrophes. The probability and the consequences of incidents risk can be minimised after considering the other organisation factors such as leadership, supervisory rile, permit to work, etc. The study outcomes are beneficial to safety officers and facility owners for they can develop risks and incidents control mechanisms and strategy on deterministic and probabilistic elements to manage risks and hazards due to asset and integrity, methods for undertaking equipment's deficits, quality assurance and quality control plans that support and help equipment's programs. Additionally, the findings provide implications on the planning and the activities linked with safety training, auditing, monitoring, and safety process assessment. These activities can strengthen the monitoring and auditing system of safety process management through the regulatory body and certification body. In this sense, the study results support developing a robust safety training scale and syllabus content that focuses on leadership styles to improve the safety process and safety at the workplace.

1.6 LIMITATIONS OF STUDY

This study was designed in a sectional format in a multicultural organisational culture. As a result, cross-sectional causality conclusions are impossible to draw. For instance, this study does not address the relationships between process safety and its indicators at different management levels.

Second, the study sample consisted of highly educated and trained workers in a process sector, with the majority holding a vocational diploma as the minimum qualification. This study relied on responses gathered from employees with multiple backgrounds and nationalities. Thus, the generalizability of the study outcomes is limited to skilled employees in the process industry, and the homogeneity of the sample cannot be concluded.

Third, this study updated the variable measures used in previous investigations. (see Anwar et al., 2019; Gao et al., 2019; Loosemore & Malouf, 2019) to better fit the context of this present study, which might affect reliability and validity. Although earlier studies have used various factors of safety climate measurements to assess safety climate, none had considered the multi-level construct of safety climate (e.g., top management and supervisory levels). Hence, the constructs were gathered from the literature. The psychometric properties of process safety are yet to be measured in the safety research context.

Finally, this study solely looked at safety training as a moderating element in determining the relationships between safety climate and process safety. As a result, employees who had undergone at least one safety training program were considered potential employees in this study. The moderator does not indicate the number of training which improves the employee performance and engagement to process safety.

1.7 DEFINITION OF TERMS

1.7.1 PROCESS SAFETY

The literature contains a vast range of definitions about process safety depending on the context and the discipline. Some describe it based on what it entails or as a constituent of safety in general. For example, Marshall and Ruhemann (2001) defined process safety as “the branch of safety which is concerned with the control of those accidents which are special and characteristic features of the process industries” (p. 8). The authors added that the central concern of process safety is to prevent acute releases of substances or energy in detrimental quantities and the limitation of the repercussions and extents of such releases in case they happen. The preoccupation of process safety is with significant releases, along with the potential to injure both the workers and the public, damage offsite and onsite properties, or generate severe environmental harm (Marshall & Ruhemann, 2001).

The American Petroleum Institute (API) (2010) defined process safety as “a disciplined framework for managing the integrity of hazardous operating systems and processes by applying good design principles, engineering, and operating and maintenance practice” (p. 754). Mannan et al. (2016) explained that process safety has the fundamental goal of ensuring that hazardous energy and materials are kept in the piping system and equipment to avert disastrous toxic releases, fires, and explosions. According to Narayanasamy et al. (2019), process safety is about process-related failures such as vessel overflow, pipe raptures, and chemical reactions. The authors also included their general view of process safety with API's (2010) perspective to define process safety as "a blend of engineering, management, and operational skills and practices that focuses on preventing any catastrophic incidents" (p. 171).

Process safety has also been defined as the technical or asset integrity of installations or systems (Swuste, Gulijk, & van Zwaard, 2010). According to Amyotte (2013), process safety entails injury and damage mitigation and prevention caused by process safety incidents involving explosions, the release of toxic substances, and fires. Upon linking process safety to applying and storing hazardous materials, Mannan and colleagues (2015) presented an industry perspective from the hazardous chemicals to define process safety as avoidance of incidents related to a process that emerges following the release of hazardous material in continuous, batch, or semi-continuous industrial processes. Mohd Shariff and colleagues (2016) expressed that process safety is about holistic systems that aim to minimise risk and prevent accidents in chemical manufacturing. Khan, Rathnayaka, and Ahmed (2015) assumed a unique perspective to refer to process safety as a common universal language for communication of the necessary strategies to identify and analyse hazards, to evaluate and assess risks, to implement measures to ensure safety, and to reach safe, critical decisions. They added that process safety prevents major process accidents and incidents, such as explosions, toxic releases, and fire.

Based on the various definitions presented here, the purposes provided by API (2010), Narayanasamy and colleagues (2019) are combined to define process safety as a disciplined framework that blends operational, management, and engineering practices and skills to ensure the integrity of processes, equipment, and systems in the O&G industry to prevent catastrophic incidents, such as vessel overflow, pipe rapture, or chemical reactions that may cause injury, fatalities, property damage, and environmental hazards. The rationale for combining these definitions is that they are comprehensive and include straightforward examples of what process safety incidents and accidents involve.

1.7.2 SAFETY CLIMATE

Hendershot (2011) noted numerous definitions of safety climate in the existing industry and scholarly literature. Safety climate is the shared beliefs and values that interact with the control systems and structures of the organisation to generate behavioural norms (Utall, 1983; Reason, 1998). According to Biggs and colleagues (2010), safety climate manifests in many ways, including proactive assessments of risk, regular walkthroughs that senior management performs, personal attitude towards safety, employee commitment to safety, and effective communication. Safety climate refers to the shared worker perceptions concerning practices, policies, procedures, and how “they relate to the organisation's value and importance of safety. In short, safety climate is the measurable aspect of safety culture (Huang et al., 2013, p. 5). Safety climate also refers to the shared perceptions of policies, procedures, and practices related to workplace safety (Zohar, 1980). Cooper and Phillips (2004) explained that the theoretical and practical significance of safety climate as a construct is rooted in its ability to forecast both safety outcomes, such as injuries and accidents, and safety behaviour in various contexts, as demonstrated in numerous samples from both Eastern and Western cultural contexts.

1.7.3 SAFETY TRAINING

Vredenburgh (2002) referred to safety training as a process that involves gaining knowledge and skills to improve employee safety behaviour. Xu, Zhang, and Hou (2019) relate the safety training to varied enthusiasm, attitude, and engagement to a learning paradigm that is more experiential and kinesthetic-centred.

1.8 CHAPTER SUMMARY

This chapter commences with a section that describes the research topic's general overview, albeit with a bias towards process safety. The exact section defines the UAE as the context, while the O&G industry is the study's focus. A detailed historical account of process safety is presented in this chapter. Process Safety Management (PSM), as the critical aspect of this study, is discussed alongside the various models, frameworks, and regulations developed to aid in better PSM. The diverse models, frameworks, and regulations show the need for context-based considerations in ensuring process safety. They display that there are still contentions concerning how various countries, bodies, and scholars perceive and understand process safety and the respective means for understanding and implementing PSM. The research problem underscores the absence of a validated process safety scale within the UAE O&G sector, including the need to develop one, which is the critical gap this study has bridged.

Process safety is about controlling the risk of failures and errors; managing risk is primarily about reducing the risk of human error. However, many studies on process safety have focused on both the technical and engineering indicators of process safety, but less attention has been given to human factors. The recent significant accidents have highlighted the need for increased focus on human factors. Many studies have cited similar issues from many other accidents and have urged the industry and regulators to pay more attention to human factors. Implementing human factor engineering and policies to prevent accidents is not a new concept. Still, not many studies have devised frameworks to measure the effect of safety climate on process safety. A study found that significant accidents since the past 30 years resulted from poor control of organisational and human factors. Although many human factor elements have already been constituted in PSM, the interaction of safety training in the relationship between safety climate and process safety has not been adequately addressed.

1.9 ORGANISATION OF STUDY

This study is divided into six distinct chapters that build on each other in an interconnected manner. The introduction chapter provides a helicopter view of the dissertation that funnels the study's research questions and objectives. The second chapter elaborates on the background of the study with the introduction of the study context and history related to the study. The third chapter describes the critical theories, models, and concepts to support the development and shape the direction of this study. The literature highlights the research gaps as a guiding principle to build the research framework. The fourth chapter explains the methodologies executed in this study, including the approaches and techniques adopted. The research design includes population and sampling frame identification, procedures for sampling techniques, and ethical considerations.

CHAPTER 2

BACKGROUND OF STUDY

2.1 INTRODUCTION

This chapter discusses the study's background, setting, and history concerning process safety. The aspects of PSM are elaborated to enhance understanding regarding the collaborative partnership between process safety and management system.

2.2 PROCESS SAFETY CATASTROPHES

Some major process safety catastrophes refer to the Bhopal explosion that occurred in 1984, the 1988 Piper Alpha, the explosion at the Phillips 66 plan in Texas, USA, the 2003 Mohali cloud explosion in India’s Ranbaxy drug manufacturing plant, the 1989 Alaska Exxon Valdez oil spill in the US, the 2005 Texas explosion at the BP refinery, the 2010 Deepwater Horizon incident, the 2013 explosion in Texas’ West Fertilizer plant, the 2014 and 2015 dust explosion in Jiangsu’s Zhongrong Metal Products Company, as well as the 2015 explosion at a storage facility in Tianjin, China (Khan & Abbasi, 1999; Mannan et al., 2016; Koteswara, Reddy, & Yarrakula, 2016; Besserman & Mentzer, 2017). Other incidents have been discussed extensively by authors, such as Okoh and Haugen (2013), by describing their causes, such as scheduling, maintenance issues, execution, inadequate planning, checking, and fault diagnosis. As for the UAE petrochemical industry, there has been a marked reduction in process safety incidents, particularly since the past decade. Altogether, several incidents were reported with a few injuries and fatalities, such as the Abu Dhabi Gas Liquefaction Company (ADGAS) and Abu Dhabi Company (ADCO) Shah Oil Field onshore explosion in 2009. The two unfortunate incidents led to three fatalities and four injuries combined (Carlisle, 2009).

In response to significant process safety catastrophes, such as the 1974 Flixborough and 1984 Bhopal explosions in the UK and India, respectively, globally-renowned bodies, including the European Federation of Chemical Engineering (EFCE), the American Institute of Chemical Engineers (AIChE), the UK Health and Safety Executive (HSE), the US Environmental Protection Agency (US EPA), and the Canadian Chemical Producers' Association (CCPA), have responded swiftly by initiating new regulations and new concepts for conducting process operations within the stipulated rules to evade catastrophes. Numerous other databases, such as Norway's Offshore Blowout Database by Stiftelsen for Industriell og Teknisk Forskning (SINTEF) (Holand, 1995), the Center for Chemical Process Safety's (CCPS), Process Safety Incident Database (PSID), Major Accident Hazards Bureau (MAHB), Major

Accident Reporting System (MARS), the Center for Pollution Control and Environmental Engineering's Pondicherry University Process-Industry Accident Database (PUPAD) in India, as well as the National Institute of Advanced Industrial Science and Technology's (AIST) Relational Information System for Chemical Accidents Database (RISCAD) in Japan (Tauseef, Abbasi, & Abbasi, 2011), have all been maintained to promote safety awareness at the global arena. They have data regarding the historical accounts of accidents and the matching repercussions publicly. Although such efforts have significantly contributed to the advancement of the research field and aided in reducing the number of near-misses, catastrophes, accidents, and incidents, major process-related disasters continue to occur across the globe (Amyotte et al., 2016). Amyotte et al. (2016) have discussed the reasons behind the continued occurrences of significant accidents in chemical process industries which are exclusive in integrally poor design, non-proper organisation structure, and no awareness of cost in major accidents to the employees, societal and cultural issues, poor process safety culture, non-adequate competency, and non-carrying dynamic risk assessment. Bottom line, these accidents signify that guaranteeing process safety across various industries and countries has remained a critical challenge. Further efforts and approaches are required to advance the process safety research field.

The chemical process industries, including the petrochemical segment, have always been attempting to satiate the ever-growing human demand for technological and social needs. Hence, process industries are becoming increasingly complex to regulate and prevent process safety incidents (Amin, Khan, & Amyotte, 2019). The most concerning aspect of the chemical-related process safety sectors is that mishaps frequently spread faster than most other types of incidents. A practical process safety analysis is inevitable to prevent process safety accidents or undesired outcomes. Process safety embeds a set of encompassing aspects, including risk mitigation and analysis, identification and analysis of hazards, accident modelling, and analysis of repercussions. Identifying hazards is the screening technique that determines what may not work as expected in a given process. Risk is described as “an alternative expression of safety” (Amin, Khan, & Amyotte, 2019). Kaplan and Garrick (1981) stated that risk emanates from two questions; the accident frequency and the number of repercussions the accident will wield on the ecosystem and the process. There is a tendency for scholars and practitioners alike to mix up workplace safety and process safety. Nonetheless, these two concepts are distinct as workplace safety concerns, mainly human errors (e.g., falls, slips, and associated hazards). In contrast, process safety emphasises hazards related to toxicity, fires, and explosions (Khan et al., 2015).

2.3 PROCESS SAFETY AND THE UAE

This research focused on process safety in the oil and gas industry in the UAE. The UAE occupies 83,600 square kilometres. It is located in the south-eastern region within the Arabian basin bordering Saudi Arabia and Oman (The World Factbook, 2019) at longitudes $51^{o}22'$ to $56^{o}22$ latitudes $22^{o}40$ to $26^{o}00'$. The United Nations (UN) population estimates released in July 2017 revealed that

9,701,315 people resided in the UAE, with immigrants constituting over 88% of the population. The UAE comprises seven Emirates, including Abu Dhabi, Ajman, Sharjah, Umm al Qaiwain, Dubai, Fujairah, and Ras Al Khaimah. The UAE was declared independent from the UK and declared the union of the Emirates in 1971, although Ras Al Khaimah joined the other six Emirates in 1972. The UAE is politically stable and has been that way for a long. For instance, it did not suffer the Arab Spring predicament that befell many of the Middle East and North Africa countries in 2010/11. Recently, the government has been instrumental in shaping the regional affairs in the Middle East, including fighting ISIS and allying with Saudi Arabia in the Yemeni stabilisation quest (The World Factbook, 2019).

The UAE ranks seventh in the top 10 lists of the largest oil producers globally. It is a member of the Gas Exporting Countries Forum (GECF) and the Organisation of Petroleum Exporting Countries (OPEC) since 1967. Overall, the estimated crude oil reserve in the UAE is 97.8 million barrels (U.S.-U.A.E. Business Council, 2019). It houses Upper Zakum, the second-largest offshore oilfield managed by the Abu Dhabi National Oil Company (ADNOC). Upper Zakum is a 1963 discovery that was founded based on conventional offshore platforms. The chances of discovering another oil well are low. However, the UAE employs Enhanced Oil Recovery (EOR) approaches to expand its mature oil fields (US EIA, 2017).

From 2009 through 2016, the liquid natural gas production in the UAE had reached 3.7 million barrels per day, which reflected a 28% increment. Crude oil production increased to reach 2.97 million barrels per day during the same period (U.S.-U.A.E. Business Council, 2019). The long-term contracts with Asian markets to supply oil are the main drivers of the growing crude oil exports, as Asia accounted for up to 96% of crude oil exports by the UAE in 2014. The UAE uses oil locally in massive amounts, which has caused the need to import extra diesel, heavy fuel oil, and gasoline to gratify the high demands for energy. Hitherto, the UAE has invested heavily in developing infrastructure to cater to midstream and downstream infrastructures.

An example is the robust pipeline network connected to four operational refineries with a total capacity of 1.1 million barrels per day (U.S.-U.A.E. Business Council, 2019). The latest addition to the pipeline network is the 236-mile Abu Dhabi Crude Oil Pipeline (ADCOP) that links Habshan and Fujairah. It connects directly to the global markets and the fields located in the Gulf of Oman with 1.5 million barrels per day, projecting that this capacity will hit 1.8 million barrels per day. The UAE can export substantial amounts of its daily production and bypass the Strait of Hormuz. Hormuz is the busiest chokepoint for energy globally and is responsible for 30% of all oil traded seaborne (US EIA, 2017).

In terms of storage infrastructure, the UAE unveiled the Fujairah storage facilities in March 2015 with a capacity of 16 million petroleum products and crude oil barrels daily. The terminal will also be expanded with “three new subsea loading lines, an intermediate pumping station, and three offshore buoys intended for deep-water tanker loading.” (US EIA, 2015, p. 5). With a capacity of 200,000 barrels per day, this refinery is bound to offer fuel for both export and domestic markets when operations commenced in 2020. Fujairah is rapidly establishing itself as a crucial node within the global export and refining network with its growing storage and refining capacities after the numerous expansion projects that are still ongoing (US EIA, 2015). The biggest of the five facilities for oil refinement in the UAE is the Ruwais facility, with more than double capacity following its expansion to reach 817,000 barrels per day. This high refining capacity in the UAE to 1.1 million barrels per day has led the country to be the fourth biggest refiner within the Persian Gulf. Related investments include a new refining complex being erected in Fujairah with a target capacity of 200,000 barrels per day by 2020 (Middle East Economic Survey, 2015).

2.4 PROCESS SAFETY AT ADNOC REFINERY

This study was set within the organisational context of the ADNOC Refinery, previously known as Takreer. Founded in 1999 in Abu Dhabi, the ADNOC Refining has its headquarters at the Sheikh Khalifa Energy Complex along Corniche Street (Gulf Petrochemicals and Chemicals Association [GPCA], 2019). It is a company with an international and regional reputation in the oil refinery business, being the fourth largest worldwide (ADNOC, 2019) with a workforce of 4,713 employees (GPCA, 2019). The ADNOC Refining runs the Abu Dhabi and Ruwais refinery plants, which are responsible for producing approximately 40 million tons of refined products annually. The refinery has a daily refining capacity of 922,000 bb/d and a daily processing capacity of 837 barrels. The petroleum products produced by ADNOC Refining include Liquefied Petroleum Gas (LPG), fuel oil, jet fuel, base oils and gas oil, propylene and petrochemical feedstock, and naphtha. The company also produces specialised products, such as Anode Coke and Carbon Black. The ADNOC Refining is a member of the Gulf Technology Advisory Council, which was established in 2014. In the same year, the Refinery made the debut production of bio-jet fuel at the Abu Dhabi facilities (ADNOC, 2019). Figure 2 illustrates the location of the two refineries run by ADNOC Refinery on the UAE Map.

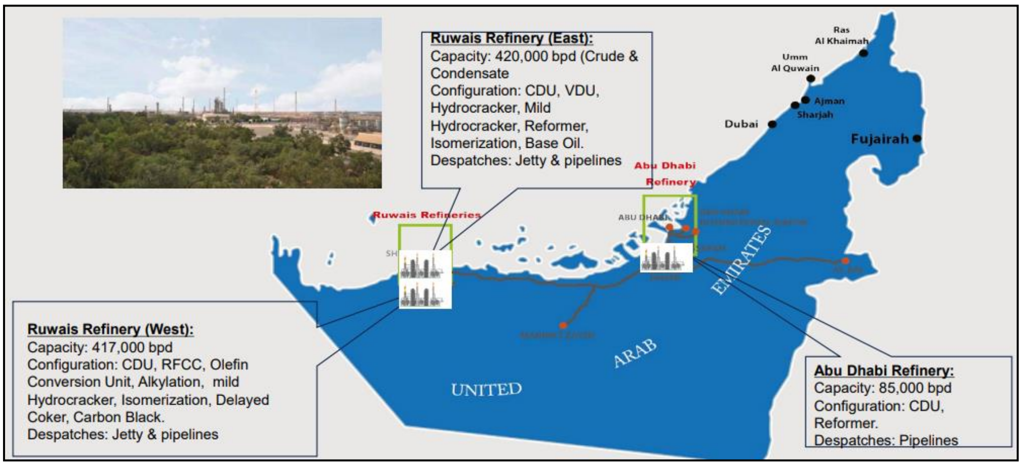


Figure 2. A map and illustration of ADNOC

As part of the ADNOC Group of Companies, ADNOC Refining adheres to the ADNOC Group HSE Policy that aims at protecting “people, communities, and the environment; ensuring effective security and business continuity measures; and following sustainable business practices" (ADNOC Group, 2018, p. 1). The HSE Policy outlines 13 commitments that all companies within the ADNOC Group commit to implementing. These commitments are about the pursuit of a no-harm goal to the community and people, environmental protection and support for the commitment of the UAE in addressing the climate challenge, and execution of cost-effective approaches to enhance energy efficiency and renewable energy use. The commitments also outline obligatory compliance with all relevant HSE policies, regulations, laws, and policies, ensuring high-level response to emergencies, business continuity, and crisis management measures. The HSE policy addresses risk management, incident prevention via PSM and asset integrity, sustainability promotion, Corporate Social Responsibility (CSR), and staff welfare. The total embedment of HSE culture, which empowers contractors and workers to handle unsafe work, sustenance, and development of HSE critical competencies among workers, holds all employees, supervisors, and management accountable for the performance of HSE. The last two commitments refer to setting HSE performance targets, including continuous improvement and working with business partners who commit to 100% HSE. The ADNOC Group implements the HSE policy through a comprehensive management system (ADNOC Group, 2018). The ADNOC Refining claims that the Abu Dhabi O&G industry is the safest globally with low Lost Time Injury Frequency (LTIF) (ADNOC, 2019). The ADNOC Refining has several accreditations, such as ISO 14001 on environmental aspects and 18001 on health and safety (Al-Blooshi, 2018).

2.5 THE HISTORY OF PROCESS SAFETY

Klein (2009) explained that process safety had been an essential industrial practice aspect since the advent of industrialisation. Nevertheless, most historical reviews about process safety have looked into the last half a century or so, with the typical commencement being the Flixborough process safety catastrophe of 1974 in England (Kerin, 2017). The explosion injured and killed 89 and 28 individuals, respectively, while simultaneously destroying the plant and causing secondary damage to the community. The principal factors of the explosion were inadequate evaluation of the effect of making temporary changes to design during maintenance and lack of expertise onsite. The following outcomes and investigation stimulated the desire to adopt more robust process safety initiatives to constitute the first generation. This first-generation underscored design Management of Change (MoC) included developing systemic processes for analyses, such as Hazards and Operability (HAZOP) studies. The subsequent developments in the site designs integrated some effective features, including safe building locations and blast-proof control rooms (Atherton & Gil, 2008).

The Flixborough catastrophe compelled adjustments to the Health and Safety at Work Act of 1974 in the UK. The 1976 Icmesa chemical firm disaster in Seveso, Italy, inspired the most significant changes in regulation through the Seveso Directive (da Cruz & Bentes, 2013). This directive brought about outcome-based legislation requiring every chemical facility to demonstrate how they managed their operations according to the safety case concept. The Seveso

Directive was later amended to extend its scope in reaction to events, such as the toxic release at Bhopal, India, in 1984 and the fire at Basel's Sandoz chemical factory in 1986. The 2000 Baia Mare cyanide spill in Romania, the Enschede explosion in a fireworks factory in The Netherlands, and the explosion in Toulouse that involved ammonium nitrate in 2001 led to the expansion of the Seveso's scope. Kerin (2015) asserted that the Seveso II scope embedded processing and storing in mining, as well as storing pyrotechnics. Seveso III was later released in 2012 (Kerin, 2017). According to the UN (2011), the scopes had more components, such as the community's rights to be informed, in line with the Globally Harmonized System (GHS) of Classification and Labelling Chemicals.

Hendershot (2009) elaborated a dramatic expansion of the process safety scope by underscoring the Canterbury Tales by Geoffrey Chaucer in the 14th century as the earliest traceable process safety accident. Geoffrey outlined a crucible explosion in an alchemical process that triggered the investigation. Similarly, the Industrial Revolution at the beginning of the 19th century is viewed as the onset of process safety development which stemmed from a reaction to several explosions involving steam boilers. Onsite nitro-glycerine manufacture during the US railroad expansion in the 1860s refers to an initial example of safer designers that mitigated risk to the public while transporting the compound. During the same period, the dynamite invented by Alfred Nobel that absorbed nitro-glycerine on an inert carrier to stabilise better is another instance of using a hazardous material in a less hazardous form (Hendershot, 2009).

The Piper Alpha explosion informed the extension of the outcome-based legislation of safety case to cover the oil and gas industry offshore. Meanwhile, the Esso Longford explosion in Australia in 1998 affected the process safety regulation profoundly. It led to the development of the Victorian legislation to address hazard facilities, which were informed by Seveso II that affected the establishment of unique units, which focused on facilities considered a significant hazard by most OHS regulators (Kerin, 2015). The explosion at Piper Alpha had shifted the paradigm on the importance of safe work systems, especially the practices linked with lock-out tag-out, isolation, and permit-to-work procedures (Kerin, 2017). These techniques would play a critical part in several subsequent disasters, including the Texan Phillips Petroleum explosion in 1989 and the Delaware City refinery in 2001 (Atherton & Gil, 2008).

Poor MoC connected with unavailability or scarcity of specialist expertise onsite emerged as the theme that consistently analysed process safety catastrophes (Kerin, 2017). This scarcity was related to organisational culture, which also affected other aspects of process safety disasters. For instance, Union Carbide - the Bhopal plant company – had process and technology know-how. Nonetheless, the standard-setting and management were left to the onsite management under local pressure (WorkSafe Victoria, 2011). Organisational culture also featured predominantly during the analysis of the Chernobyl explosion in 1986.

Mannan (2012) highlighted the precursors to crucial disasters within the petrochemical, chemical, and oil industries, which essentially compelled changes within safety management in these industry segments. While chemical plants before the 1960s were typically small in size and could start or shut down, the severity of operating conditions, such as temperature and pressure, worsened. The energy kept within the process rose and turned into an even more significant hazard. As a result, plants in the process industry increased to operate a single stream, yet they comprised colossal equipment. The degree of interlinkages between different plants led to further exchanging of by-products. These factors contributed to the increased probability of both economic and human loss (Mannan, 2012).

While not exhaustive, understanding process safety can be improved by recognizing its history while drawing attention to the impending failure to learn from prior disasters (Kerin, 2017). An earlier observation in this view was presented by Kletz (1993), who depicted that an outsider may judge the occurrence of industrial accidents as ignorance by the industry practitioners on how to prevent them. Nonetheless, such mishaps continued to occur primarily because practitioners and industry operators failed to apply the knowledge available. Organisations fail to learn from previous experiences but move on with their knowledge, thus causing forgetfulness by the entire organisation (Kletz, 1993). Similarly, Hopkins (1999) expressed that every disaster is eminently preventable despite being unprecedented and unforeseeable. In numerous instances, the circumstances of a process disaster resemble those of previous ones and end up being replicas of past disasters. Preventability is subject to learning from and applying lessons from past mishaps. The preventability of process accidents based on prior accidents was manifested best in the 2015 explosion and fire at the Tianjin chemical warehouse in China and the serial loss-of-containment incidents in 2015 and 2016 at PEMEX Oil Company in Mexico (Kerin, 2017). This realisation explains the increasing scholarly and practitioner attention towards PSM.

Other sources trace process safety origins to a different school of thought. Swuste and colleagues (2016) argued that mass industrial processes emergent after World War II triggered the initiation of the safety movement during the early 1960s. This movement was critical within the domain of safety, which was later known as "Loss Prevention". The chemical industry also increased its output, complicating the control of such processes. The complexity in controlling chemical processes led to emissions of toxic substances, explosions, and fires. Public anxiety about the likelihood of large-scale accidents stemmed from process incidents and accidents (e.g., pollution) in the chemical industries (Carson, 1962). Publications regarding loss prevention in the US and the UK followed in this regard. However, the publications were released after incidents in ammonia plants (Hendershot, 2009). The publication of the article by F. G. Kerry in the Boston meeting of AIChE in December 1956 pioneered and provoked both practitioners and academicians to dialogue around process safety. After the meeting, the symposium entitled 'Safety in Air and Ammonia Plants' has turned into an annual event since 1957 (Hendershot, 2009).

Engineering approaches dominated loss prevention during the period, emphasising controlling loss and keeping chemicals inside the pipes (Swuste et al., 2016). Process improvement methods prescribed by HAZOP studies in the process industry appeared to be dominant. Failure Mode and Effects Analysis (FMEA) and Free Tree Analysis (FTA), which are employed in the military sector, equally contributed to the process safety discourse. Several major global incidents, especially the Bhopal and Chernobyl incidents, were instrumental in shaping dialogue regarding process safety. Notably, process safety history tends to be fuzzy, especially with the upstream context. The numerous disastrous fires and explosions within oil plants and petrochemical informed the Texas loss prevention symposium (Hendershot, 2009).

Within the O&G upstream sector, process safety emerged due to the industry or regulatory bodies after severe accidents. Hence, to meet various safety and environmental requirements (Johnstone, Spangler, & Hansen, 2017). The 1969 oil spill in the ocean in Santa Barbara had adversely affected the environment, especially marine mammals, birds, and beaches. The Environmental Protection Agency (EPA) was then founded, offshore cooperatives, and obligatory blowout training. The hydrogen sulphide leakage in 1975 in Denver City, which led to nine fatalities, had inspired the establishment of Material and Engineering standards, as well as the regulations tailored to hydrogen sulphide in precise. The 1988 Piper Alpha explosion process safety disaster resulted in the landmark institutionalization of the 1992 Safety Case, often known as the Offshore Installations Regulations. Even in the 21st century, process safety incidents that continued occurring informed the development of various agencies and regulatory bodies. For example, the spill of 4.9 million barrels of oil into the ocean caused 11 fatalities. This catastrophe led to the establishment of new regulations for drilling and contingency and the formation of the Bureau of Safety and Environmental Enforcement (BSEE) (Johnstone, Spangler, & Hansen, 2017).

2.6 PROCESS SAFETY MANAGEMENT (PSM)

In the US Code of Federal Regulations (CFR) by the Office of the Federal Register (1987), PSM is described as “the proactive identification, evaluation, and mitigation or prevention of chemical releases that occur as a result of failures in processes, procedures, or equipment” (p. 185). This definition anchors on the understanding that PSM is mainly targeted at highly hazardous chemicals and potentially causing catastrophic incidents. The PSM has also been referred to as “the application of management principles to identify, understand, and control hazards while preventing process-related injuries and accidents” (Aziz & Mohd Shariff, 2017, p. 1). Here, PSM is meant to prevent, prepare for, mitigate, respond to, and restore following catastrophic energy releases or chemicals (Abu Bakar & Ismail, 2015). Hence, PSM is all about developing and implementing an effective system or program for ensuring that the equipment and practices employed during hazardous processes are adequate to guarantee safety and that their maintenance is performed appropriately. There is a need for ongoing efforts to prevent catastrophic accidents that involve hazardous energy or materials. Implementing PSM effectively triggers positive outcomes on the safety of process industries. Metrics involved in determining the effectiveness of PSM in process industries is reduced or nil fatality, shutdown incidents, property damage, as well as near-miss and injury. They include improving productivity and quality, properly reorganising technical data, and addressing reinsurance issues (Mohd Shariff, Aziz, & Majid, 2016).

The global acceptance of PSM as critical to ascertain safety has led to several PSM systems in varied regions and countries. Such systems signify the need for contextual development of PSM systems and frameworks within different countries. For instance, the Canadian Society for Chemical Engineering (CSChE, 2012) recommended a PSM system with the most recent guidelines available in its fourth edition. The guide was developed to give a general PSM overview and introduce the first edition standard based on the earlier system that the CCPS had developed previously. Mason (2001a, 2001b) described the first three elements of US-regulated PSM and the remaining eleven, respectively. The US EPA regulates the PSM in the USA within the CFR.

Later on, the CCPS recommended newer PSM guidelines called the Risk-based Process Safety (RBPS). It is comprised of the PSM elements and the prevention of accidents pillar (CCPS, 2014). Amyotte and colleagues (2016) explained that the RBPS fits the Vision 20/20 of the CCPS. It envisions a near future that shows how the perfect process safety is executed when an industry champions it based on five tenets; management systems, lessons learned, competency, standards, and culture. The AIChE made a new contributory column entitled Process Safety Visions (PSV) (2016) to communicate the themes and tenets of Vision 20/20, including a commitment to the process safety culture. McCavit and colleagues (2015) have extensively discussed Vision 20/20. Rosen (2015) developed Ten Commandments to characterise the best practices of the RPSM. Upon reviewing the different PSM standards, guidelines, and frameworks, Amyotte and Lupien (2017) concluded that the original CCPS, CSChE, EPA, OSHA, and RBPS CCPS share numerous similarities despite the variations in their naming, arrangement, and the number of elements.

2.7 MODELS AND METHODS OF PROCESS SAFETY

Process safety and risk analysis studies have resulted in the creation of several approaches aimed at demystifying the mechanisms of accidents, the factors that cause them, and the consequences of such accidents. The most common approaches entail identifying hazards, analysing risk propagation, analysing the risk itself, and simulations. Apart from process safety, safety science has been described as lacking in adequate theories that provide sufficient representations of past events, capacity to predict future events or to analyse the existing ones in a manner that mitigates safety accidents (Swuste, van Gulijk, & van Zwaard, 2010). Despite this, there are safety models, theories, and metaphors that may aid in the understanding of process safety dialogue. The safety metaphors, theories, and models have been classified into system-dynamic, epidemiological, and sequential theories, as reviewed extensively in the following chapter (see Chapter Three).

Global bodies, including CCPA, AIChE, HSE, US EPA, and EFCE, were at the forefront of introducing concepts and regulations for conducting process safety operations to prevent process disasters (Amin, Khan, & Amyotte, 2019). Databases containing accident data, such as MAHB, MARS, CCPS, PSID, and the National Institute of AIST’s RISCAD from Japan, have been established to promote global safety awareness. Such databases store data and histories of process-related catastrophes, and their related repercussions are available for the public. Such efforts significantly advance research in the process safety domain. They have contributed to reducing the frequency of undesired near-misses, catastrophes, and accidents (Amin, Khan, & Amyotte, 2019).

Although the extant literature does not necessarily offer new methodologies or models for process safety, it considerably contributes to providing a precise and updated overview of how the field and the research in the area are flourishing. Numerous reviews have been conducted by process safety researchers on different process safety aspects. For example, Cameron et al. (2017) investigated how some continental tools, such as FMEA and HAZOP, have been developed. The findings faulted the tools on their inability to guarantee complete hazard analysis performance. A decade earlier, Abbasi and Abbasi (2007) reviewed dust explosions, their repercussions, causes, and techniques for mitigating them. The findings portrayed venting as the most popular method to mitigate the adversity of process safety explosion incidents.

Khan and Abbasi (1999) and Koteswara Reddy and Yarrakula (2016) reviewed process accidents between 1926 and 2015. The results showed that the models employed to predict and deal with process safety incidents did not guarantee optimum prevention. Upon reviewing, 225 process safety accidents were considered pertinent to domino effects, in which Darbra and colleagues (2010) concluded that external causes (e.g., lightning, explosion, and fire) and mechanical failures (e.g., overpressure, overheating, hose failure, and leaking) ranked the highest in causing process safety accidents. A review conducted by Kadri and Châtelet (2013) focused on different software tools and methods used to analyse domino effects. Although the study lacked relative comparison in terms of the performance of the various techniques and tools, it was evident that they were inadequate to prevent process safety accidents in totality. Altogether, it emerged that consequence modelling is critical in forecasting accident severity.

Tausee and colleagues (2017) looked into 14 distinctive software tools for consequence analysis to outline their limitations and strengths, whereas Al-shanini, Ahmad, and Khan (2014) reviewed different Dynamic Sequential Accident Models (DSAMs). Both studies concluded that all the models could offer robust performance as they displayed the capacity to update risk profiles based on precursors. The researchers also ranked Rathnayaka, Khan, and Amyotte's (2011) System Hazard Identification, Prevention, and Prediction (SHIPP) methodology as the highest among the DSAM category. They attributed this high ranking to the capacity of SHIPP to embed human errors, organisational errors, management errors, and potential hazards. Tixier and colleagues (2002) reviewed 62 methods for analysing industry risk and concluded that process plants were so unique that a general way of analysing risk might be covered.

Khan and colleagues (2015) reviewed the evolution of models and methods used in process safety. However, the study included only eight significant risk analysis and process safety journals, thus limiting its domain and scope. Mannan and colleagues (2016) assessed how process safety analysis was involved and briefly mentioned the various crucial aspects and areas. Jain and colleagues (2017) discussed how safety regulations have evolved in Norway, the UK, the US, and Australia, which seemed ineffective. Besserman and Mentzer (2017) evaluated safety regulations in India, the UK, China, and the US. They concluded that safety regulations could promote process safety.

An earlier review was performed by De Rademaeker and colleagues (2014) regarding the aspects of preventing loss and promoting safety in process safety industries within the context of Europe. The authors underscored the need to enhance the analysis of organisational and human factors that prevent loss and promote safety. Swuste and colleagues (2016) presented an overview of the main safety indicators and suggested that the indicators were insightful in aiding the development of a company's safety policy. Jain and colleagues (2018) surveyed various resilience metrics and contributed to understanding the significances of incorporating resilience metrics into risk management. They cited alarm management as a critical component to ascertain efficiency in plant operation towards promoting acceptable safety levels. Meanwhile, Goel, Datta, and Mannan (2017) looked into the current guidelines, standards, challenges, and regulations linked with industry-based alarm management systems.

Several studies have attempted to predict process accidents. For example, Bier and Yi (1995) proposed precursor-based estimators to estimate the frequency of rare events using simple mathematical operators. They described the estimators as being user-friendly in terms of ease of use and simplicity. Nonetheless, the estimators were affected by massive errors and failed to incorporate the process of accident propagation. The estimators omitted the means through which precursor events might transform into major process accidents. Phimister and colleagues (2003), on the other hand, built a systematic framework to analyse and improve near misses. Their proposed management framework has the strength to facilitate identifying, reporting, and investigating near misses and the execution of suitable actions.

Nevertheless, the framework failed to amalgamate statistical tools, thus making the measurement prediction difficult. Another prediction study by Yang, Khan, and Lye (2013) used the hierarchical Bayesian approach to update the probabilities applied in a process accident event tree. Their approach was robust to the extent that it could use generic data to estimate the frequency of rare events. The proposed approach could model the existing variability between the various data sources. On the downside, the system was unclear about every likely scenario of a process safety accident and only considered the sequential scenarios of a process safety accident.

Khakzad and colleagues (2015) used a Bayesian network to predict the likelihood of significant process safety accidents using near misses' data. Analysis of information was performed to identify near misses that were considered as most informative. The strengths of this approach are that its implementation is simple and can capture the information that near misses provide. The method may model the dynamic properties of a process accident. However, it is impossible to predetermine or update the accident scenarios. Lee, Kim, and Heo (2017) proposed a dynamic probabilistic approach to assess safety to predict significant process safety accidents using precursor data. For implementation, both ETs and dynamic FTs were adopted. The model can integrate the interactions between the operator's actions and the physical state of a plant. However, it dismissed the likelihood of safety systems failing.

2.8 CHAPTER SUMMARY

The history, context, management, model, and methodologies of process safety are all elaborated upon in this chapter. The explanation is essential to provide an overall view of process safety to address the gap identified in prior studies, highlighted in the subsequent chapter. Chapter Three presents the theoretical review of literature revolving around safety theories and models, safety climate, and process safety. The second significant section of Chapter Three highlights the contemporary literature and its relation to process safety.

CHAPTER 3

RESEARCH FRAMEWORK

3.1 INTRODUCTION

This chapter contains a review of the literature under two significant sections. The first section depicts the theoretical review of literature on safety theories and models, safety climate, and process safety. The second section of this chapter highlights the contemporary literature and its relation to process safety.

3.2 THEORIES RELATED TO PROCESS SAFETY

The historical development of safety theories and models is centuries old. A range of studies (see Swuste et al., 2010; 2014; 2016a; 2016b) have contributed to the literature concerning process safety theories and models. Scholars have depicted the differences between system-dynamic, sequential, and epidemiological theories, as well as safety models. Each category contains theories and safety models that are integral to comprehend process safety and the occurrence of process safety incidents, including triggers, accelerators, and means for containing or mitigating the impacts of such safety events.

Earlier studies have described the history of safety models and theories (see Swuste, Theunissen, Schmitz, Reniers, & Blokland, 2016; Swuste et al., 2020). There are three types of metaphors, models, and theories in this literature: sequential, epidemiological, and system-dynamic. Heinrich (1941) defined an occupational accident process as a sequential series of events caused by human or technical errors. Technical errors associated with exposure to mechanical, electrical or chemical hazards, such as order and cleanliness, missing enclosures of rotating parts of the machine, uneven floors, and unguarded holes and heights, are far out the most dominant causes of accidents (Heinrich, 1941). Next to immediate causes, epidemiological models and theories emphasise latent failures and conditions originating from the organisation and management of production. Turner (1978) was the first to highlight the concept of 'incubation period of major accidents', which refers to a period when weak signals of serious accidents go undetected. The bowtie metaphor (Nielsen, 1971; Johnson, 1973; Wijk, 1977), the Tripod theory (Groeneweg, 1992; Wagenaar et al., 1994), and the Swiss cheese metaphor (Reason, 1997) are instances classified in this group - all are meant to analyse occupational and significant accidents. These metaphors and theories are still sequential in origin and focus on so-called 'frontline operators' errors. Nevertheless, these errors are almost unavoidable in the context of the organisation in which they occur. The models are also known as complex sequential, mainly because several scenarios may lead to accidents.

3.2.1 SYSTEM-DYNAMIC THEORIES AND MODELS

Perrow's (1981) Normal Accident Theory (NAT), the Systems Theoretic Accident Model and Processes (STAMP) (Leveson, 2004), Hollnagel's (2012) Functional Resonance Analysis Method (FRAM), the 'drift to danger' model (Rasmussen, 1997), and the drift into failure model (Dekker, 2011) are categorised into the system-dynamic theories and models. Perrow (1981, 1999) developed and revised the NAT following the 1979 Three-Mile Island accident. Perrow (1981) suggested the system accident or "normal accident" respond to the investigation of the incident and the recommendations, arguing that accidents occur due to multiple failure interactions. Such failures are not necessarily in direct sequence operationally, and the accident incomprehensibility aggravates the occurrence of the accident (Perrow, 1999). Simply put, Perrow viewed system characteristics as the primary accident causes instead of human ones (Grant et al., 2018). Hopkins (2001) contested that the research conducted by Perrow in light of the Three-Mile Island constituted a critical tipping point in studies related to safety science.

3.2.2 THE SWISS CHEESE MODEL

Prescribed by James Reason (1997), the Swiss Cheese Model ranks highly among the theories and paradigms used to analyse system failure occurrence in multiple fields. As Reason (1975, 1976, 1979) probed into psychological error mechanisms, the model development is rooted in psychology. Upon analysing the daily lapses and slips, Reason (1990) developed human error mechanism models and introduced active and latent errors concepts. Reason (1997) asserted that accidents occur because of individual operator errors and the broader systemic organisational factors within the upper organisation levels. Figure 2 illustrates the Swiss Cheese Model (Swuste et al., 2016a).

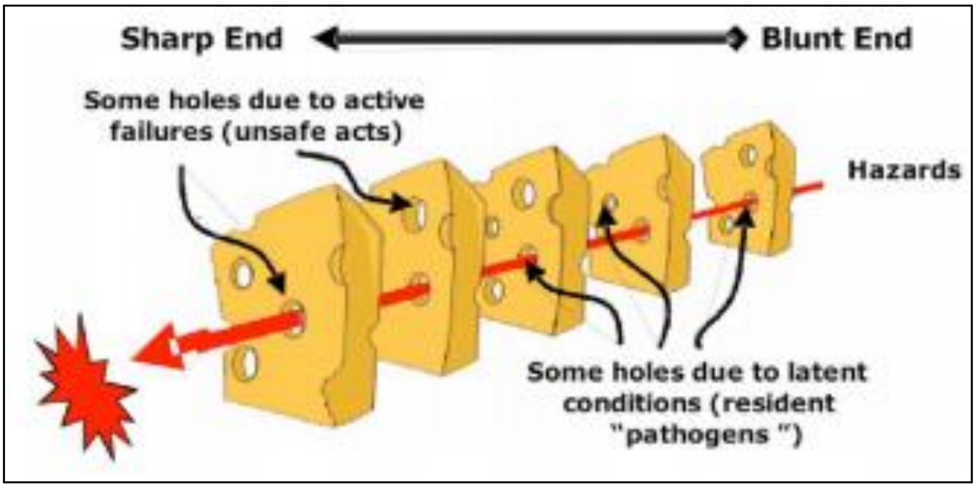


Figure 3. The Swiss Cheese Model

3.2.3 BOWTIE METAPHOR

The bowtie metaphor was developed by synthesising the Event Tree Analysis (ETA) and the Fault Tree Analysis (FTA), which are popular tools in conventional analysis of safety (Lijie, Bo, & Ze, 2017). The ETA displays the relationship between the initial and outcome events and the possibility of computing the potential of the outcome using the model. On the other hand, FTA exhibits the relationship between the basic and top events, besides computing the top event using basic events and Boolean operation probabilities.

Upon combining ETA and FTA, the bowtie model excels in synergising the two safety analysis models (Couronneau & Tripathi, 2003). The model has two parts; event tree (ET) and fault tree (FT), right and left. The FT side denotes events that trigger the accident and are known as unexpected or basic events.

In contrast, the ET side outlines the consequences of accidents and the numerous remedial and mitigation measures. In the bowtie model, the top event constitutes the critical event for connecting the outcome with basic events of accidents. It more readily understands the relationships between accident hazards and their consequences by breaking down essential and outcome events barriers. (Lijie, Bo, & Ze, 2017).

3.2.4 THE TRIPOD MODEL

The Tripod model reflects a joint project by the Dutch University of Leiden and the UK's University of Manchester regarding the oil industry (Wagenaar et al., 1994). The Tripod theory is based on the accident causation model developed by Reason (1997). The rationale behind the Tripod is that failures in an organisation are the principal causation factors for an accident to happen. The model upholds that accidents occur when at least a barrier (defence or control) fails. Meanwhile, operational failures (unsafe acts) are the direct reasons for barrier failures that occur upon generation of any fundamental mechanism that acts within an organisation. The said mechanisms are known as General Failure Types (GFTs).

3.2.5 THE ACTION THEORY

The development of action theory, which is based on the theories of reasoned action (TRA) and social action theory, suggests that there is a need to go beyond simple psychological analyses of individual risk perception and consider broader social, cultural, and environmental explanations of risk behaviour (Weyman & Kelly, 1999). Action theory places human agency and social practices at the centre stage. This option follows a pragmatist and pluralistic position on the emergence and social level (Pieper, Karvonen, & Vaarama, 2019). Action theories have become an essential perspective when introducing and discussing safety issues of sustainability, especially within the context of social policy, responsibility, and accountability. It is also closest to our everyday experiences of a good society. This stance on social practices facilitates mediating between disciplines and empirical approaches to explain human behaviour, apart from integrating ethical standards into social sustainability. Based on the action theory, the approach to safety among managers and supervisors can significantly affect the perception of safety and risk among employees. When management demonstrates a commitment to safety, employees' perception of the safety management system is positively influenced, thus resulting in less risk-taking behaviour and reduced injury rates (O'Toole, 2002). In a related study, Garcia, Boix, and Canosa (2004) found that workers exposed themselves to more risks and were less likely to comply with safety rules when they rated the safety climate of their organisation poorly. Action theory suggests that workers can be desensitised to hazardous tasks and the environment when they repeatedly perform them in a given context.

Interventions directed towards more tenured employees can help others to refocus their attention on safety and use the experiences and skills they have gained over the years (Murphy, Huang, Lee, Robertson, & Jeffries, 2019). Past studies claimed that action theory is used to explain how management can act effectively at the strategic, tactical, and operations level to minimise safety risk and to motivate employees to engage in more safety behaviours, thus leading to fewer accidents (Casey, Neal, & Griffin, 2019; Murphy, Huang, Lee, Robertson, & Jeffries, 2019; Neal & Griffin, 2006). Therefore, action theory postulates that action is more accessible as the behaviour can follow from the attitude (Dejoy et al., 2017).

3.2.6 THEORY OF REASONED ACTION (TRA)

Scholars have used the TRA (Fishbein & Ajzen, 1975) in numerous high-risk industry settings to understand safety management decision making. A fair amount of empirical studies tends to support the conceptual relationships of the TRA in the context of safety management decision making: attitudes and subjective norms regarding the influence of safety environment on behavioural intentions, wherein intentions generally affect decisions. A recent study suggested that TRA offers a valuable foundation to comprehend how pressure from management and immediate supervisors encourage the adoption of safety practices (Guerin & Toland, 2020). This theory suggests attitudes precede behaviours through behavioural intention. The TRA upholds that commitment and approach of the management are required regularly to ensure optimal behaviour from employees.

Further sustainability action of employees demands supporting systems and management structure (DeJoy et al., 2017). Hence, safe behaviour-focused may underestimate the importance of unsafe behaviour, thus creating a blind spot for conduct that is most likely to increase exposure to risk (Hopkins, 2014). The advice from safety culture research - managers have a strong influence on the attitudes and behaviour of workers, wherein a supportive manager is more effective than a behavioural monitor (Cooper, 2000; 2015). It encourages a focus on the last line of defence in incident trajectories (i.e., one’s risk exposure during a specific job task), which is often insufficient in preventing organisational incidents as it fails to address the potential impact of process safety conditions (Reason, 1997; 2000).

3.2.7 SOCIAL ACTION THEORY

The social action theory (Giddens, 1984) has many applications. Still, when it comes to risk, this theory states that people take risks due to peer pressure or the general community perception that an activity is a low risk. Giddens’ theory interprets the general principles among social actors, social structures and institutions, and the processes that mediate between them. Social actors communicate and interact to produce and reproduce social systems—at least three levels of the social dimension (Pieper, Karvonen, & Vaarama, 2019). One may be persuaded to engage in unsafe behaviour if everyone else is doing it or the community perceives unsafe actions. The social action theory states that the social meaning attached to high-risk behaviours can drive and motivate people to engage in them. The propensity towards risk can be affected by co-workers' expectations. Individuals conform to group norms to identify with the group and accept the perceptions and behaviour of the group (Cooper, 2003; Cooper & Finley, 2013). This tendency to conform can have positive outcomes when a workgroup or an organisation has a strong safety culture. For instance, workers who have more positive safety interactions with co-workers through safety conversations and rewards for safe behaviour tend to have more positive perceptions of safety, thus perform work more safely (Choudhry & Fang, 2008; Mullen, 2004). However, the negative consequences of social conformity are equal, if not more prevalent, in studies on risk-taking (Naqvi, Raza, Ybarra, Salehi, & Teodoriu, 2019; Shamim Buang, Anjum, & Khan, 2019). Conformity to the social expectations of peers and the larger community often leads to more, rather than less, risk-taking behaviour.

The four common principles of process safety that the chemical process industries commonly employ are represented by the metaphors, models, and theories presented above. These include active, inherent, procedural, and passive strategies (Hendershot, 2010). Kidam and colleagues (2014) concurred with CCPS (2010), while Amyotte et al. (2009) asserted that the process safety strategies are presented in a hierarchical order. Kletz (2003) discussed this hierarchy in detail. Heikkilä and colleagues (1996) pointed out that procedural, active, and passive schemes of process safety are integrally classifiable as external layers of safety.

Meanwhile, Hendershot (2011) described the inherent process safety strategy as an intrinsic protection layer that eliminates hazards. Amyotte and colleagues (2009) concluded that passive and inherent safety strategies are superior to the others, as these two categories of strategies dismiss continual maintenance. Despite the different classes of process safety strategies, Athar, Mohd Sharif, and Buang (2019) claimed that an ideal and inherently safe process omits additional protection. The view put forward by Sanders (2003) is that it is practically impossible to accomplish ideal safety. Instead, reducing the frequency or severity of accident scenarios is the only practical thing to do. Similarly, Heinrich (1959) explained that the increased focus on inherent safety strategies includes the human factor into process safety to ensure the sustainability of process designs.

3.3 PROCESS SAFETY

Numerous process safety incidents happen when employees undertake no routine tasks and during the emergence of unforeseen events (Dahl & Kongsvik, 2018; Gravina, Cummins, & Austin, 2017; Ramos et al., 2020). Following the Bhopal disaster, there has been a surge in implementing effective process safety in industries to minimise the adversity of incidents compared to previous performances. Before the year 1990, operational activities and processes had been under the guidance of minimal regulations (AlNabhani, Khan, & Yang, 2016). Frequent damages in the facilities and decline in productivity levels (Lundteigen & Rausand, 2007). Consistent with Hunter and Wolf (2016), this study defines process safety to prevent major accidents involving hazardous chemical processes. Unfortunately, these steps were only undertaken after many major process catastrophes characterised by high rates of fatalities and casualties (Theophilus et al., 2017). Since the past three decades, many regulatory requirements regarding PSM have been initiated across the US, Australia, and Europe. Despite this, the current approaches towards risk evaluation within the process safety still lack "systems and thus often still results in a non-comprehensive risk analysis that can overlook, and therefore, cause some catastrophic incidents" (Jain et al., 2018, p. 64). The above discussion is in line with scholars who advocate integrating human factors, and additional contextual factors are likely to influence process safety (Behari, 2019; Hendershot, Herber, & King, 2011; Mearns, 2017; Ostroff, Kinicki, & Muhammad, 2012; Swuste et al., 2020a; 2020b).

It is impossible to investigate and comprehend the underlying theoretical perspective that underpins the various PSM elements (Amyotte & Lupien, 2017). However, these elements have been recognised by different institutional bodies, such as the Canadian Society for Chemical Engineering (CSChE), the Organisational Safety and Health (OSH), and the Energy Institute, as essential elements concerned with process safety regulations and setting of standards. However, recent research contends that other integral elements are yet to be identified but are important for process safety (Ramos et al., 2020; Song & Suh, 2019). Tanjin Amin and colleagues (2019) asserted that although CSChE has comprehensively provided PSE elements with 12 elements and components, human factors and features of human error assessment and the effectiveness of safety training are not given much attention in process safety risk assessment exercises and practices. As a result, a gap is found in studies concerning process safety. The recent studies about the petroleum industry found that audits and corrective actions do not ascertain improvement in fewer errors due to human factors without the effects of employees' knowledge and attitudes, as well as the contributions of safety climate effects on the employees' process safety factors (de Almeida & Vinnem, 2020). Another study in the same industry suggested that knowledge and attitude best execution occurs in a collaborative and learning supportive environment. Consistent with CSChE (2012a, 2012b), PSM elements emphasizing the importance of process safety knowledge enhancement. However, process safety knowledge enhancement is only effective when the top management and the direct supervisory level are committed and practice behaviour that mitigates unsafe behaviour or errors (e.g., bad habits/ wrong skills). Furthermore, they should encourage employees and co-workers to learn from these mistakes (knowledge), as well as encourage them (employees and co-workers) to criticize and challenge the factors that may lead to or set the stage for the occurrence of errors and mistakes (attitude) (Saedi et al., 2020).

Earlier studies have distinguished among the concepts of employee’s safety engagement, employee’s safety performance, and safe working environment for employees based on individual variables in safety-related studies (Aryee & Hsiung, 2016; Mearns et al., 2010; Vinodkumar & Bhasi, 2011). However, the present study departs from the earlier research work by investigating these factors as dimensions of process safety. Consistent with recent studies that reported collaborative environments to minimise the potential threatening effect of human errors, whereby the employees are led to appreciate the goal and the meaning of process safety more positively and constructively (see Amaya-Gómez et al., 2019; Saedi et al., 2020; Swuste et al., 2020). As a result, exemplary top management commitment and practices, as well as the effective role of the supervisor in practising safety, may affect the following: safety climate of both employers and employees via teamwork and spirit of collaboration; safety behaviour of employees via process safety; and both employers and employees' equal perceptions of the plants' general PSM.

3.4 SAFETY CLIMATE

Safety culture and safety climate are interchangeably applied in safety research. The first emergence dates back to the International Nuclear Safety Advisory Group (INSAG) review of the Chernobyl disaster in 1986 (Cooper, 2000). A review by Lee (1995) of the same disaster concluded that the errors and violations of the operational procedures culminating in the explosion were evidence of a poor safety culture. A comprehensive review of the significant characteristics of safety culture in extant academic research and public inquiry outcomes following process safety catastrophes was performed by Cooper (2018), who demonstrated consensus in six traits. The six traits, namely risk, management/supervision, procedures and rules, competence, work pressure, and safety systems, are features in modern safety management systems, such as ANSI-Z10:2012 and OSHA (S) 18001:2007, which have been implemented in numerous countries. In process safety, the risk characteristic of safety culture is composed of three components: risk control, risk assessment, and risk appraisal. Studies concerning Loss of Primary Containment (LOPC) have displayed many failures within each area. It signifies that the risk characteristic of safety culture denotes an underlying weakness within most companies (Cooper, 2018). Stemn and colleagues (2019) adopted a safety culture framework in their study that was embedded with informal and formal risk assessments as indicators to elements of risks and hazards management.

In describing safety climate, Zohar (1980) defined climate as “a summary of molar perceptions that employees share about their work environments” (p. 96). He proposed and tested a safety climate model based on a 40-item questionnaire, which included Israeli factories from various industries. Zohar (1980) deduced seven safety climate dimensions from the literature, namely perceptions of employees concerning the attitudes of management towards safety, perceptions of the impact of safe behaviour on promotion, perceptions of the impact of safe behaviour on social status, perceived safety training effectiveness and importance, perceived workplace risk levels, perceived safety officer’s organisational status, and perceived enforcement effectiveness compared to the guidance offered to promote safety. Upon analysing the data quantitatively, Zohar (1980) discovered that perceptions of employees concerning management attitudes towards safety and perceived safety relevance in overall production processes were the two dimensions that ranked highest in terms of importance. Later on, Zohar (2003) described safety climate as employees' perceptions concerning procedures, practices, and policies in light of safety. As applied in the context of process safety, safety climate borrows from the concept of organisational climate. For its part, organisational climate refers to employees' perceptions towards workplace occurrences and the organisation's expectations about workplace norms, behaviours, and attitudes (Ostroff, Kinicki, & Tamkins, 2003). Based on the definitions of organisational climate and safety climate, Payne et al. (2010) described process safety climate as “employees’ perceptions of policies, procedures, and practices concerning process safety” (p. 807). Safety climate affects process safety either as a lagging or a leading indicator. Safety climate is a lagging process safety indicator when connected to later outcomes, whereas a leading indicator of process safety is linked to previous events (Payne et al., 2009). Since this study looked into the psychological factors of humans and their perceptions of safety at the workplace, safety climate is an integral aspect.

3.5 THE RESEARCH GAPS

Since the beginning of the 21st century, process safety has received global attention due to its link to occupational accidents and injuries (Ramos, Droguett, Mosleh, & Moura, 2020; Song & Suh, 2019). Employers and OHS professionals have a substantial interest in enhancing process safety (Swuste et al., 2020a; 2020b). According to studies, ineffective process safety is linked to adverse mishaps such as explosions, fires, and toxic spills, which cause fatalities, injuries, property destruction, environmental degradation, and production loss (Ramos et al., 2020; Song & Suh, 2019; Swuste et al., 2020a; 2020b).

Organisations bear a significant and long-term financial burden due to these incidents (Amin, Khan, & Amyotte, 2019; Anwar, Mustafa, & Ali, 2019). Swuste and colleagues (2020a; 2020b) urged safety researchers in the 21st century to move from technical and engineering factors to human factors. In line with earlier studies that have focused more on the continuance to move from the individual worker to the broader organisational context, there has been the emphasis on leadership and organisational climate research (Amin et al., 2019; Hendershot, Herber, & King, 2011; Gao, Fan, Li, & Pei, 2019; Mearns, 2017; Ostroff, Kinicki, & Muhammad, 2012; Ramos et al., 2020; Song & Suh, 2019; Zaranezhad, Mahabadi, & Dehghani, 2019). Nonetheless, to improve process safety and mitigate occupational hazards, it is vital to understand the factors that influence process safety.

Safety climate deserves greater attention within the process safety context. Reniers and colleagues (2006) asserted that process plants are becoming difficult to control owing to a sudden increase in the scale and complexity of modern process industries. Thus, the effects on safety climate factors are indeed inevitable (Amin et al., 2019; Gao et al., 2019; Kidam & Hurme, 2012; Song & Suh, 2019). Many theories depict that the impact on safety climate may be problematic in terms of occupational accidents and injuries in general and on safety process in precise (von Wehrden et al., 2012). Studies on the relationship between safety climate factors and process safety and its dimensions are in scarcity. Research on system maintenance and technical issues overshadows that on human factors and management systems issues. Most studies have focused mainly on antecedents, such as safety culture

(Behari, 2019; Swuste et al., 2020a), safety climate (Gao, Fan, Li, & Pei, 2019; Stackhouse & Turner, 2019), and engineering and technical-related issues (Amaya-Gómez et al., 2019; Srinivasan, Srinivasan, Iqbal, Nemet, & Kravanja, 2019). Past studies and meta-analyses tend to conclude that the relationships between safety climate factors and process safety are vague, thus requiring further investigations (Behari, 2019; Hendershot, 2012). The conflicting findings on the relationship between safety climate and process safety have been attributed to various factors. Hunter and Wolf (2016) claimed that some safety climate factors (e.g., supervisor safety behaviour) might be more crucial to process protection than other safety climate factors (e.g., top management commitment to safety and top management safety practices). It has been put forward that safety climate factors might have different effects on the varied dimensions of process safety (Mearns, Hope, Ford, & Tetrick, 2010; Pousette, Larsman, Eklöf, & Törner, 2017; Zaranezhad et al., 2019). The present study adopts the recommendations stated in past studies (see Amin et al., 2019; Gao et al., 2019; Khan et al., 2016; Kidam & Hurme, 2012; Song & Suh, 2019; Swuste, Theunissen, Schmitz, Reniers, & Blokland, 2016) to assess the safety climate factors embedded in process safety.

Poor process safety refers to repeated issues in the process industry worldwide. Despite a substantial body of research on the importance of safety training in developing positive safety attitudes, much of the evidence appears to be subjective (Loosemore & Malouf, 2019). The process safety training indicators have failed to address changes adequately (Webb, 2009). Despite focusing all research on the importance of safety training as an improvement intervention, Bhandari, Hallowell, and Correll (2019) found that the high-risk industry invests less in safety training than many other lower-risk industries, such as retail and catering. While the exact reasons for this relatively low rate of safety training are unclear, studies have pointed out that certain factors, including time and cost pressures on the refinery industry, make safety training a burden, and there is an issue of limited resources to invest in training (Guennoc, Chauvin, & Le Coze, 2019; Martinez, 2016). Despite emphasising the significance of safety training, this aspect has always been absent in many research studies (Fakhru'l-Razi, Iyuke, Hassan, & Aini, 2003; Loosemore & Malouf, 2019). Many studies found safety training as a significant factor in proving safety climate (Dahl & Kongsvik, 2018; Kvalheim & Dahl, 2016; Saedi, Majid, & Isa, 2020), but the association of effective safety training to facilitate the correlation between safety climate and process safety is often not applied at workplace (Loosemore & Malouf, 2019). Although the researchers claimed that safety training might create significant changes in employee safety attitudes, no statistical support had ascertained that safety training intervention significantly affects attitudes and perceptions toward process safety (Saedi, Majid, & Isa, 2020).

This study employs the bibliometric review method to summarise the safety research process and the gaps in this research. The initial search revealed 22,835 sources comprising different article types with research articles being the majority (*n*= 14,440) followed by conference abstracts (*n*= 2,055), book chapters (*n*= 1,793), and review articles (*n*= 1,365) to complete the list of article types with more than 1,000 items. All the items were published between 1996 and 2020. A filter was invoked to select research articles, review articles, book chapters, conference abstracts, case reports, discussion papers, and mini-reviews to bring the total articles reviewed to 19,968, as broken down in Table 1 below and the refinement of research shown in Table 2, and the final refinement research shown in Table 3.

Table 1. Publication types based on the first search string

Article Type	**n**
Research articles	14,440
Conference abstracts	2,055
Book chapters	1,793
Review articles	1,365
Discussion	140
Mini reviews	108
Data articles	34
Case reports	18
Practice guidelines	11
Patent reports	4
Total	19,968

Table 2. Refined documents to include only review-relevant terms

Article Type	**n**
Research articles	14,190
Conference abstracts	1,762
Book chapters	1,793
Review articles	1,350
Discussion	124
Mini reviews	108
Data articles	34
Case reports	18
Practice guidelines	11
Patent reports	4
Total	19,394

Table 3. Final document refinement

Article Type	n	%
Research articles	4,105	69.27%
Book chapters	963	16.25%
Review articles	472	7.96%
Conference abstracts	299	5.05%
Discussion	60	1.01%
Mini reviews	16	0.27%
Case reports	5	0.08%
Practice guidelines	5	0.08%
Data articles	1	0.02%
Total	5,926	100.00%

Documents in the framework/model development category are those that contain information such as process safety analysis, identification of hazards, modelling of process safety and general safety accidents, incidents, or events, and strategies and approaches towards PSM (e.g. Leveson, 2004; Guo, Yiu, & González, 2016; Roe & Schulman, 2018). Documents in the academia-oriented category included those where the focus of researchers is to research and inform academia on matters concerning safety in general and process safety as well. The documents in this category also provide safety theories and metaphors to help understand process safety and safety in both practice and theory in academic institutions (Haukelid, 2008; Waring, 2015; Campione & Famolaro, 2018; Amaya et al., 2019).

The documents in the data sources' category included studies and publications that had the potential to contribute to the validation of models because they present data or information about existing and new databases (e.g., Jacobsson, Sales, & Mushtaq, 2009; Bitar et al., 2018; Anwar, Mustafa, & Ali, 2019). Documents in the safety guidelines and principles included general safety guides and manuals, best practices and approaches for enhancing and regulating safety, process safety, and PSM in general (Kapin, 1999; Majid et al., 2016; Nævestad et al., 2019).

The documents classified under research trends and evidence reviews were mainly literature reviews (e.g., Edwards, Davey, & Armstrong, 2013; Aburumman, Newnam, & Fildes, 2019; Behzadifar et al., 2019). Documents in the category of discussions (e.g., Prugh, 1992; Rollenhagen, 2010; Zwetsloot et al., 2013) were mainly commentaries, debates, and expert opinions expressed by industry practitioners and researchers in the field of safety on how to prevent, reduce, or eliminate safety incidents and accidents. Such discussion documents are platforms through which safety experts, practitioners, and actors express their views for improving safety, PSM, and organisational safety.

Besides the categorization by publication type and document focus, the 5,926 documents were further categorized based on publication type and year of publication. Generally, if we look at Fig.4, there was a notable growth trend in the number of publications, especially from 2003 when the documents first exceed 100. An incremental trend of publications signals growing interest by researchers and practitioners in safety and safety management, including process safety.

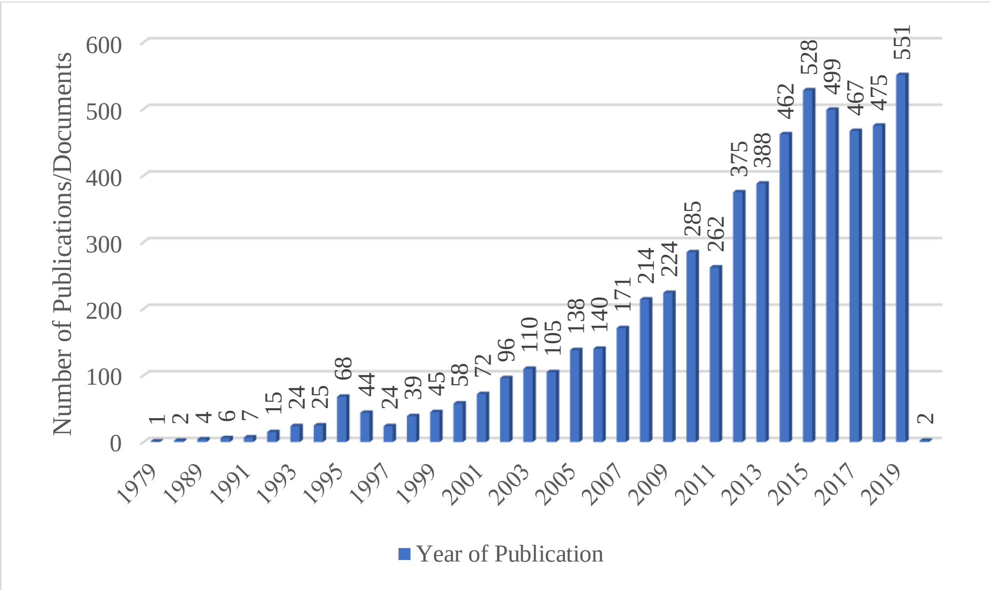


Figure 4. Number of publications/documents by year

The oldest publication (Trauboth & Frey, 1979) was a conference paper that presented "a framework of guidelines for safety management of computerized automation systems" (p. 41). Design and performance of systems and plants were the focus of most documents published between 1979 and 1990 (e.g., Sten et al., 1988; Palmgren, 1988, 1989; Pikaar, Braithwaite & Cox, 1990). Most documents published between 1991 and 2000 were mainly about interrogating, setting and maintaining safety standards, safety regulation, reviewing previous safety incidents, and developing a new PSM approach. There was also a notable emphasis on drawing lessons from landmark safety disasters such as Chernobyl and Bhopal. For example, Kharband and Stallworthy (1991) focused on the 1984 Bhopal disaster to investigate the potential of self-regulation in ensuring process safety incidents are avoided.

Similarly, Shrivastava (1994) used the Exxon Valdez and Bhopal safety disasters to explore the "implications for managing hazardous waste" (p. 237). Most articles were published between 1991 and 2000, and they introduced models and systems for ensuring better safety management, including mitigation of accident impacts. For example, Gillespie (1995) focused on the obsoletion of conventional procedures for plant information management by the demands for EPA and OSHA requirements and came up with a methodology to help practitioners to plan, cost-justify, and implement a contemporary Electronic Document Management System (EDMS) that covers the entire plant. Fthenakis and Blewitt (1995) used mathematical modelling to aid in the investigation and documentation of installing systems that would aid in the detecting, containing, and mitigating accidental releases, focusing on water-spray mitigation systems. In their book chapter, Cheremisinoff and Graffia (1995) provided information about process hazard analysis (PHA). Documents published in later years within the decade (e.g., Ostrom et al., 1996; Hendershot, 1997; Bickel & Sidaras, 1998; Specter, 1999; Kirwan, 2000) continued to contribute toward better safety management and PSM using the lesson-based approach and review of extant evidence from industry-based accidents and incidents.

The publication trend began changing in 2001 with a shift from focusing on systems and machines to including human factors in understanding and enhancing safety management and building safety cultures. There were three main sub-categories of publication trends that emerged from the focus of the documents published between 2001 and 2010.

The first sub-category included documents whose primary focus was on the role of organisational leaders such as engineers, managers and supervisors in the provision of safety leadership and steering of the establishment of safety practices and safety culture (Tweeddale, 2001; Fung et al., 2005; Lardner & Scaife, 2006; Grote, 2007; Verbano & Turra, 2010).

The second subcategory of documents dealt with employee and safety practitioners perceptions of safety precautions worldwide (Hughes & Kornowa-Weichel, 2004; Tharaldsen, Olsen, & Rundmo, 2008; Lin et al., 2008; Lu & Tsai, 2010).

The third subcategory of publications concentrated on organisational-wide approaches to improving safety culture and safety management, such as the creation of learning cultures (Holbeche, 2009; Saw, Wilday, & Harte, 2010), organisational management and practices (Strutt et al., 2006; Geldart et al., 2010), loss prevention (Chen et al., 2010), risk reduction and management (Vinnem, 2010; van Beuzekom et al., 2010), and resource management (Prem, Ng, & Mannan, 2010) approaches.

2011 and 2020 recorded the highest number of documents at 4,298, about 89.39% of all the documents extracted for this bibliometric review. A similar bulging trend in the count of documents by article type was registered for review articles, book chapters, conference abstracts, discussions, and mini-reviews. Notably, all practice guidelines (*n*= 5) included in this review were published in the current decade. On the other hand, most of the documents published in the recent decade were mainly research articles (*n*= 2,981) and constituted approximately 72.61% of all research articles extracted in this research review. The documents published within the decade demonstrated a trend towards introducing advanced methodological approaches for developing and testing complex safety systems. For example, an emergence of studies about fuzzy expert systems to understand safety performance (Tang, Dawal, & Olugu, 2018), fuzzy logic approaches for identification of representative accident scenarios (Markowski & Siuta, 2018), and fuzzy evaluation for digital simulation to promote safe behaviour (Li et al., 2018) was observed. Fig. 5 below is an illustrated summary of the publication trends.

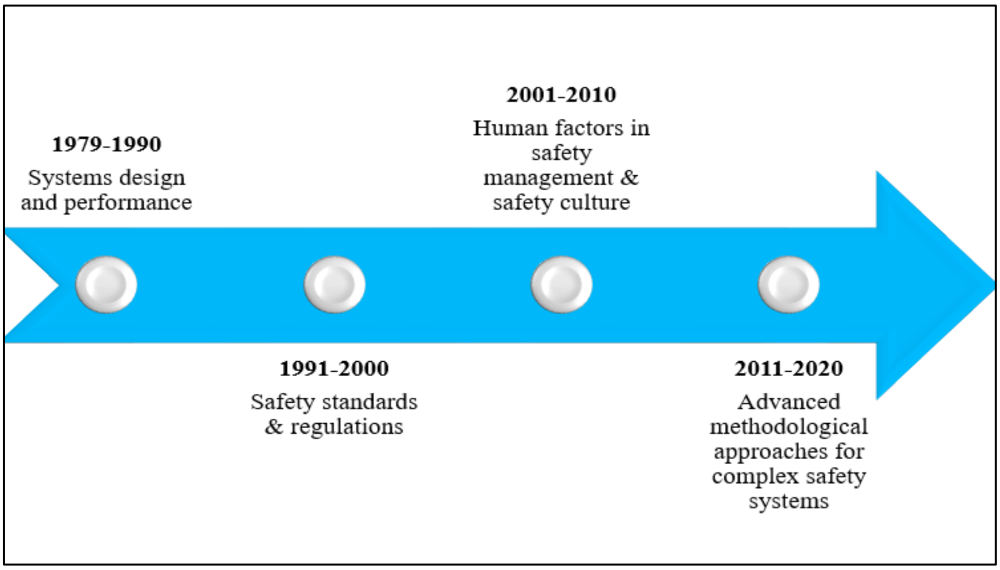


Figure 5. An illustrated summary of the Publication Trends (1979-2020)

Furthermore, to determine the principal areas of focus, VOSviewer was used. A map was created in VOSviewer based on text data since this option enables creating a co-occurrence map based on terms deduced from the text citation data. Terms were extracted from both title and abstract fields while ignoring copyright statements and structured abstract labels. Fig.6 below shows density visualization of keyword occurrence of process safety.

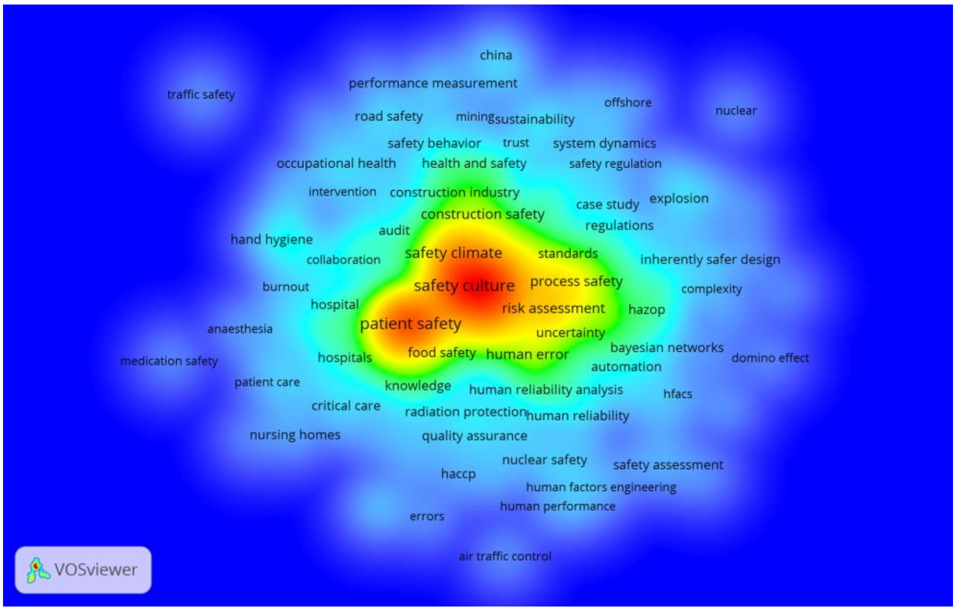


Figure 6. Density visualization of occurrence of Process Safety

The citation data was also analyzed in VOSviewer to show the most commonly used tools and approaches in safety analysis and process safety based on occurrence scores and the density visualization map shown in Fig. 7 below.

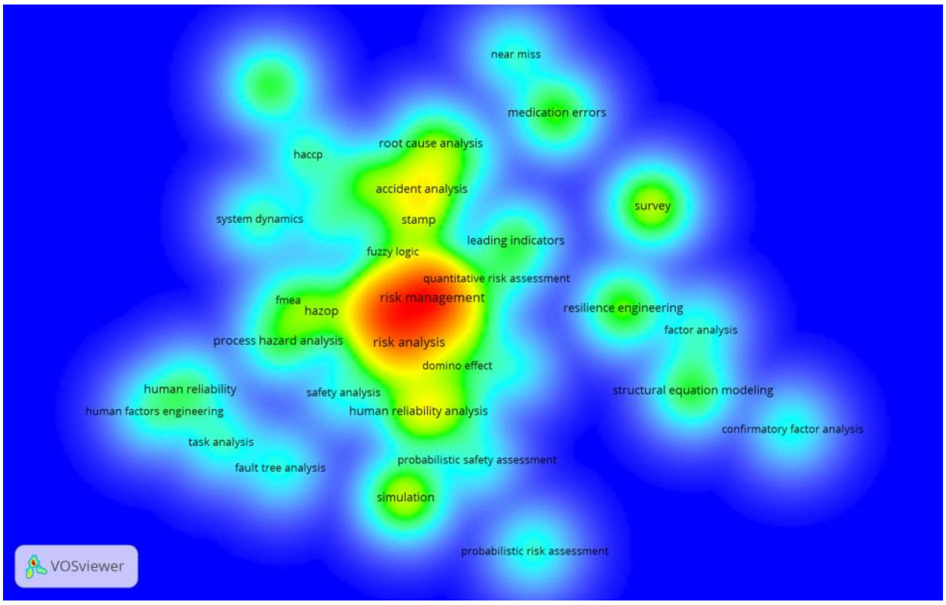


Figure 7. Density map illustrating the most commonly used tools in risk.

The preceding discussion is consistent with scholars who argue that incorporating human factors and other contextual factors is likely to influence process safety (Behari, 2019; Hendershot, Herber, & King, 2011; Mearns, 2017; Ostroff, Kinicki, & Muhammad, 2012; Swuste et al., 2020a; 2020b). This present study provides empirical evidence to support the notion that employees' perceptions of safety climate reflect the necessity to include safety training intervention, apart from reckoning the importance of addressing employees' participation to create an effective process safety system. Investigating these relationships, which are integrated into a more extensive system of variables with a multilevel approach, can aid one to understand the mechanisms that influence human factors of process safety, which influence behaviour at work to affect health and safety. Therefore, it is essential to identify the organisational instruments that may address the human factors of process safety, besides understanding the factors that may affect process safety and further improving process safety. This present study assessed the influence of safety training perceptions among employees in ADNOC Refinery on safety climate factors and process safety.

3.6 HYPOTHESES DEVELOPMENT

This section highlights the gap and lists predictions based on the phenomenon justified and supported by the empirical findings from related studies.

3.6.1 PROCESS SAFETY

It is critical to focus on processes to improve workplace safety in modern industries. Nevertheless, progress in process safety research has been slow, owing to the inconsistent definition of "process safety." Hunter and Wolf (2016) described process safety as preventing major accidents that involve hazardous chemical processes. This description is consistent with Hendershot (2012) prescribed, who suggested that process safety concerns control the risk of failures and errors caused by humans. Earlier safety studies have distinguished the concepts of employees' safety engagement, employees' safety performance, and a safe working environment for employees based on individual variables (Aryee & Hsiung, 2016; Mearns et al., 2010). The present study, however, departs from earlier research work by acknowledging the concepts of employees' safety engagement, employees' safety performance, and safe working environment for employees as human factors that may affect process safety (Engemenn & Scott, in press; Hendershot, 2012; Huang et al., 2016; Prussia, Willis, & Rao, 2019; Wachter & Yorio, 2014). In precise, this study assessed process safety as a higher-order construct. They comprise three dimensions: employees' safety engagement, employees' safety performance, and a safe working environment. Employees' safety engagement refers to employees expressing concern regarding health and safety hazards (e.g., provision of personal protective equipment, PPE, safety glasses, and fall protection harnesses) (Cooper, 2015). Employees' safety performance is safety-related behaviour at work (e.g., wearing PPE and encouraging coworkers to wear PPE) (Neal & Griffin, 2006). Meanwhile, a safe working environment denotes working conditions that do not harm employees but protect their well-being (e.g., routine health-care check-ups and PPE tests & inspections) (Sieberhagen, Rothmann, & Pienaar, 2009).

Gao and colleagues (2019) found that safety management practices positively impacted process safety across Chinese process industries. They went on to say that while previous studies had theoretically and conceptually assessed the relationships between safety management practices and process safety, nothing had been developed thus far. Therefore, the unknown correlations between these variables had created barriers to process safety. This gap emphasizes the importance of linking safety management practices to process safety, which is required to prevent mishaps in organisations with complex technological systems. A total of 405 participants from the oil industry in Shandong province participated in the study. Four safety management practices, namely organising responsibilities/procedures, communication and coordination, safety training, and inspection and monitoring, positively affected process safety, with assessment and tracking the highest effect.

Liaw (2019), who studied process safety, provided the fundamental information necessary for developing PSM elements. The study reported management deficiencies found in PSM audits across more than 70 plants in China. The deficiencies found were frequently encountered in the management of the process safety element. The study asserted that the chemical hazards information provided was inadequate and inappropriate to measure human errors in mitigating mishaps. The study highlighted the importance of top management and supervisory levels as a significant factor in chemical hazards in developing effective strategies to ensure process safety. The study evidenced that process incidents resulting from undesired reactions were more frequent than from desired responses. Therefore, the process chemistry of undesired responses is essential for efficient process technology in terms of safety.

Human factors have a considerable role in creating and optimising process safety for offshore drilling and controlling the related operations by assessing and mitigating human errors (Naqvi, Raza, Ybarra, Salehi, & Teodoriu, 2019). The current industry practice relies on simulation-based training for its drilling crews, lacking technical skills and measuring and evaluating human factors. They suggested the critical role of an individual's performance and non-technical skills, but no psychological tool has been validated for offshore drilling operations. The study applied content analysis and process tracing techniques to identify psychological processes via communication. It was found that simulation-approach can substantially improve human factors in drilling and effectively control activities. The research outcomes highlighted the significance of content analysis as a tool that enhances evaluation performance and optimises process safety.

A case study conducted by Behari (2019) revealed that a process safety maturity assessment is integral to measure the human factors linked with man-machine, employee job roles, and organisational culture interfaces. Numerous global process safety with catastrophic outcomes were caused by human factors, prompting investigations into underlying human and organisational behaviours to manage key process safety risks. They found that leadership behaviour is the main reason that can hinder process safety maturity, including an unwillingness to accept accountability, employee blame, fear, and lack of trust, which had been associated with inadequate process safety incident reporting and organisational learning. The human factor risks identified from the case study were commitment towards continuous improvement; incident reporting effectiveness. Examining interdependent team leadership behaviour via process safety balance scorecard metrics will update operating procedures, the competence of critical staff, and ineffective safety communication that can lead to process safety incidents.

Anwar and colleagues (2019) asserted that understanding the execution and practice of process safety is critical due to limited data access, lack of incident and near-miss reporting & recording, and lack of understanding and implementation of PSM in the global industries. A qualitative study via an interview with petroleum refining sector veterans in Pakistan revealed the absence of local process safety regulations, lack of process safety awareness, inadequate leadership commitment, lack of implementation of a dedicated process safety system, ineffective near-miss and incident reporting, as well as database maintaining policy as the main causes of the most prone-to-incident process industries globally.

A study conducted in Malaysia by Shamim, Buang, Anjum, and Khan (2019) found that safety performance has become a focal spot for forthcoming studies, mainly because PSM has ignored the insight behaviour of performance indicators and their associated metrics. Thus, it is imperative to develop the metrics for PSM elements. Their study evaluated emergency planning and response (EPR) performance, which appeared as an essential element of the PSM standard. Although this element is not a contributing factor to disasters, the study contended that it is more likely to be accepted as mitigation and controlling technique. The tested model on a major accident case study in the process industry revealed that poor performing metrics could lead to accident-prone cases in process industries. They suggest that the empirical findings reported in the study support sustainable safety performance.

Halim and Mannan (2018) conducted a systematic literature review. They reported that exceptional process safety could reduce the probability of chemical incidents, mitigate the consequences of incidents when they occur, and provide adequate emergency response, thus contributing to sustainability, quality, and improved productivity. The review revealed that process safety incidents are linked to internal organisational issues and commitment and practices from the company's highest levels of leadership. The organisational factors start from the importance of appropriate top management practices through appropriate regulations and how they are committed to implementing these regulations by setting and enforcing strict operational discipline, ensuring the competency of all employees, and executing the learnings from past incidents to enhance process safety performance.

Swuste, Theunissen, Schmitz, Reniers, and Blokland (2016) asserted that indicators for process safety could provide insight into the safety levels of a process in an organisation. The literature review highlighted that the safety indicator for management and organisation has a vague correlation with human errors and conditions in process safety, thus reconsidering safety analyses of significant accidents. They revealed that indicators for occupational safety do not necessarily correlate with process safety. Regulators of major hazard companies are required to identify and implement both lagging and leading indicators and anchor these indicators in a safe climate.

The preceding studies highlight the skewed relationship between safety climate and process safety across cultures. Scholars recommend that future research look into the leading and lagging human factors of process safety (see Naqvi et al., 2019; Swuste et al., 2016). Studies have reported that insight behaviour of performance and human factors encourage examining underlying human and organisational behaviour to manage key process safety risks.

Previous studies examined process safety indicators related to employees' psychological conditions, including employee performance, working environment, and employee engagement on safety. These indicators are consistent with PSM elements defined by CSChE (2012a, 2012b) that human factors are the essential process safety indicator. Although more studies have assessed process safety and its indicators since the past decade, none has been conducted in the Gulf Countries Cooperation (GCC) and the UAE. Gao (2019), Naqvi and colleagues (2019) contended that psychological and human indicators of process safety are crucial to a practical process safety and safety performance evaluation – through optimisation of human factors. These findings shed light on the opportunities and threats related to process safety that has been overlooked in safety research. Table 4 summarizes the Process Safety studies around the world.

Table 4. The Summary of Process Safety studies around the world

Authors/Year	**Country**	**Method & Analysis**	**Process Safety Indicators**
Gao et al. (2019)	China	The survey, N = 405 employees of process industries	Four safety management practices: organising responsibilities/procedures, communication and coordination, safety training, and inspection and monitoring
Liaw (2019)	China	Audit data, N = 70 plants in China	Chemical hazards information is insufficient and may be inapt to measure the

			human error in mitigating the risk of incidents
Naqvi, Raza, Ybarra, Salehi, and Teodoriu (2019)	Pakistan	Simulation and content analysis in offshore drilling operation, $N = 4$ drillers (two experts and two novices)	Lack of measurement and evaluation of human factors and non-technical skills
Behari (2019)	Canada	A case study in speciality gas operation Canada	Operating procedures, the competence of critical staff, and ineffective safety communication
Anwar et al. (2019)	Pakistan	Interview, $N = 15$ petroleum refining sector veterans	Limited data access, lack of incident and near-miss reporting & recording trends, as well as lack of understanding and implementation of process safety
Shamim, Buang, Anjum, and Khan (2019)	Malaysia	Case study	Evaluation of the performance of emergency planning and response (EPR)
Halim and Mannan (2018)		Systematic review	Ensuring competency of all employees, as well as implementing the learnings from past incidents
Swuste, Theunissen, Schmitz, Reniers, and Blokland (2016)	Norway	Systematic review	Safety indicators for management and organisation have an unclear relationship with human errors and conditions in process safety. The identification and implementation of both

	lagging and leading indicators

3.6.2 SAFETY CLIMATE AND PROCESS SAFETY

This present study adopted the action theory to understand why safety climate and process safety are causally related. Action theory suggests that objective situational factors, such as management commitment to safety, management safety practices, and supervisory safety behaviour, are social actions that must be embedded within the systems of action orientation at the organisation level (Griffin & Neal, 2000). For example, if an employee thinks that the top management is not committed to protecting their wellbeing at the workplace, this could lead to process safety failure. This theory upholds that safety climate is an emergent model due to its complex reciprocal interactions and relationships with safety based on how safety climate factors influence action (Dekker, Cilliers, & Hofmeyr, 2011). While some studies support the action theory's suggestion about the relationship between safety climate factors and process safety (Kiani & Khodabakhsh, 2013; Kouabenan, Ngueutsa, & Mbaye, 2015), there are inconsistent results (Flin, 2007, p. 91). These inconsistencies have led to a growing recognition that the role of management in the context of safety climate differs from that in the relationship with process safety (Oah, Na, & Moon, 2017). Other researchers have regarded different multilevel management roles that may have robust relationships with process safety. On the contrary, the general management role offers ambiguous results concerning safety climate and process safety relationship.

Several safety climate scales or measurements have been developed within the O&G industry across the world. Safety climate tools have been developed since the early 1990s across different countries. Flin and colleagues (1998) used the Offshore Safety Questionnaire to assess organisational and human factors that affected the safety of 10 offshore installations. The questionnaire was completed by 722 offshore workers in the UK, comprised scales that measured safety attitudes, satisfaction with the existing safety measures, job communication, work pressure, safety behaviour, work pressure, and risk perception. The study's underlying characteristics of measuring safety climate were feelings of safety concerning various offshore hazards and expressions of satisfaction with existing safety measures. Despite the evidence of various safety subcultures based on occupation, seniority, age, previous involvement in accidents, and shift work; the findings showed general satisfaction with the existing safety measures and negligible risk-taking behaviour, thus “indicating a lack of a positive, concerted ‘safety culture’ (Flin et al., 1998, p. 238).

A cross-sectional survey conducted by Bjerkan (2010) in the Norwegian offshore O&G industry involved 9,945 employees examining the work environment's correlation with health and safety. The 152-item questionnaire was composed of 40 subsections under six significant sections. A total of 46 items measured work safety climate perception, whereas nine items assessed risk perception. Psychometrically, six items from the dimension construction were dropped, while five dimensions of safety climate and risk based on the review work of Flin and colleagues (2000) were merged. These safety climate dimensions included competence, work pressure, management, risk, and safety system. The results displayed the need to consider the work group when evaluating the work environment and work safety climate on accident frequency and subjective health status (Bjerkan, 2010).

Khdair, Shamsudin, and Subramanim (2011) reviewed empirical literature about safety performance based on leadership behaviour and management practices and their impacts on safety performance in the Iraqi O&G industry. Based on their review, the identified safety performance factors, management safety practices factors, and leadership behaviour emerged as the main categorical dimensions of safety performance. The safety performance factors included human, behavioural, economic, psychological, organisational, individual-level, individual and social, and environmental factors. As exemplified in management safety culture practices, management safety performance practices included training, reward, and management commitment. The leadership safety performance behaviour was reviewed in leadership forms, such as transformation leadership and traits about general organisational leadership. In the end, the proposed and validated framework only included management practices and leadership behaviour as the influential factors of safety performance and its dimensions (Khdair, Shamsudin, & Subramanim, 2011).

Vongvitayapirom and Phusavat (2013) created a safety culture questionnaire to assess the attitudes and perceptions of workers in Thailand's oil and gas industry. The 20-item questionnaire, administered to 2,251 respondents, had been based on the International Association of Oil and Gas Producers (OGP) report No. 435 and Shell company's best practices. It covered seven dimensions: audit and review, monitoring and measurement, leadership and commitment, organisation resources and documentation, implementation and operational control, policy and strategic objective, and evaluation and risk management. The gathered data were analysed through simple descriptive mean rankings and expert opinion. The results showed that the commitment of top management to safety through leadership and commitment attribute emerged as the essential dimension, followed by policy and strategic objective, as well as organisational resources and documentation (Vongvitayapirom & Phusavat, 2013).

Musa and colleagues (2015) looked into the levels of Safety, Health, and Environment (SHE) perceptions and the corresponding values among employees of an O&G company located in Indonesia. They developed a safety climate survey to measure safety values at the individual, working unit, and organisation levels. They identified seven safety climate variables distributed across the three safety climate dimensions. In total, 436 workers from employee to top management levels completed the questionnaire. The findings revealed that overall SHE perception was moderate, as were safety values at the organisational, group, and individual levels. It was inferred that the HSE perceptions among the workers required improvement by strengthening the implementation of the Safety, Health, and Environmental Management System (SHEMS), individual skill improvement, regular and intense two-way communication, and the development of safety competencies (Musa et al., 2015).

Kvalheim, Antonsen, and Haugen (2016) examined the ability of safety climate tools to assess the plant-level risk of major accidents from the stance of decision-makers. They used secondary questionnaire data gathered from the Petroleum Safety Authority (PSA) Trends in Risk Level Project biennial safety climate questionnaire data from 2001 and the Norwegian Offshore risk and safety climate inventory (NORSCI) survey data. The total sample comprised 51,803 employees from the Norwegian O&G industry, focusing on three major safety incidents. Five safety climate dimensions were interrogated, including safety prioritisation, safety management worker involvement, safety versus production conflict, individual motivation, and system comprehension. Quantitative data analysis was conducted using Principal Component Analysis (PCA) and independent samples t-tests via Statistical Package for Social Sciences (SPSS). The results were inconclusive, with no significant evidence of deviation from the average industry installations (Kvalheim, Antonsen, & Haugen, 2016).

A study by Kvalheim and Dahl (2016) in the Norwegian O&G industry performed multiple tests to assess the causal relationship between safety compliance and safety climate. Using data obtained from a biennial cross-sectional survey administered by Norway's PSA for seven years, the researchers gathered data from 31,350 employees who undertook safety-critical tasks typically within hazardous working environments, such as crane operators, maintenance personnel, roughnecks, and derrick men. Using exploratory factor analysis (EFA) and Cronbach's alpha for validity check, they identified safety system, supervision, work pressure, and safety competence as the four dimensions of safety climate. The results from the hierarchical regression showed that all four factors had high predictive validity in safety climate prediction within the petroleum sector (Kvalheim & Dahl, 2016).

In the UAE O&G industry, Kashwani and Nielsen (2017) examined implementing a safety engineering system using a risk assessment tool. They combined quantitative and qualitative methods. A five-item questionnaire was formulated to assess employee knowledge on the risk assessment tools, employee development, risk assessment procedural features, organisational commitment to safety, and technical safety. The questionnaire was administered to 350 employees. Z score tests were performed to verify the statistical significance of the items and the safety culture level. The findings revealed that both employees and management lacked knowledge of risk assessment tools and that quality employee training was required (Kashwani & Nielsen, 2017).

A Ghanaian upstream O&G sector was studied by Horbah, Pathirage, and Kulatunga (2017) to assess the predictive influences of safety climate on significant accident risks. They created and distributed to 212 respondents a safety climate questionnaire containing 60 items derived from the literature and classified into 14 safety climate dimensions. Safety policies, safety behaviour, safety motivation, safety priority, safety empowerment, safety training, supportive environment, management commitment, safety supervision, safety rules and procedures, safety involvement, change management, equipment maintenance, and safety communication were among the 14 constructs. The collected data were analysed in SPSS, along with Cronbach's alpha, Pearson correlation tests, EFA, and multiple regression statistics, which unravelled four factors, namely management commitment, safety supervision, safety empowerment, and management of change, as the final safety climate dimensions (Horbah, Pathirage, & Kulatunga, 2017).

Dahl and Kongsvik (2018) investigated the relationship between mindful safety practices as a component of safety behaviour and safety climate. They employed data from the PSA biannual cross-sectional survey of employees within the O&G industry in Norway, along with the combination of other data types, such as exposure, accident, and near-miss data, to assess HSE conditions. The final sample comprised 5,712 workers and a 19-item questionnaire. Work pressure emerged as a negative predictor of mindful safety practices, whereas safety leadership, competence, and safety system were identified as positive predictors. Safety leadership was the most influential of the four factors (Dahl & Kongsvik, 2018). Notably, these safety climate factors were extracted from Flin and colleagues (2000).

Ho, Dawal, and Dawal (2018) examined the possible usage of a set of safety factors to evaluate performance and reporting on the Malaysian offshore O&G sector. Hence, a framework was used to assess the safety performance and to study the correlations between the performances of lagging and leading safety factors. They developed the indicators based on a literature review, whereby a 63-item questionnaire with 14 safety indicators drawn from Tang and colleagues (2017) was completed by 172 industrial practitioners. Quantitative and statistical analyses were employed to test the framework. The traffic light system of numbering was applied to score the indicators, in which the safety scores of 10 Malaysian oil platforms were computed. The 14 safety indicators were inspection and maintenance, start-ups and shutdown, emergency management, number of near-misses and incidents, documentation, personal safety, plant design, management and work engagement, management of change, contractors' safety, instrumentation and alarm, hazard identification and risk assessment, competence, as well as operation and operating procedures. Framework validation was carried out against the status reports on the groups of safety-critical elements in two offshore oil platforms. As a result, all 14 factors appeared to be crucial safety elements in offshore platforms in Malaysia (Ho, Dawal, & Dawal, 2018). Table 2 presents the meta-data of safety climate scales in the O&G industry across the world.

Saedi and colleagues (2020) conducted a study on the west coast of peninsular Malaysia by using a validated and tested measurement of safety climate developed by Cox and Cheyne (2000), Mearns, Whitaker, and Flin (2003), and Vinodkumar and Bhasi (2011). The safety climate dimensions were management commitment, safety communication, safety rules, workers involvement, safety promotion policies, work environment, safety priority, management compliance, and safety training. The respondents were safety officers, supervisors, and employees in operation lines, administrators, and general workers with 111 valid answers. As a result, all the dimensions of safety climate impacted safety participation, while safety attitudes and safety knowledge mediated the correlations. This study prescribed that future research should examine the effect of safety training on the relationship between safety climate and safety behaviour, mainly because the study found that safety climate factors had more effect on safety knowledge and attitudes. The effect of safety training sheds light on how cognitive levels can be affected by safety climate, thus influencing the human factors of process safety.

The studies highlighted the ongoing importance of safety climate research in the O&G industry. The safety climate measurement depicted in the above studies revolved around Flin's studies (1998; 2000). Among the dimensions of safety climate measured by these studies were top management safety commitment, management safety practices, and supervisor safety behaviour, which emerged as the major factors. Despite increasing studies in this area from 2000, they mainly focused on outside the GCC and the UAE. There is a gap in safety climate research in the UAE, especially in the oil refinery industry - an essential segment of the O&G industry. Dov (2008) asserted that most studies had only focused on measurement and application in safety climate for over three decades, thus the need for an extension on the multi-level framework of safety climate that has been overlooked in safety research. Table 5 summarises the safety climate studies in the O&G industry around the world. Based on these arguments, the following hypotheses are formulated:

Hypothesis 1: Safety climate has a significantly positive impact on process safety in the ADNOC refinery context.

Hypothesis 2: Top management commitment significantly impacts process safety in the ADNOC refinery context.

Hypothesis 3: Top management safety practices significantly impact process safety in the ADNOC refinery context.

Hypothesis 4: Supervisory safety behaviour significantly impacts process safety in the ADNOC refinery context.

Table 5. Summary of Global Safety Climate Studies in the Oil and Gas Industry

Authors/Year	Country	Method & Analysis	Safety Climate Dimensions
Flin et al. (1998)	UK	A survey, *N*= 722 offshore workers	Safety attitudes, satisfaction with existing safety measures, job communication, work pressure, safety behaviour, work pressure, and risk perception
Bjerkan (2010)	Norway	A survey, *N*= 9,945 offshore employees	Competence, work pressure, management, risk, and safety system
Khdair, Shamsudin, and Subramanim (2011)	Iraq	Literature review	Management practices, leadership behaviour

Vongvitayapirom and Phusavat (2013)	Thailand	A survey, *N*= 2,251 employees	Audit and review, monitoring and measurement, leadership and commitment, organisation resources and documentation, implementation and operational control, policy and strategic objective, and evaluation and risk management
Musa et al. (2015)	Indonesia	A survey, *N*= 436 employees	Individual-level, group-level, and organisation-level safety values
Kvalheim, Antonsen, and Haugen (2016)	Norway	A survey, *N*= 51,803	Safety prioritisation, safety management worker involvement, safety versus production conflict, individual motivation, and system comprehension
Kvalheim and Dahl (2016)	Norway	Meta-analysis, *N*= 51,803 employees	Safety system, safety supervision, work pressure, and safety competence
Kashwani and Nielsen (2017)	UAE	Survey, *N*= 350	Level of employee knowledge on risk assessment tools, employee development, risk assessment procedural features, organisational commitment to safety, and technical safety
Horbah, Pathirage, and Kulatunga (2017)	Ghana	Survey, *N*= 212 employees	Management commitment, safety supervision, safety empowerment, and management of change

Dahl and Kongsvik (2018)	Norway	Meta-analysis, N= 5,712 employees	Safety leadership, work pressure, safety competence, and safety system
Ho, Dawal, and Dawal (2018)	Malaysia	Survey, N = 172 employees and interview, N = 30 experts review, secondary data	Inspection and maintenance, start-ups and shutdown, emergency management, number of near-misses and incidents, documentation, personal safety, plant design, management and work engagement, management of change, contractors' safety, instrumentation and alarm, hazard identification and risk assessment, competence, and operation procedures
Saedi et al. (2020)	Malaysia	Survey, N = 111 employees	Management commitment, safety communication, safety rules, workers involvement, safety promotion policies, work environment, safety priority, and management compliance on training and safety training

3.6.3 PLAUSIBLE MODERATING ROLE OF SAFETY TRAINING ON THE RELATIONSHIP BETWEEN SAFETY CLIMATE AND PROCESS SAFETY

Saedi and colleagues (2020) worked on 111 participants from two refinery industries located on the west coast of peninsular Malaysia. They found that regular safety training with the management's specific observation helped the employees enhance their safety knowledge, which improved their attitude towards process safety. The study displayed that continuous improvement of syllabus, curriculum and content of safety training had made a difference in training perception among the employees, thus exerting a substantial effect on the employees' safety process in the two refineries.

In the context of China, Gao and colleagues (2019) studied 405 respondents from the oil industry and process industries. They discovered that the role of safety management practices on process safety was insufficient to mitigate risks. Future research can determine the moderating effect of safety training on the relationship between safety management practices and process safety.

Naqvi and colleagues (2019) reported that cognitive processes (e.g., working memory, long-term memory, and metacognition) used during safety training are essential to assess the non-technical skills of drillers due to the effects of psychological processes process safety. The problem-solving methods used between novice and expert drillers differed and affected the optimisation of human factors in process safety.

Butler, Bodnar, Cooper, Burkey, and Anastasio (2019) argued that despite process safety and ethical decision-making being recognized as priorities in many chemical companies, process safety incidents continued to occur with unfortunate regularity. As a result, it is critical to investigate employees' decision-making habits in chemical companies and better understand the differences between the influences of ethics and behavioural ethics in process safety decision-making. The cognitive knowledge from safety training can affect ethical attitudes and behaviour, thus driving ethical decision making in process safety. Comparison of safety training perceptions is essential to classify high and low ethical decision making in process safety.

Zhang, He, and Mitri (2019) tested and using virtual reality (VR) training to measure process safety in the mining sector. The outcomes revealed that undergraduate and postgraduate personal situations, physical and psychological conditions moderated the evaluation of safety climate as essential planning resources on process safety system components.

Iqbal, Waheed, Haider, Tesfamariam, and Sadiq (2019) investigated the safety of O&G pipelines of 17 upstream O&G pipeline-operating companies in the province of British Columbia, Canada. They discovered an increasing concern for the public, government regulators, and the industry on the role of safety training to create a safe climate and process safety effectively. The measurement of views, beliefs, and traditions about safety via safety climate was a daunting task with indistinct findings related to process safety. Safety training and competency moderated the link between safety climate and process safety in O&G companies. This framework distinctively affected the probability of failure in non-compliance with regulatory and program requirements, the severity of non-compliance, and the effectiveness of corrective actions, thus remarking improvement in process safety.

These studies have proven the fragmented findings from earlier research and suggest that safety training variability measure the correlation between safety climate and process safety; warrants future research. Employee engagement and participation in process safety are required as part of safety training levels, in addition to creating a safe working environment through their safety, cognitive, and psychological needs at the workplace (Swuste et al., 2020). Given that the organisations' process safety is to a great extent dependent on workers and management skills, as well as on knowledge and skills from the training, it is imminent to investigate employees' perceptions of safety training in connection with the entire structure of safety culture (Saedi et al., 2020). Mkpat, Reniers, and Cozzani (2018) highlighted that process safety revealed that safety training is a grey area in safety literature. A typical background emerged, although possibilities for human optimisation of process safety are subjected to a meaningful experience of safety training among the employees (Naqvi et al., 2019). The subjectivity of experience between employees relies on their perception of the effectiveness of the given training as prevention of major accidents in the chemical industry (Gao et al., 2019).

Although safety training has become compulsory in most process safety industries, recent studies revealed that workers may still perceive safety differently (Bhandari, Hallowell, & Correll, 2019; Leder, Horlitz, Puschmann, Wittstock, & Schütz, 2019; Zhang, He, & Mitri, 2019). Researchers have argued that old-fashioned learning methods are outdated and useless when developing skills, mainly because safety demands employees to develop from repeated training and real-life experiences (e.g., peer-observation, adaptation, and habitual mindset). Consistent with Leder et al. (2019), safety training identifies conveying information through written descriptions that can be offered to only low levels of engagement. In contrast, simulations provide a high degree of engagement because learning via simulation is based on interactive elements that enable active participation and the opportunity to experience the consequences of one's actions.

Since earlier research has only focused on defining standards for safety training while neglecting how training programs control human errors, it warrants further examination of the moderating role of safety training in measuring process safety. Table 6 lists the summary of safety training studies across cultures. Based on the body of literature, the following hypothesis is formulated:

Hypothesis 5: The positive relationship between safety climate and process safety is more robust when high safety training.

Table 6. Summary of Safety Training studies across culture

Authors/Year	Country	Method & Analysis	Results and Implications
Saedi et al. (2020)	Malaysia	Survey, *N*= 111 employees of two refinery industries	Safety training syllabus, curriculum, and content of safety training made a difference in safety training perceptions of employees; thus, a substantial effect on employees' safety process in the two studied refineries.
Gao et al. (2019)	China	Survey, *N*= 405 participants of the oil industry and process industries	Inconclusive findings on safety training in previous research grant opportunities for future research to measure the moderating effect of safety training on the relationship between safety management practices and process safety.
Naqvi et al. (2019)	Pakistan	Simulation and content analysis in offshore drilling operation (2 experts and two novice drillers)	Safety training between novice and expert drillers differ, thus can affect the optimisation of human factors in process safety.
Butler, Bodnar, Cooper, Burkey, and Anastasio (2019)	USA	Case study	The cognitive knowledge from safety training can affect the ethical attitudes and behaviour – driving ethical decision making in process safety. As a result, a comparison of safety training perceptions is essential

			to classify the high-low ethical decision-making in process safety.
Zhang, He, and Mitri (2019)	China	Simulation studies using VR	A personal situation, physical, and psychological conditions between undergraduate and postgraduate moderate the evaluation of safety climate as essential planning resources on process safety system components.
Iqbal, Waheed, Haider, Tesfamariam, and Sadiq (2019)	Canada	Case study, 17 upstream O&G pipeline-operating companies	Safety training and competency moderated the link between safety climate and process safety in O&G companies.

3.7 RESEARCH FRAMEWORK

Although the hypotheses presented are grounded in the literature and arrived from understanding the concepts, further empirical testing is required to test these hypotheses to establish the model as applicable in relating to the effects of safety climate and safety training on process safety. From the collection of previous research studies, a research framework was developed (see Figure 8).

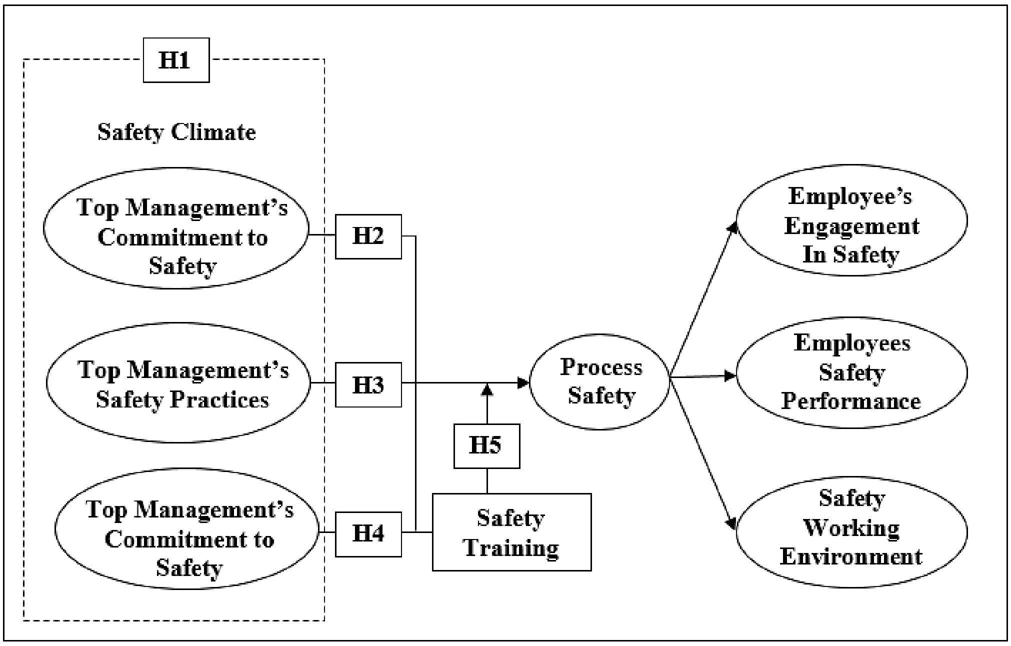


Figure 8. Research Framework

3.8 CHAPTER SUMMARY

Past studies have pointed out the absence of a universal set of process safety factors and that the complexity of modern process industries influences safety climate. The factors that influence the safety climate of industry might be invalid for another sector, primarily because organisations differ in multi-level management styles and safety regulations, resulting in varied safety perceptions. The chapter discusses the key concepts and theories that have been tested in the literature. The synthesis of these components serves as the foundation for this study. While a significant body of literature provides a list of priorities to the future employability skill sets that industries seek, there is also debate over the skill sets perceived by undergraduates for future employment. The literature confirms the gap between future skill sets and impact on career adaptability. Hence, attention over what the future skillsets encompass and how proficiency with such skill is measured towards career adaptability are explored.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter is composed of four main parts. The first section depicts the research design, which includes the instrument development and data analysis method. The research design section covers research philosophy, approach, strategy, self-administrated questionnaire, translation of the questionnaire, and ethical considerations. The second part covers the development of process safety scales and testing, including construct definition, item generation, pilot study, scale refinement and validation, the sample size for factor analysis, factor analysis, EFA, cross-validation, and hierarchical multiple regression. The third part covers the research population and sampling technique used for data collection. The final part covers the instrumentation and evaluation of reliability, validity, and common method variance (CMV).

4.2 RESEARCH DESIGN

The main aims of this study are to embed human factors in process safety scale and to test the relationships among top management's commitment to safety, top management safety practices, supervisory behaviour, and the human element in light of process safety, as well as the moderating role of safety training on the correlations. The study used data triangulation by combining information from focus group discussions, interviews, and quantitative analysis. The research design describes the research philosophy, the approach, the data collection method, and the time horizon.

4.2.1 DEDUCTION

The deductive approach was adopted in this study by testing an existing theory (Saunders et al., 2012; Woiceshyn & Daellenbach, 2018). Deduction produces an analysis with a highly structured methodology that helps future replication (Collis & Hussey, 2003; Cooper & Schindler, 2008; Zikmund, Babin, Carr, & Griffin, 2010). Four reasons are outlined to adopt the deductive approach in this present study. First, the deductive approach is linked to the positivist paradigm (Saunders et al., 2012). Second, this study tested hypotheses driven from the conceptual framework, as well as system-dynamic, sequential, and epidemiological theories and models of safety, in which the correlations between the variables are, explained (top management's commitment to safety, top management safety practices, supervisory behaviour, and the human factor in process safety, as well as the moderating effect of safety training). To test the hypotheses, quantitative data were collected (Hair et al., 2010; Saunders et al., 2012; Zikmund et al., 2010). Third, Saunders and colleagues (2012, p. 86) asserted that the researcher is independent of the study, as the concepts are operationalised to be measured quantitatively. Finally, this study selected a large sample to produce more stable and reliable results to facilitate generalisation of the outcomes (Byrne, 2010; Hair et al., 2010; Saunders et al., 2012; Zikmund et al., 2010).

4.2.2 RESEARCH STRATEGY

Zikmund and colleagues (2010) described research design as "a master plan specifying the methods and procedures for collecting and analysing the needed information". Therefore, requisite data can be gathered and analysed to arrive at a solution (Sekaran & Bougie, 2010). The survey strategy was selected due to the available resources and time, and the underpinning philosophical paradigm. A consistency exists between research philosophy assumptions and survey strategy to answer the research questions, to meet the research objectives, and to produce reliable and valid results (Cooper & Schindler, 2008; Hair et al., 2010; Saunders et al., 2012; Sekaran & Bougie, 2010; Zikmund et al., 2010).

4.2.3 POPULATION AND SAMPLING

The population of this study is composed of 55,000 ADNOC staff (REUTERS, 2016), spanning from ADNOC exploration and production of O&G, including processing, refining, marketing, and distribution. The ADNOC processing and refining employees from the low and middle management levels were selected as the study sample. Their perceptions of top management commitment and practices and supervisor safety behaviour can better understand process safety in the human context. Their safety training levels reflect how employees' psychological effects of safety training effectiveness can affect the correlation between safety climate and safety process. Consequently, the overall strategies of mitigating safety incidents and reducing process safety risk.

According to Krejcie and Morgan (1970), 382 is sizeable sample size for a population of 55,000. The sample size was in line with the rule of thumb for determining the sample size proposed by Roscoe (1975). He claimed that a sample size of between 30 and 500 is appropriate for most research. Another approach to calculating the required sampling size in behavioural science (Cohen, 1992) agrees that a sample size between 85 and 217 is acceptable for correlation analysis.

This study used random probability sampling to generate highly generalizable findings (Fosnacht, Sarraf, Howe & Peck, 2017; Tipton et al., 2016). It is often desirable to have estimates of the population that represent the target population and eliminate sampling bias. Besides, simple random sampling is less hassle and complicated (Fosnacht, Sarraf, Howe & Peck, 2017).

This approach enables all known individuals to have an equal chance of being selected as a study subject.

4.2.4 QUANTITATIVE VERSUS QUALITATIVE RESEARCH

Quantitative research examines associations and causality of the study variables, making research findings more objective (Zikmund et al., 2010). Quantitative research can test hypotheses due to its ability to measure data using statistics (Roscoe, 1975). Meanwhile, qualitative research is heavily focused on the process. Quantitative research emphasises structural matters to test hypotheses (Saunders, Lewis & Thornhill, 2007), thus offering a more objective view of the study and its participants (Hair et al., 2010). Hypothesis testing in quantitative research enables interpretation of empirical results, hence normalising the data.

This study used both qualitative and quantitative approaches. It is a robust investigation on the effect of safety climate and safety training on human factors in the safety process in the UAE’s oil-refining industry. The triangulation research increases the credibility and validity of results. The triangulation approach works best when combined with qualitative and quantitative data that can be generalized to the population of interest. Cohen, Manion, and Morrison (2000) refer to triangulation as an approach that maps out and explains in detail the richness and complexity of human behaviour by studying it from more than a standpoint (p. 254). O'Donoghue and Punch (2003) mentioned triangulation is a method of cross-checking data from multiple sources to search for regularities in the research data (p. 78).

Similarly, Altrichter, Feldman, Posch, and Somekh (2008) concurred both qualitative as inquiry and quantitative as validation in research gives a more detailed and balanced picture of the situation (p. 147). For this study, a quantitative method was used for data collection and analyses in the pilot test. In comparison, both qualitative and quantitative were therefore used for the data collection and analyses in the main study.

4.2.5 DATA COLLECTION METHOD

This research involved three phases of data collection. Qualitative and quantitative data were utilised for scale development and testing, and quantitative data were used for the main study to nomological relationships. During the scale development and testing process, qualitative data was collected through focus group discussions and interviews for dimensional consolidation and the generation of the initial item pool of the process safety scale. The qualitative data as inquiry is analysed using content analysis. The quantitative data validation strategy entailed gathering and measuring information on a set of variables in a systematic and established manner.

The first round of quantitative data collection then was collected using a survey for scale refinement, scale validation, and test of proposed factor structure to ensure the ability of replication for a structural model. The developed and tested scale was replicated in the main study because the psychometric scale-development procedures were fulfilled. In sum, errors resulted from poor design can be minimised (Zikmund et al., 2010). Scale development and testing also help identify and rectify problems with the instruments (Sekaran & Bougie, 2010), allowing modification. Testing manipulations and measures in advance are essential because the original instruments were tested in very different contexts (Brandt et al., 2014).

The second round of data collection was conducted via survey to test the nomological validity of the process safety scale and its link with top management’s commitment to safety, top management safety practices, supervisory behaviour and process safety, and safety training as a moderator.

This procedure allowed the researcher to answer the research questions and assess the study's findings. A formal data collection process is necessary to ensure that data are defined and accurate and that decisions based on the findings are valid (Cooper & Schindler, 2008). The process establishes a baseline from which to measure and identify areas for improvement. The collection of accurate data is critical to the integrity of research. (Zikmund et al., 2010). It requires selecting appropriate data collection techniques and instruments and clearly defined instructions for their correct use to reduce the likelihood of errors (Sekaran & Bougie, 2010).

4.2.6 PRIMARY VERSUS SECONDARY DATA

Data can be gathered from primary and secondary sources (Sekaran & Bougie, 2010). Primary data were adopted for this study since the secondary source data was inadequate for the information needs in this study. Secondary data is used to support the interest phenomena to enable hypotheses and research framework development. However, since the secondary data was gathered from the literature, thus it requires further inquiry and validation for the current study.

Primary data was obtained using various techniques such as interviews (personal, telephone or computer-based), questionnaires (mail, electronically or personally administered), focus groups, observation, and experimentation (Sekaran & Bougie, 2010). This study used focus group discussions and interviews as a source of inquiry and an online survey to measure validity and reliability and for nomological validity. Primary data from this source are considered reliable for replicating procedures and checking the result because of the familiarity of the data collection procedure and analysis methods (Cooper & Schindler, 2008). The data were expected to provide up-to-date information that would directly address the research questions.

4.2.6.1 FOCUS GROUP DISCUSSIONS

Focus group discussion was used as one of the primary data in this study to inquire about the root-caused of the issue. Focus group discussions are defined as "a method of collecting qualitative data that entails engaging a small number of people in an informal group discussion (or discussions) focused on a specific topic or set of issues." (Ochieng, Wilson, Derrick, & Mukherjee, 2018, p. 24). While Krueger and Casey (2000) recommend that researchers conducting focus groups avoid "mixing people who may feel they have different levels of expertise or power related to the issue" (p. 27).

Previous research in social science often relies on focus group discussions to identifying survey questions (Kaufman, Ryan, & Hill, 2018). Some claimed that focus group is a prominent element of complex social stimuli and the precursor to further quantitative tests (Reay, Smith-MacDonald, Then, Hall, & Rankin, 2019). Besides, focus group data collection was mainly to assess respondent's attitudes, perspectives, and opinions (Naznin, Currie, & Logan, 2018). Due to the sensitive nature of the safety research, focus group discussion is adapted into this study due to its flexible nature of including workplace community-based participatory research (Naznin et al., 2018; Song & Guo, 2019).

For this reason, focus group discussion was identified as an appropriate technique to be employed in this study since it has been used for pretesting and pilot-testing phases in safety and process safety research (DeJoy, Smith, & Dyal, 2017; Naznin et al., 2018; Reay et al., 2019; Song & Guo, 2019). Focus group discussion is most effective in the small group of six to twelve participants (Krueger & Casey, 2009). Further, a small focus group was utilised to reduce the potential bias due to the subject's sensitive nature (Krueger & Casey, 2009; Song & Guo, 2019). Nevertheless, Krueger and Casey (2009) emphasised that focus group discussion must fulfil the characteristics of "people who possess certain characteristics that provide qualitative data in a focused discussion to help understand the topic of interest" (p.10).

4.2.6.2 INTERVIEWS

The interview has appeared as an essential method for identifying and correcting problems with survey questions. For this purpose, all relevant data were collected, and 662 process safety items were identified from previously published research. After reducing this study's main objectives and intent, the number of items was reduced to 50. The selection and screening process used the inclusion and exclusion criteria. This approach is supported by other researchers that have explained interviews as most employed in the scale construction and an important method to evaluate the functioning of questionnaires in safety research (e.g., Anwar et al., 2019; Ho et al., 2018; Née et al., 2019). In this study, the interview was applied dimensional consolidation phase in the process safety scale development. The interview helps capture the hidden factors or issues that could shed further light on the dimensions of process safety in the process industry context.

The interview relies on the four-stage model introduced by Tourangeau, Rips, and Rasinski (2000). In his model, stages of the survey responses process begin with comprehension of the questions. At this stage, the respondent's verbalisation of the thought process was facilitated through the role of the interviewer in guiding the interaction proactively or commonly known as think-aloud. According to Kircher and Ahlstrom (2018), the think-aloud procedure in safety research helps establish the meaning of the questions and, consistent with the interviewer's intent. In this procedure, the interviewer generally asks additional and direct questions about the basis for responses or known as probe questions (e.g., “tell me what you are thinking .. how you are responding to this?”). The probing process involved with the interviewer assists the respondent to retrieve memory information to externalise their thought process that requires problem-solving to help identify potential problems (Chessa & Holleman, 2007). The probe questions help to initiate a decision, judgment, or estimation process concerned with the answer's adequacy, accuracy, and acceptability. Finally, the response mapping process produced a response expected by the interviewer. Jabine, Straf, Tanur, and Tourangeau (1984) have explained that the fundamental purpose of the interview is not for quantitative data gathering but rather to obtain mainly qualitative information. The interview responses were summarised, while the questions were modified to rectify the problem observed. This method enhanced the understanding of the key subjects that can be fully assessed via interview. Their thinking-aloud perspectives are probing in an intensive and investigative manner that facilitates to advocate a relatively quick and efficient approach for scale development, pretesting and pilot testing the survey questions. The survey questions are suitable and appropriate in minimising error in resulting data in safety research (e.g., Anwar et al., 2019; Ho et al., 2018; Née, et al., 2019). Similarly, previous research has indicated that different stages of test development are critical for identifying various types of valid evidence. (Al Mazrouei, Khalid, Davidson, & Abdallah, 2019; Schwarz, 2007), while interviews contributed valuable information to validity evidence at various stages of development.

4.2.6.3 SURVEY QUESTIONNAIRE

To date, the questionnaire is still considered a popular method for data collection in safety research as its advantages superseded its disadvantages (Stephens et al., 2017; Yousefi et al., 2016). As cost is the most hindrance for many studies, employing this method provides flexibility at a low cost. Respondent anonymity, confidentiality, and response leisureliness make the questionnaire an attractive method (Sekaran & Bougie, 2010). To minimise the non-response bias, it is suggested to double the number of online questionnaires distributed to ensure that an adequate sample was collected (Dolnicar, Grün, & Leisch, 2016). With attention to response rate, Frohlich (2002) has concluded that response rates between 30% and 35% are considered acceptable for generalisation of the study. Bartlett, Kotrlich and Higgins (2001) recommended a minimum returned sample size of 119 for the generalisability of the study.

This study used an online survey for data collection in both pilot and main studies. The questionnaire was addressed explicitly to TAKREER's middle and lower-level employees to capture their perception of safety climate and the difference between top management and supervisor roles in process safety. The perception of safety training was also weighed in for this study

4.3 INSTRUMENT DEVELOPMENT

The instrument development for this study is outlined as the following:

4.3.1 ETHICAL CONSIDERATION

Special care is given to ethical issues to avoid any possible harm, embarrassment, or disclosing any personal or confidential information which may threaten participants' current or future careers. The questionnaire was sent to the Institutional Research Board for Ethical Research (IRB) of Abu Dhabi University to avoid any ethical issues. Based on their suggestions, some changes were made (see Appendix A and Appendix B). Assuring the anonymity and confidentiality of the participants has helped in more accessible access to the organisations and individuals (Cooper & Schindler, 2008; van den Bos & Tan, 2019). Research ethics in this study involves designing the research, formulating, and clarifying the research topic to the participants, getting access to the sample, and storing the data (Zikmund et al., 2010).

Furthermore, Zikmund and colleagues (2010) claim that ethics related to survey strategies are more general. Before conducting focus group discussions, interviews and distributing the questionnaire, approval and a support letter were issued by the Legal Department of ADNOC Refinery (TAKREER). This letter is generalised and addressed to all employees in TAKREER (see Appendix C).

4.3.2 QUESTIONNAIRE DESIGN

In this study, the modification was made to correspond the items identified from the previous studies to the local context. Scales that have previously been validated in empirical studies are used directly in this study in various contexts and populations (Flynn et al., 1994). The questionnaire for this study was divided into seven sections: Section A gathered the demographic profile of respondents, with gender, age, academic qualification, working experience, and job position being the most frequently assessed variables in safety research (Stephens et al., 2017). Section B was identifying the process safety. Section C targeted the evaluation of safety climate dimensions. Safety training was observed in Section D. In this study, dependent variables (process safety) was placed after the independent variable (top management's commitment to safety, top management safety practices, supervisory behaviour and safety training) to diminish the effects of consistency artefacts (Schaeffer & Dykema, 2011).

As part of the response bias mitigating measure, this study also employed the Likert scale. Specifically, a 7-point Likert scale was used as scaled response format questions to offer the variety of less point scales in which adjacent options are less radically different (or more gradually different) from each other as compared to a much lesser point scale. This larger (step by step) choice spectrum offers a participant more independence to choose the best preferred (Wakita, Ueshima, & Noguchi, 2012).

4.3.2.1 PROCESS SAFETY

The three process safety dimensions (employees' engagement in safety, employees' safety performance, and safe working environment) were measured with a 7-point Likert scale that ranged from 1 = totally disagree to 7 = totally agree. Employees' engagement in safety (dimension 1) was measured with a five-item scale adapted from the communication dimension of the Questionnaire of Safety Culture Values and Practices developed by Díaz-Cabrera et al. (2008). Example items are “I feel that the organisation values my contributions to promoting process safety” and “I believe that it is possible to achieve zero process safety incidents at my organisation.” A three-item scale of employees’ safety performance (dimension 2) was employed using items adapted from Vinodkumar and Bhasi (2009). Example items are “I use all the necessary safety equipment to do my job” and “I ensure the highest levels of safety when carrying out my job.” Participants rated four items adapted from the Safety Culture Values and Practices scale (Díaz-Cabrera et al., 2008). Some of the items are “I feel that my organisation wants to reduce process safety incidents” and “My organisation ensures regular checks to ensure that process safety standards are maintained.” The Cronbach’s alpha for the overall scale was 0.830, while 0.794, 0.851, and 0.780 for employees’ engagement in safety, employees’ safety performance, and safe working environment, respectively.

4.3.2.2 TOP MANAGEMENT COMMITMENT TO SAFETY

The commitment of top management to safety was assessed using a five-item scale adapted from Vinodkumar and Bhasi (2011). This construct is highly reliable and is frequently used in safety research to indicate an organisation’s safety programs (Amponsah-Tawiah & Mensah, 2016; Casey, Griffin, Flatau Harrison, & Neal, 2017). The measurement was initially developed with a sample of process industry employees similar to this study’s sample. Example items are “Safety is given high priority by the management” and “The top management acts quickly to solve problems after near-miss accidents are reported.” Participants responded to the items on a 7-point Likert scale that ranged from 1 = totally disagree to 7 = totally agree. The alpha for the scale was 0.782.

4.3.2.3 TOP MANAGEMENT SAFETY PRACTICES

Five top management safety practices questions were measured with a 7-point Likert scale ranging from 1 = totally disagree to 7 = totally agree, adapted from Hayes, Perander, Smecko, and Trask (1998). Their study showed that safety management practices were the best predictors of accidents, safety performance, and safety-related behaviour. The findings are consistent with previous research demonstrating the importance of top management safety practices in predicting accident-related variables (Wachter & Yorio, 2014; Zohar & Luria, 2010). In a sample of process industry employees, the study found that management safety practices were positively related to employee engagement and accident prevention. Example items are “Top management conducts frequent safety inspections” and “Management provides safe working conditions.” The alpha for the scale was 0.867.

4.3.2.4 SUPERVISORY SAFETY BEHAVIOUR

Hayes et al. (1998) developed a five-item, seven-point scale to assess supervisory safety behaviour. Their results showed that supervisory safety behaviour was among the most important factors in process safety incidents/accidents. Furthermore, researchers have recently investigated the role of workplace safety perceptions in understanding industrial accidents. (Casey et al., 2017; Erdogan, Ozyilmaz, Bauer, & Emre, 2018). Example items are “My immediate supervisor involves workers in setting safety goals” and “My immediate supervisor enforces safety rules.” The alpha for the scale was 0.871.

4.3.2.5 SAFETY TRAINING

Safety training was measured with a six-item 7-point scale adapted by VinodkumarKhali and Bhasi (2011). It was discovered that safety training could moderate the relationship between safety climate and process safety in oil and gas companies (Mkpat et al., 2018; Saedi et al., 2020; Swuste et al., 2020). Furthermore, safety climate effects on process safety were argued to be subjected to a meaningful safety training experience (Naqvi et al., 2019). In this context, the subjectivity of experience between employees depends on their perception of practical safety training in the organisation context (Gao et al., 2019). Example items are “My organisation gives comprehensive training to the employees in workplace health and safety issues” and “Safety issues are given high priority in training programs”.

The moderating effects of safety training are estimated using MSEM due to its appropriateness for measuring different effects using Structural Equation Modelling (SEM) characteristics. The sample was divided into two groups to examine the moderating effects of safety training; safety training was divided by the measured items' average point (3.5 points). Then, the moderating effects of safety training were analysed by conducting a $\chi 2$ difference test between the two models. This analysis is conducted using Analysis of Moment Structure (AMOS) 23.0 (Arbuckle, 2014).

4.4 DATA ANALYSIS TECHNIQUE

The data were analysed using SPSS version 18.0 (SPSS Inc., 2009) and SEM via AMOS version 23.0 (Arbuckle, 2003). Both SPSS and SEM were used for scale development and testing and measurement and structural models testing, respectively. Descriptive and frequency analysis was used to assess the demographic and other general characteristics of the respondents. The SEM was used to simultaneously estimate multiple equations to assess the hypothesised model (Hair et al., 2010). The detailed methodological framework of this study is shown in Figure 9.

Phases	Methods	Results
Phase 1: Dimensional consolidation and generation of the initial item pool	○ Qualitative focus group ○ Prioritization analysis interviews	Initial sets of 12 items with five factors
Phase 2: Scale refinement	○ Item-to-total correlations ○ Exploratory factor analysis (EFA) ○ Quantitative data collection	Finalize of 12 items with three factors
Phase 3: Scale validation	○ Confirmatory factor analysis to check convergent and discriminant validity ○ Cronbach's alpha (α) and composite reliability (CR)	Construct validity and reliability are satisfactory
Phase 4: Test of proposed factor structure	○ Assessment of different models with Confirmatory Factor Analyses (CFAs) Model 1: Test of primary dimensions Model 2: Test of the overall second-order factor model ○ Bifactor model: Test orthogonal between first-order and higher-order factors ○ A replication study	Hierarchical factor structure of process safety is satisfactory
Phase 5: Nomological validity	○ Structural equation modeling using AMOS (SEM-AMOS) ○ Theoretically related constructs were selected to test the nomological validity	Top management commitment towards safety, top management safety practices, and supervisory safety behaviour impact process safety

Figure 9. Overview of Methodological Framework of the study

4.4.1 SCALE DEVELOPMENT AND TESTING

The first phase consists of dimensional consolidation and the generation of the initial item pool. Focus group discussions and interviews were held to stimulate dynamic discussion that leads to discovery, exploration, direction, and depth about the topics discussed (Naznin et al., 2018). Scholars have argued that focus group discussions and interviews bridge the gap between interviewees' initial perceptions and their final reports on what they have seen on the topics (Song & Guo, 2019). In addition, research suggested that focus group discussions and interviews are a unique and independent source of qualitative data that supplement quantitative data collection strategies (Reay et al., 2019). As a result, it is resourceful and valuable in a variety of areas of exploration. First, the initial identification of human factors in the process safety scale was a focus group discussion to recollect their personal experiences related to process safety at the workplace. Their responses were recorded and summarised to further probe for details and the underlying dimensions of process safety. The validity of the inquiry from the focus group discussion was tested using prioritisation analysis using interviews. It is essential to rank the items according to the most important to the least important according to employees' perceptions and experiences.

The second phase is scale refinement. Scale refinement was conducted to eliminate bias toward specific dimensions in terms of process safety. A preliminary pre-test using a survey was conducted to ensure content validity to eliminate candidate items that do not appropriately correspond to the construct definitions intended to measure. Scale refinement was conducted to eliminate bias toward specific dimensions in terms of process safety through psychometric properties in EFA. The superiority of EFA over Principal Component Analysis (PCA) is suggested by Tabachnick and Fidell (2007). Likewise, results of item-to-total correlations generated from EFA can be more effectively generalised compared to PCA (Field, 2013; Tabachnick & Fidell, 2007). EFA using principal-axis-factoring was performed to determine the number of underlying factors and factor structure of the variables specified in the process safety scale. Principal-axis-factoring was used due to its superiority over maximum likelihood (ML) that sometimes results in some problems that do not happen when principal-axis-factoring is used (de Winter & Dodou, 2012). The assumption of multivariate normality is restricted only for specific parameter estimation methods like ML. In contrast, the assumption of multivariate normality is not applied (or does not require) for PAF, which is the most popular extraction method in EFA (Hair et al., 2010; Sekaran & Bougie, 2010). The principal-axis factoring extraction method and Promax with Kaiser Normalisation rotation method were used because the process safety scale is theoretically assumed to be correlated (Hair et al., 2010). Considering the large sample size used in this study, item-to-total correlations were examined for items measurement in the scale purification approach (Anderson & Gerbing, 1988). To ensure the refined scale, the minimum value for Cronbach's α for dimensions is at 0.60 (Nunnally & Bernstein, 1994). All item-to-total correlations of the associated measurement items must be above the conventional 0.40 criteria (Field, 2013). Further, to eliminate multicollinearity for the construct, Bartlett's Test of Sphericity to confirm patterned relationship among the items to be significant at 0.000, and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) for all construct must be well above 0.50 (Hair et al., 2010). In addition, the Eigenvalues should be greater than 1, and the factor loadings ought to be 0.50 and above with the total explained variance of more than 60% (Hair et al., 2010). In this study, the EFA was conducted to finalize the 12-items serves to three latent constructs.

The third phase is scale validation. A comprehensive scale validation was conducted to assess the measurement model, construct reliability and validity of the process safety scale using the same sample in the pilot test. Confirmatory factor analysis (CFA) was conducted to check the convergent and discriminant validity of the process safety scale. A CFA was conducted using AMOS to assess the measurement model and verify process safety's construct validity and reliability. The data is satisfactory fit the model when chi-square over the degree of freedom (*df*) is less than 3.0 ($\chi 2/df$), comparative fit index (CFI) and Tucker-Lewis Index (TLI) more than 0.80, the root mean square error of approximation (RMSEA) and the standardised root mean square residual (SRMR) less than 0.08. (Bentler, 1990; Byrne, 2010; Forza & Filippini, 1998; Hair et al., 2010; Hu & Bentler, 1999). These minimum values of fit indices indicate an acceptable model. Furthermore, all items had factor loadings and average variance extracted (AVE) of more than 0.5. AVE values exceeded the construct inter-correlation values (Byrne, 2010; Hair et al., 2010), supporting adequate discriminant validity. Cronbach's α and CR must be well above 0.70

(Nunnally and Bernstein, 1994), supporting construct reliability. The test measurement model must establish a significant 0.001 level.

The fourth phase is the test of the proposed factor structure. The online questionnaire underwent pilot testing to check its validity and reliability before the main study. Connelly (2008) suggested that pilot study samples should be 10% of the sample project for the main study. Still, other authors have argued that the sample required for a pilot study does not need to be a proportion of the main study sample (Albers & Lakens, 2018; Lane & Hennes, 2018). However, determining the pilot sample size is not easy (Anderson et al., 2017). Hertzog (2008) argued that multiple factors were relevant, including the type of study. Overall, researchers have suggested that an appropriate pilot study sample size can range from 10 to 30 (Hill, 1998; Julious, 2005; Issac & Michael, 1995). At this phase, the factor structure for primary dimensions, second-order factor model, and bifactor model was tested to ensure process safety's satisfactory hierarchical factor structure.

Finally, at phase 5, the nomological validity was tested. The total disaggregation of the structural model was tested using the Structural Equation Modelling (SEM-AMOS) to measure theoretically related constructs to test for nomological validity.

4.4.2 TESTS FOR MODEL FIT

The measurement adequacy of the first order, second-order, and third-order models was further measured and verified through an assessment of model fit. It is advisable to consider several fit indices to assess the model fit in addition to the chi-square ($\chi 2$) index and degree of freedom (*df*) (Bollen, 1990; Byrne, 2010; Hooper, Coughlan & Mullen, 2008; Miles & Shevlin, 2007). At least four common fit indices are sufficient to test the structural equation models (Byrne, 2010; Hooper et al., 2008).

The SRMR, RMSEA, CFI, and the Tucker Lewis Index (TLI) are commonly used fit indexes reported when describing the fit of structural equation models (Byrne, 2010; Kline, 2015), with the RMSEA, SRMR, and CFI being among the most widely reported in the SEM literature (Kline, 2015). This study chose relative χ2 (χ2/df), CFI, TLI, RMSEA and SRMR instead of $\chi 2$ and GFI because they are less sensitive to sample size (Bollen, 1990; Kline, 2010; Miles & Shevlin, 2007). This approach is a basic task in SEM modelling that forms the basis for accepting one model over another. Table 7 shows the model fit indices for the study and the acceptable thresholds.

Table 7. Summary of the Observed Model Fit Indices and acceptable Threshold Value for this study

Fit Indices	**Recommended Threshold Value**	**Sources**
χ^2	< 0.50	Tabachnick and Fidell (2007)
(reported if sample size between 100 and 200)	< 0.30	Ullman (2001)
		Kline (2005)
Relative χ^2 (χ^2/d.f)	< 2.0	Tabachnick and Fidell (2007)
(reported if sample size more than 200)	< 3.0	Ullman (2001)
	< 5.0	Kline (2005)
		Bentler (1990)
		Marsh et al. (2004)
		Schumacker and Lomax (2004)
		Wheaton et al. (1977)
Comparative Fit Index (CFI)	> 0.80	Forza and Filippini (1998)
	> 0.90	Bentler (1990)
	> 0.90	Hatcher (1994)
	> 0.95	Hu and Bentler (1999)
Tucker–Lewis Index (TLI)	> 0.80	Bentler (1990)
	> 0.80	Hair et al. (2010)
	> 0.90	Byrne (2010)
	> 0.95	Hu and Bentler (1999)
	> 0.95	Tabachnick and Fidell (2007)

Root Mean Square Error of Approximation (RMSEA)	< 0.08	Byrne (2010)
	< 0.08	MacCallum et al. (1996)
	< 0.08	Steiger (1998)
	< 0.06	Hu and Bentler (1999)
	< 0.05	Browne and Cudeck (1993)
Standardised Root Mean Square Residual (SRMR)	< 0.05	Byrne (2010)
	< 0.05	Diamantopoulos and Siguaw (2000)
	< 0.08	Hooper et al. (2008)
	< 0.08	Hu and Bentler (1999)

The assessment of dimensions' psychometric properties led to testing the proposed factor structure of process safety using the sample from the pilot test. This assessment determines whether the dimensions are the best indicators of the overall process safety. This study adopted the same instrument to replicate our findings with new samples to mitigate errors resulting from capitalisation of chance for robustness and generalisation. Consistent with Taylor and colleagues (2019), a series of CFAs were conducted to test the primary dimensions, test the overall second-order factor model, and test the bifactor model. CFA was used for the measurement model, with convergent and discriminant validity. Convergent validity specifies the set of items that measure a construct (Kline, 2015). It also tests the dimensionality of items to represent a common, latent construct (Ziegler & Hagemann, 2015) that explains a significant proportion of variance in the latent variables (Wang, French, & Clay, 2015). Discriminant validity specifies the extent to which a construct is truly distinct from other constructs (Byrne, 2010). It, therefore, tends to indicate a much lower proportion of variance from other latent variables (Wang et al., 2015)

To enable the subscale to be described in a broader construct and more specific dimensions, the bifactor measurement model is conducted to measure whether the instruments are suited for a comprehensive examination of these sources of construct-relevant variance. A bifactor measurement model is a beneficial approach for this purpose (Stenling, Ivarsson, Hassmén, & Lindwall, 2015). Theory-based multidimensional scales, such as safety climate and safety culture, frequently correspond to a bifactor structure with a general latent construct alongside several latent subdimensions that are more narrowly defined (Reise, Kim, Mansolf, & Widaman, 2016).

Before the replication procedure can be conducted, common method variance (CMV) was assessed. CMV occurs due to using a common method to collect data since an amount of false covariance will be shared between the variables in the study (Kline et al., 2015). CMV leads to the creation of spurious internal consistency. The common source of the variables produces apparent correlations among them and extra bias of the estimates of the associations between the variables (Podsakoff, Mackenzie, & Podsakoff, 2012). Several approaches are suggested to minimise or control the CMV (e.g., Podsakoff et al., 2012). To deal with potential CMV, this study has used two approaches. The first is known as the ex-ante approach and is used when the study is designed, and the second is known as ex-post statistical analyses and is used after the study is conducted (Podsakoff et al., 2012). Before conducting the study, the confidentiality and anonymity of the participants are secured (Malhotra, Kim, & Patil, 2006; Podsakoff et al., 2012), and participants are well informed about the study to facilitate more accurate and valid responses (Sekaran & Bougie, 2010). Furthermore, survey items were randomised to reduce bias and CMV (Carroll, Toumpakari, Johnson, & Betts, 2017). The second approach is viewed as the best choice to avoid false correlations caused by CMV (Chang, van Witteloostuijn, & Eden, 2010).

Measurement invariance was conducted to control for false discoveries in research, split-sample analyses were performed as a mechanism to limit the social desirability bias. Kline (2015) proposed the multi-group CFA as one of the most widely used strategies to assess the measurement invariance. Unlike CFA that assesses the measurement model fit, the multi-group CFA specifically compares the measurement model across groups, which comprises three stages with specific invariance conditions of (1) configural invariance, (2) metric invariance, and (3) scalar invariance (Kline, 2015; Vandenberg & Lance, 2000). Firstly, a test on the configural invariance was conducted. No equality constraints were imposed on any parameters within the model (Byrne, 2010), thereby implying that the conceptual framework was identical across groups.

This study performed the measurement fit of these models based on the proposed common criteria by Hu and Bentler (1999)—robust chi-square, CFI (< 0.90), and RMSEA (< 0.08). When a similar measurement model fits across groups, configurable invariance is assumed to be supported. The next step required an assessment of metric invariance, whereby only the factor loadings were constrained as equivalent across groups (Byrne, 2010). Metric invariance was determined by comparing the metric model's fit to the configurable model's fit. The chi-square sensitivity was different compared to non-normality and large sample sizes, resulting in the invariance decisions being made in consideration of the changes in CFI (ΔCFI), RMSEA (ΔRMSEA), and SRMR (ΔSRMR) values. Accordingly, the changes in the CFI ≤ 0.02, RMSEA ≤ 0.03, and SRMR ≤ 0.03, respectively, for metric invariance were deemed as most appropriate and indicative of non-invariance with a large sample size (Chen, 2007; Rutkowski and Svetina, 2014).

In a baseline model, factor loadings are estimated across groups with no constraints, whereas in an invariance model, factor loadings are constrained to be equivalent across groups. The chi-square difference test (Muthén, 1989) and the ΔCFI (Cheung & Rensvold, 2002; Meade & Lautenschlager, 2004) are applied to assess these differences in two nested models.

The final step required measuring the scalar invariance model, with factor loading and indicator intercepts limited to identical across groups. The invariance model is assumed to possess a better fit (compared to the baseline model) if the chi-square difference test reveals an insignificant result (Muthén, 1989). On the contrary, the baseline model is assumed to be better if the chi-square difference test shows a significant effect. Thus, indicating that the underlying constructs differ across groups. However, there are certain limitations to the chi-square difference test, such as high sensitivity to the sample size and indifference to a lack of invariance (Cheung & Rensvold, 2002;

Meade & Lautenschlager, 2004). This places the ΔCFI (value of less than 0.01 suggests invariance) as a better alternative, which was reaffirmed in certain studies on the comparison of several goodness-of-fit indices (GFI) (Cheung & Rensvold, 2002; Meade & Lautenschlager, 2004), with its indifference to the sample size and model complexities. Besides that, Meade et al. (2008) indicated that any observed difference across groups based on a sample size exceeding 200 is likely to be negligible if the ΔCFI result suggests invariance—even if the chi-square difference test shows that the underlying constructs differ across groups (significant result). The complete metric invariance, which assumes similar underlying meanings across groups, is realistically uncommon. Still, the partial metric invariance that propounds only several latent constructs with similar underlying meanings across groups highlights the need to perform the next stage (to examine scalar invariance).

Thus, the means of these latent constructs are compared using a similar nested model comparison strategy. In this case, instead of factor loadings, the means are estimated across groups without any constraint in a baseline model. In contrast, the means are constrained to be equivalent across groups in an invariance model. Then, the metric and scalar invariance models were subjected to a comparison by evaluating the changes of CFI, RMSEA, and SRMR ($\Delta SRMR \leq 0.015$) values (Chen, 2007; Rutkowski & Svetina, 2014).

This assessment is widely regarded as the most effective and versatile method for testing across groups (Vandenberg & Lance, 2000).

Finally, nomological testing is carried out. The structural model is tested at this stage with a new sample collection as a test-retest mechanism for validity and reliability verification. SEM is increasingly being used in social science research, and it has quickly become a dominant multivariate technique. (Hair et al., 2010). Three different strategies are often used in its application: (1) affirmative modelling strategy, (2) competing modelling strategy, and (3) model development strategy. These help researchers estimate a complex set of relationships.

This study used SEM to investigate the relationship between top management commitment to safety, management safety practices, and supervisory safety behaviour on process safety and the variables outlined in the research framework and the moderating model of safety climate. SEM was therefore considered appropriate for this study because it estimates the strength of all hypothesised relationships between variables in the theoretical model (Byrne, 2010; Schreiber, Nora, Stage, Barlow & King, 2006; Tomarken & Waller, 2005). Researchers can develop more sophisticated theories (Williams, Gavin & Hartman, 2004).

A confirmatory modelling strategy was applied to the hypothesised model. Kline (2015) stated that the researcher specifies a model within a confirmatory modelling strategy, and SEM determines whether the model fits the data. Byrne (2010), Hair and colleagues (2010) explained that a good fit of the data does not mean that the proposed model is proven but is confirmed as one of several possible acceptable models. To ensure the SEM procedures were performed appropriately, Byrne (2010) provided three fundamental levels of analyses for SEM with AMOS (Arbuckle, 2014). For this study, the comprehensive “six stages in SEM” proposed by Hair and colleagues (2010) were applied to test both measurement theory (how the constructs are represented) and structural theory (how the constructs relate to each other).

Finally, the moderation model of safety training was tested using multilevel modelling (MLM) and SEM commonly used in social and behavioural sciences. The main advantage of MLM is that complex relationships among variables can be studied on different levels and across different levels (Pritikin, Hunter, von Oertzen, Brick, & Boker, 2017). In addition, MLM is exceptionally flexible and can be used for a great variety of different data structures. However, the main advantage of SEM is to directly model the measurement error and investigate complex relationships among latent variables (Bollen, 1989).

Furthermore, the fit of a given structural equation model can be evaluated by different fit criteria. Multilevel structural equation modelling (MSEM) combines MLM and SEM's advantages to scrutinise complex relationships between latent variables on different levels (Muthén, 1989). The moderating effects of safety training are estimated using MSEM due to its appropriateness for measuring different effects using the characteristics of SEM.

The sample was divided into two groups to examine the moderating effects of safety training; safety training was divided by the measured items' average point (3.5 points). Based on these, and unconstrained (or free) model was employed, which does not impose restrictions that relations between latent variables differ from the effects of moderating variable and equality constrained model, which assumes that the sizes of associations between variables are equal to each other. Then, the moderating effects of safety training were analysed by conducting a $\chi 2$ difference test between the two models. This analysis is undertaken using AMOS 23.0 (Arbuckle, 2014). Considering the numerous advantages, MSEM is an appropriate and efficient evaluation strategy for the moderation model in this study. MSEM ensures the robustness of the evaluation and supports the recent methodological developments of the new modelling framework (Ahmad & Khalid, 2017; Davidov, Dülmer, Schlüter, Schmidt, & Meuleman, 2012).

4.5 CHAPTER SUMMARY

Creating a new scale with high construct validity is a time-consuming and challenging process. Reliability and validity are crucial to establish scales, and developing a rigorous scale is not easy. Besides, statistical analysis that overlooks measurement accuracy should not be given much emphasis. This chapter develops and tests instruments that can improve the efficiency of data collection and data analysis.

CHAPTER 5

DATA ANALYSIS AND RESULTS

5.1 INTRODUCTION

This chapter describes the data analysis procedure used to test the hypotheses developed in this study. This chapter is divided into four parts. The results of the pilot tests are reported in the first section. The second section provides information about the respondents' profiles as well as descriptive statistics. The third section describes the variables' measurement models. Finally, the fourth section depicts the structural model that was used to validate the proposed research framework. This study develops the human factor of the process safety scale. When its reliability and validity are supported, it tests a set of relationships and hypotheses. Data were checked for errors, and missing values were recorded (Field, 2013; Hair et al., 2010). The reliability of the scales was evaluated, and items with low reliability and Corrected Item-total Correlation (CITC) were removed from further analysis. Summated scales for top management's commitment to safety (MCS), top management safety practices (MSP), and Supervisory Safety Behaviour (SSB) was calculated. A summated human factor of process safety scale was created after its development process was finished. In the next step, the following analyses were conducted: normality test, validity, correlation, assessing CMV, EFA, CFA, assumptions of multiple regression and hierarchical MR using SEM-AMOS. The new scale is created after CFA confirms the results of the EFA. As expected, hypothesis analysis reveals that SSB is the strongest predictor of the human factor of process safety. TMCS, TMSP and SSB are much contributed to a safe working environment (SWE, 91%), followed by employee's engagement in safety (ESE, 90%) and employee's safety performance (ESP, 61%). Multigroup SEM was conducted to measure the impact of different perceptions of safety training in the relation between TMCS, TMSP, and SSB on the human factor in process safety.

5.2 DEVELOPING THE PROCESS SAFETY SCALE

This study adopted the psychometric scale-development procedures advanced by safety research studies (Ghahramani & Khalkhali, 2015; Probst, Goldenhar, Byrd, & Betit, 2019; Vinodkumar & Bhasi, 2011; Yeoh, Ibrahim, Oxley, Hamid, & Syed Abd. Rashid, 2016). Table 8 lists the five phases of the scale development process.

Table 8. Overview of the Scale Development Process

Phases	Methods	Results
Phase 1: Dimensional consolidation and generation of the initial item pool	○ Focus group discussion with 10 TAKREER employees ○ Prioritisation analysis with 50 TAKREER employees	The initial set of twelve items with three dimensions
Phase 2: Scale refinement	○ EFA ○ Data of 180 middle and lower-level management employees of TAKREER were used	The final set of twelve items with three dimensions
Phase 3: Scale validation	○ CFA to check convergent and discriminant validity ○ Cronbach's and composite reliability (CR) to check the reliability	Construct validity and reliability are satisfactory
Phase 4: Test of the proposed factor structure	○ Assessments of different models with CFAs ○ Model 1: the test of the primary dimensions ○ Model 2: the test of the subdimensions ○ Model 3: the test of the overall third-order factor model	The hierarchical factor structure of process safety is adequate

5.2.1 PHASE 1: DIMENSIONAL CONSOLIDATION AND GENERATION OF THE INITIAL ITEM POOL

5.2.1.1 DIMENSIONAL CONSOLIDATION OF PROCESS SAFETY

The preceding discussions of the three sources of process safety (employees' safety engagement, employees' safety performance, safe working environment) are mainly based on the human elements of process safety instead of the technical dimensions of process safety. These process safety dimensions may be more subject to the perception of safety behaviour and safety attitudes. For instance, employees may find process safety is more affecting their psychological rather than physical (Swuste et al., 2016; de Almeida & Vinnem, 2020). To assess whether the human factor of process safety is also psychological, qualitative interviews with middle and lower management-level employees in TAKREER was conducted using a focus group. Ten TAKREER employees, four males and six females, were recruited for this purpose. The focus group discussion started with introducing the participants to the concepts of process safety. Then they were asked to recall their personal experiences related to the human factor of process safety at the workplace. Details and the underlying dimensions of process safety were elicited from spontaneous responses. If the human dimensions of process safety were not mentioned spontaneously, they were prompted for discussion wherever possible. All human dimensions of process safety from prior literature are probed whenever possible, with process safety items were identified from previously published articles (Bakar et al., 2014). The discussion ended after the participants described all human dimensions of process safety experiences in total.

In summary, the qualitative focus group discussion analyses indicate that process safety perceptions align with literature-based human factor dimensions. These dimensions are listed in Table 9. Integrating the findings from the process safety literature review and the qualitative focus group discussion, this study proposes that process safety has an essential hierarchical dimension. The summary of responses to the narrative is tabulated in Table 10.

Table 9. Initial Dimensions of Process Safety generated from the Qualitative Group Discussion

Dimension	Definition	Symbol
Employee's engagement in safety	Employee's safety engagement refers to concern by employees against health and safety hazards (e.g., provision of personal protective equipment, PPE, e.g., safety glasses and fall protection harnesses). It reflects on the workers' involvement in employee engagement in influencing safety levels and safety perceptions. Involvement and engagement of workers in safety influences safety perceptions and accident prevention significantly.	ESE
Employees' safety performance	Highly efficient individuals demonstrate favourable employee perceptions and behaviour toward organisational safety. Employees' safety performance is a critical element of their perceptions towards process safety	ESP
Safety working environment	The work environment is an essential element of process safety. Hazardous environment affected perceptions towards process safety. Worker behaviour is subject to the influence of various environmental conditions and stimuli. Some environmental variables are capable of predictably affecting safety choices.	SWE

Table 10. The Summary of Responses to Narrative

Dimensions	Supporting quotes from focus group discussions and interviews
Employee's engagement in safety	○ "… the sense a person has about the safety of the workplace and how serious safety is taken by the people that work there." ○ "… sense of how safe the facility is and how people feel about safety and safety rules." ○ "… work safely and follow the protocols as well as the overall attitude towards safety in general." ○ "… sense a person has about the safety of the workplace and how serious safety is taken by the people that work there." ○ "… attitude toward the safety, for instance, are they proactive, reactive, or antagonistic toward safety."
Employees' safety performance	○ "… degree in which safety of the person is taken into consideration." ○ ". following safety procedures and behave in appropriate manners." ○ "… follows the safety rules because trusted by the management." ○ "… using personal protective equipment regularly at the workplace." ○ "… following safety procedures."
Safety working environment	○ "… safe people feel while at work and their attitude about safety and safety rules." ○ "… more safety meetings and relay information about the impact safety programs." ○ "… senior manager notifies inspections and is present to answer safety-related questions." ○ "… supervisors making sure safety rules are followed in the workplace." ○ "… embrace changes and enforce safety rules."

5.2.1.2 GENERATION OF THE INITIAL ITEM POOL

In conjunction with the work of dimensional consolidation of process safety, this study first generated an initial item pool for the three dimensions, with a total of twelve candidate items. Each construct corresponds to three to five measurement items. A preliminary pre-test was conducted to ensure content validity to eliminate candidate items that do not appropriately correspond to the construct definitions intended to measure. Pre-test participants consisted of fifty middle and lower management level workers in TAKREER was involved in prioritisation analysis conducted for dimensional consolidation and generation of the initial item pool. These participants were first given the definitions of the target construct. Then, they were interviewed to understand their priority of process safety further. Later, participants were requested to rank order the twelve candidate items according to how well the content of each item fitted the given definition of target construct. Low rankings reflect that the candidate item statements do not fit well with the content domain for its corresponding construct, indicating inferior content validity quality. Accordingly, through this prioritisation analysis, this study does not eliminate any items with lower priority rankings. As a result, all items were retained for further screenings. The measurement questions were in the form of statements describing employees' experiences of process safety concerning each dimension. They were measured on a seven-point Likert scale ranging from "Highly disagree" to "Highly agree. The priority ranking is tabulated in Table 11. The results show that the priority ranking between interviews and survey were consistent.

Table 11. Priority Ranking

Dimensions	Interviews	Survey
Employee’s engagement in safety	75%	72%
Employees’ safety performance	50%	70%
Safety working environment	80%	85%

5.2.2 PHASE 2: SCALE REFINEMENT

5.2.2.1 PARTICIPANTS AND PROCEDURE

Middle and lower management level workers in TAKREER was selected for process safety evaluations. The data for this study were gathered using online survey sites, which provide ease of data collection at a low cost (Hatfield & Boufous, 2016). The invitation to participate in the research was anonymous to the workers' email with the approval of TAKREER. Employees who agreed to participate would be led to the survey pages upon completing the data collection procedure. A total of 180 participants who were recruited completed the questionnaire. This study’s participants were 180 workers with various jobs at TAKREER. Of the participants, 131 (72.8%) were male, and 49 (27.2%) were female. The workers’ ages ranged from 22 to 60 years, with a mean age of 38.8 years (*SD* = 0.89). In terms of the highest educational level attained, 53 participants (29.4%) held a high school diploma or technical certificate, 68 (37.8%) had an undergraduate university degree, and 59 (32.8%) held a graduate university degree. Job tenure ranged from 6 months to 30 years, with mean job tenure of 12.3 years (*SD* = 0.71). Most participants were Emirati (79; 43.9%); 17 (9.4%) participants were from other Gulf Cooperation Council states, and 22 (12.2%) participants were from other Middle Eastern or North African nations. The remaining participants were North American (3; 1.7%), Asian (49; 27.2%), African (8; 4.4%), and others (2; 1.1%). In terms of job position, 55.6% worked at lower management level, and 44.4% worked at middle management level. Table 12 summarised the demographic sample of the study.

Table 12. Demographic Sample of the Study

Variables		**Frequency**	**Percentage**
Gender	Male	131	72.8
	Female	49	27.2
Age	22 – 30 years old	70	38.9
	31 – 40 years old	62	34.4
	41 – 50 years old	40	22.2
	51 – 60 years old	8	4.4
Education	High school diploma or technical certificate	53	29.4
	Undergraduate university degree	68	37.8
	Graduate university degree	59	32.7
Job tenure	6 months to a year	5	2.7
	One year to 5 years	24	13.3
	6 years to 15 years	78	43.3
	16 years to 30 years	73	40.6
Nationality	Emirati	79	43.9
	Gulf Cooperation Council states (except Emirati)	17	9.4
	Middle Eastern or North African nations	22	12.2

	North American	3	1.7
	Asian	49	27.2
	African	8	4.4
	Others	2	1.1
Job level	Lower management level	100	55.6
	Middle management level	80	44.4

5.2.2.2 SCALE PURIFICATION

All items were grouped under respective factors and summarized in Table 13 based on the eigenvalues and factor loadings from the EFA. The EFA revealed that the underlying dimensions of process safety (i.e., employees' engagement in safety, employees' safety performance, and safe working environment) were sufficient, and no issue of multicollinearity existed [$\chi 2$ (66) = 1616.651, $p < 0.05$, KMO = 0.912]. The results were consistent with the cut-off values suggested by Hair et al. (2010). All factor loadings were more significant than 0.50, KMO was greater than 0.50, Bartlett's significant value was greater than 0.05, and eigenvalues were greater than 1.0. This research aligns with the theoretical view of process safety (i.e., literature-based approach) and the workers' perception of process safety (i.e., survey-based empirical assessment). Figure 10 shows the indicators of process safety and the result of being tested reflectively (Bollen et al. 1991).

Table 13. Summary of Exploratory Analysis

Dimension		Items	Mean	SD	Factor loadings	Eigenvalues	Total variance explained
Employees' safety engagement (ESE)	ESE1	My organisation values my contribution to promoting process safety	5.63	1.07	0.86	6.952	57.933
	ESE2	My organisation values employees' suggestions on improving safety	5.71	1.04	0.87		
	ESE3	My organisation values employees' adherence to process safety procedures	5.64	1.09	0.82		
	ESE4	My organisation regularly promotes process safety	5.71	1.05	0.80		
	ESE5	My organisation can achieve zero process safety events/incidents	5.70	1.18	0.79		
Employees' safety performance (ESP)	ESP1	I use all of the necessary safety equipment when doing my job	5.72	1.06	0.79	4.615	31.897
	ESP2	I ensure the highest levels of safety when carrying out my job	5.71	1.12	0.76		
	ESP3	I know how to use safety equipment and understand standard work procedures	5.68	1.14	0.73		

Safe working environment (SWE)	SWE 1	My organisation wants to eliminate process safety incidents	5.71	1.32	0.73	3.427	22.892
	SWE 2	The leadership at my organisation reviews process safety procedures after an event/incident occurs	5.92	0.97	0.71		
	SWE 3	My organisation conducts regular checks to ensure that process safety standards are maintained	5.77	1.05	0.72		
	SWE 4	I feel safe when working at my organisation	5.71	1.18	0.67		

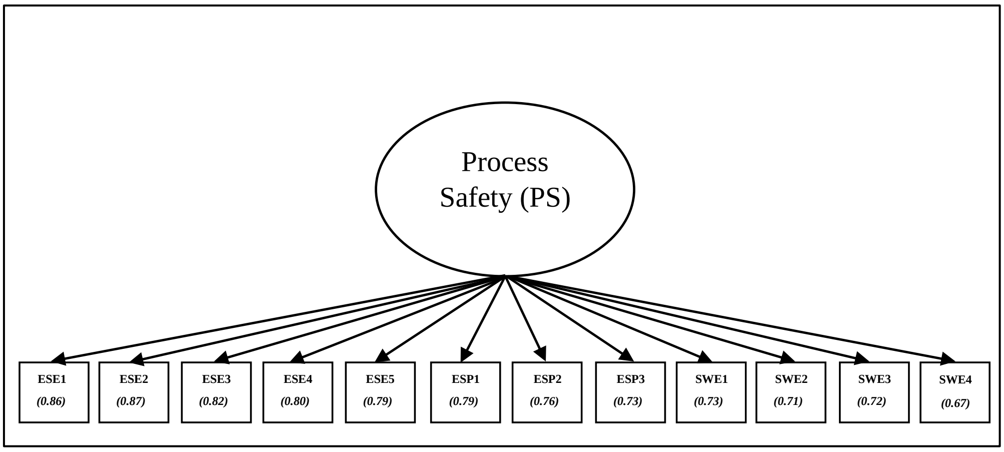


Figure 10. The Indicators of Process Safety

5.2.3 PHASE 3: SCALE VALIDATION

In the correlated model, twelve items from the three dimensions of process safety were examined and constrained to load onto their corresponding factors. The results of the CFA model indicate a good fit ($\chi 2$ = 76.615, $p < 0.01$, df = 39; CFI = 0.982; TLI = 0.975; RMSEA = 0.058; SRMR = 0.045). As shown in Table 8, the CFA loadings for all items ranged between 0.80 and 0.98, were statistically significant, and were loaded onto their respective factors. All Cronbach's alpha (α) and composite reliability values far exceed 0.70, which supports the construct reliability of the process safety dimensions (see Table 8). The results showed adequate convergent and discriminant validity: AVEs exceeded 0.50 (Kline, 2010), and the square roots of AVE values exceeded the construct correlation values (Fornell & Larcker, 1981). In addition, all factor loadings far exceeded 0.50, and the t-values were statistically significant (p < 0.01) (Hair et al., 2010). Because the three process safety dimensions were highly and positively correlated ($0.82 \leq r \leq 0.88$, $p < 0.001$; see Table 14), the standardised regression coefficients may be associated with large standard errors due to potential multicollinearity (Winship & Western, 2016). As a result, we investigated the variance inflation factors (VIFs), which estimate the extent to which the standard error of a regression coefficient for a given predictor is inflated due to predictor correlations compared to the situation with completely uncorrelated predictors. The rule-of-thumb range for VIFs to indicate severe multicollinearity among predictor variables is between 4 and 10 (Yoo et al., 2014). The causal model showed that the VIFs for the three process safety dimensions were 1.35 for employees' engagement in safety, 3.35 for employees' safety performance, and 1.52 for a safe working environment. These values suggest that although there was some multicollinearity due to inflated standard errors, it was not a serious problem. Therefore, the comprehensive validation procedures have established that the three dimensions and 12 items constitute a good instrument for measuring process safety. Figure 11 show the dimensions of process safety.

Table 14. Summary of Confirmatory Factor Analyses for Dimensions of Process Safety

	Construct	1 - ESE	2 - ESP	3 - SWE
1.	Employee's engagement in safety (ESE)	*0.85*		
2.	Employees' safety performance (ESP)	0.83**	*0.90*	
3.	Safe working environment (SWE)	0.82**	0.88**	*0.91*
	Average variance extracted (AVE)	0.72	0.80	0.83
	Cronbach's α	0.85	0.89	0.89
	Composite reliability	0.96	0.92	0.94
	Factor loadings	0.80 – 0.91	0.88 – 0.91	0.84 – 0.98

Note: N = 180; all are significant at ** p < 0.01, values on the diagonal are the square-root of the AVE for each construct

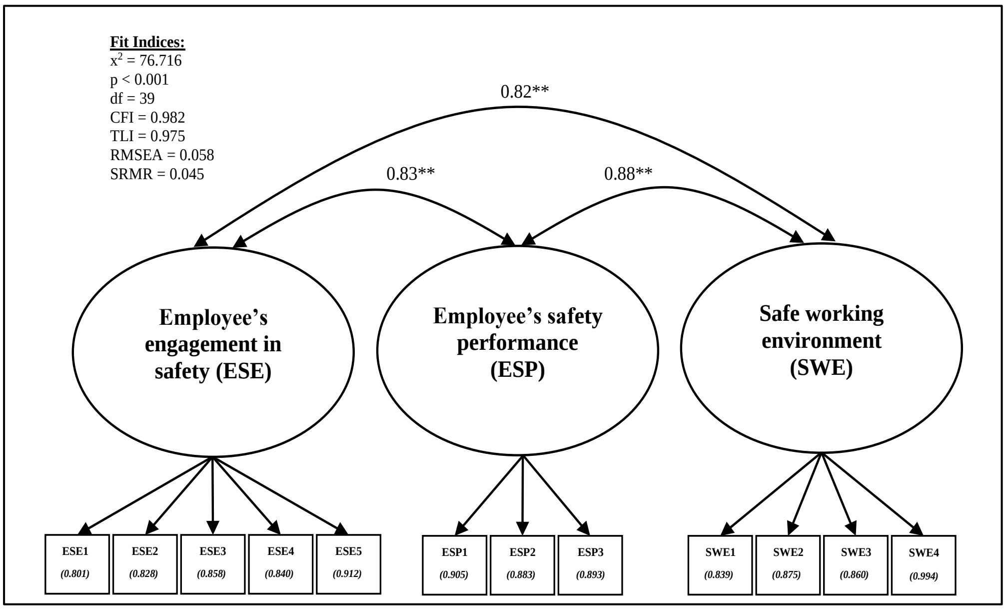


Figure 11. The dimensions of Process Safety.

Note: *N*=180, all are significant at ** *p* < 0.001, factor loadings are in parentheses and italic.

5.2.4 PHASE 4: TEST OF THE PROPOSED FACTOR STRUCTURE OF PROCESS SAFETY

This study suggests that process safety is a hierarchical, multidimensional construct based on the preceding discussions. Process safety can be conceptualised as a second-order factor model. Consistent with Prussia et al. (2019), this study examined this model in three stages. The first step was to test the 12 indicators of process safety. As shown in Table 12, the model indicates a satisfactory fit ($\chi 2$ = 82.898, *df* = 39; CFI = 0.972; TLI = 0.953; RMSEA = 0.079; SRMR = 0.062). These results suggest that the 12 indicators are adequate to measure process safety. The second step was to test the three dimensions of process safety. As shown in Table 3, the model suggests a good fit ($\chi 2$ = 62.697, $p < 0.01$, *df* = 39; CFI = 0.985; TLI = 0.975; RMSEA = 0.058; SRMR = 0.045). The final step was to assess the three dimensions of process safety, to which this study models process safety as the overall second-order factor model. All three dimensions have between three and five items. As shown in Table 15, this proposed model indicates a good fit ($\chi 2$ = 63.168, *df* = 39; CFI = 0.985; TLI = 0.976; RMSEA = 0.057; SRMR = 0.042). These results suggest that the three dimensions are suitable for and capable of measuring process safety in a process industry context. All three stages of the proposed hierarchical structure of process safety are well supported, thus demonstrating the validity of the full model of process safety. In this context, process industry workers evaluate process safety on the three dimensions and observe process safety as a higher-order factor corresponding to the 12 indicators. Figure 12 shows the second-order factor model of process safety.

Table 15. Summary of Fit Indices for the Proposed Factor Structure of Process Safety

Model assessments	χ^2	Df	CFI	TLI	RMSEA	SRMR
Model 1: test of process safety indicators	82.898	39	0.972	0.953	0.079	0.062
Model 2: test of process safety dimensions	62.697	39	0.985	0.975	0.058	0.045
Model 3: test of the second-order factor	63.168	39	0.985	0.976	0.057	0.042

Note: $N = 180$

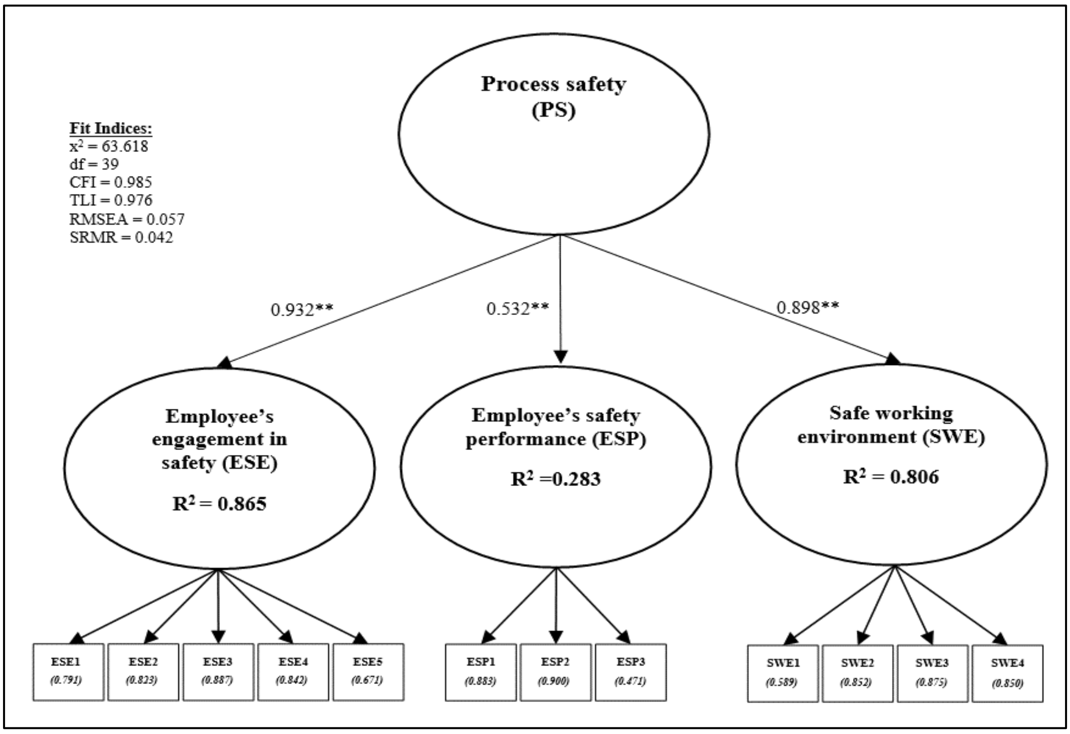


Figure 12. The Second Order Factor Model of Process Safety.

Note: N=180, all are significant at ** $p < 0.001$, factor loadings are in parentheses and italic.

5.2.5 THE MAIN STUDY

In the main study, a replication model was run with a new data set in the main study to measure the relationships between process safety and its theoretically related constructs through nomological testing. The extant literature has offered affluent evidence in support of the links between safety climate and process safety.

The middle and lower management level workers in TAKREER were selected for process safety evaluations for the main study. The data for this study were collected through online survey sites because it provides ease of data gathering at minimal costs (Hatfield & Boufous, 2016). The invitation to participate in the research was anonymous to the workers' email with the approval of TAKREER. Employees who agreed to participate would be led to the survey pages upon completing the data collection procedure. A total of 545 participants who were recruited completed the questionnaire. This study's participants were 545 workers with various jobs at TAKREER. Of the participants, 404 (74.1%) were male, and 141 (25.9%) were female. The workers' ages ranged from 25 to 60 years, with a mean age of 35.6 years (*SD* = 0.82). In terms of the highest educational level attained, 175 participants (32.1%) held a high school diploma or technical certificate, 246 (45.1%) held an undergraduate university degree, and 124 (22.8%) held a graduate university degree. Job tenure ranged from one year to 30 years, with mean job tenure of 15.4 years (*SD* = 0.73). Most participants were Emirati (262; 48.1%); 50 (9.2%) participants were from other Gulf Cooperation Council states, and 40 (7.3%)

participants were from other Middle Eastern or North African nations. The remaining participants were North American (30; 5.5%), Asian (128; 23.5%), African (33; 6.1%), and others (2; 0.4%). Regarding job positions, 67.3% worked at the lower management level, and 32.7% worked at the middle management level. Table 16 summarised the demographic sample of the study. From 545 participants, 53.6% were generated from the first wave of the data collection between May and June 2019, while 46.4% was from the second wave of data collection between August and September 2019.

Table 16. Frequency and Percentage of Demographic Variables

Variables		**Frequency**	**Percentage**
Gender	Male	404	74.1
	Female	141	25.9
Age	22 – 30 years old	172	31.6
	31 – 40 years old	249	45.7
	41 – 50 years old	101	18.5
	51 – 60 years old	23	4.2
Education	High school diploma or technical certificate	175	32.1
	Undergraduate university degree	246	45.1
	Postgraduate university degree	124	22.8
Job tenure	One year to 5 years	112	20.6
	6 years to 15 years	250	45.6
	16 years to 30 years	183	33.6
Nationality	Emirati	262	48.1
	Gulf Cooperation Council states (except Emirati)	50	9.2
	Middle Eastern or North African nations	40	7.3

	North American	30	5.5
	Asian	128	23.5
	African	33	6.1
	Others	2	0.4
Job level	Lower management level	367	67.3
	Middle management level	178	32.7
Segments	Wave 1	292	53.6
	Wave 2	253	46.4

5.2.5.1 NORMALITY OF DISTRIBUTION

The data was also generally distributed because all studied items were found between ± 2 for skewness and ± 7 for kurtosis (P = .000 < 0.001). These values were consistent with the suggestion by Kim (2013) and West, Finch, and Curran (1995) that for sample sizes larger than 300, ± 2 for skewness and ± 7 for kurtosis are appropriate as reference values for determining normality of data. Furthermore, the scores of many scales used in social sciences are positively or negatively skewed, which does not necessarily indicate problems with the scales (Field, 2013; Hair et al., 2010).

5.2.5.2 EXPLORATORY FACTOR ANALYSIS

All items were grouped under respective variables and summarized in Table 17 based on the eigenvalues and factor loadings from the EFA. The EFA revealed that all variables were sufficient, and no issue of multicollinearity existed [$\chi 2$ (351) = 6470.524, $p < 0.05$, KMO = 0.951]. The results were consistent with the cut-off values suggested by Hair et al. (2010). All factor loadings were greater than 0.50, KMO was greater than 0.50, Bartlett’s significant value was greater than 0.05, and eigenvalues were greater than 1.0. This research aligns with the theoretical view of process safety and safety climate (i.e., literature-based approach) and the workers’ perception of process safety (i.e., survey-based empirical assessment) through the EFA procedures.

Table 17. Summary of Exploratory Analysis

Dimension	**Items**	**Number of items**	**Mean**	**SD**	**Factor loadings**	**Eigenvalues**	**Total variance explained**
Employees' safety engagement (ESE)	ESE1	5	5.94	0.861	0.756	2.827	56.542
	ESE2		5.81	0.832	0.763		
	ESE3		5.89	0.885	0.814		
	ESE4		5.81	0.895	0.722		
	ESE5		5.82	0.898	0.700		
Employees' safety performance (ESP)	ESP1	3	5.93	0.838	0.826	1.957	65.233
	ESP2		5.85	0.856	0.821		
	ESP3		5.87	0.856	0.775		
Safe working environment (SWE)	SWE1	4	5.95	0.959	0.708	2.270	56.742
	SWE2		5.95	0.820	0.747		
	SWE3		5.89	0.844	0.815		
	SWE4		5.70	0.920	0.740		

Top management commitment to safety (TMCS)	TMCS1	5	6.13	0.819	0.763	2.748	54.954
	TMCS2		5.91	0.801	0.759		
	TMCS3		5.92	1.020	0.732		
	TMCS4		5.92	0.921	0.729		
	TMCS5		5.95	0.854	0.722		
Top management safety practices (TMSP)	TMSP1	5	5.88	8.23	0.676	2.916	58.324
	TMSP2		5.97	0.846	0.748		
	TMSP3		5.98	0.848	0.784		
	TMSP4		5.97	0.858	0.724		
	TMSP5		5.99	0.887	0.778		
Supervisory safety behaviour (SSB)	SSB1	5	5.90	0.920	0.772	3.054	61.084
	SSB2		5.86	0.904	0.771		
	SSB3		5.90	0.873	0.828		
	SSB4		5.81	0.938	0.767		
	SSB5		5.91	0.856	0.768		

5.2.5.3 CONFIRMATORY FACTOR ANALYSIS

The correlated model examined three dimensions of process safety (i.e., employee engagement in safety (ESE), employee safety performance (ESP), safe working environment (SWE), top management commitment to safety (TMSC), top management safety practices (TMSP), and supervisory safety behaviour (SSB). The results of the CFA model indicate a good fit ($\chi 2$ = 509.000, $p < 0.01$, $df = 282$; CFI = 0.964; TLI = 0.955; RMSEA = 0.038; SRMR = 0.033). As shown in Table 15, all variables were found to be positively correlated ($0.594 \leq r \leq 0.722$, $p < 0.001$; see Table 18), and the square root of AVE were more than correlation values (Fornell & Larcker, 1981). The CFA loadings for all items ranged from 0.59 to 0.78, were statistically significant, and were loaded onto their respective factors, as shown in Table 16. All Cronbach's alpha (α) and composite reliability values far exceed 0.70, which supports the construct reliability of the process safety dimensions (see Table 19). The results showed adequate convergent and discriminant validity: AVEs exceeded 0.50 (Kline, 2010), and the square roots of AVE values exceeded the construct correlation values (Fornell & Larcker, 1981). Furthermore, all factor loadings were greater than 0.50, 0.50, and the t-values were statistically significant ($p < 0.01$) (Hair et al., 2010). This study had no issue of multicollinearity because all correlation values were less than 0.80 as suggested by scholars (Cohen, Manion, & Morrison, 2007; Winship & Western, 2016; Yoo et al., 2014). The results indicate that the comprehensive validation procedures have established that all studied variables constitute a good measurement instrument.

Table 18. Correlations Coefficient of the Studied Variables

	Dimensions/ Variables	**1-TMCS**	**2-TMSP**	**3-SSB**	**4-ESE**	**5-ESP**	**6-SWE**
1	Top management commitment to safety (TMCS)	(0.728)					
2	Top management safety practices (TMSP)	0.722	(0.718)				
3	Supervisory safety behaviour (SSB)	0.603	0.642	(0.715)			
4	Employee’s engagement in safety (ESE)	0.699	0.688	0.691	(0.718)		
5	Employee’s safety performance (ESP)	0.594	0.637	0.634	0.692	(0.725)	
6	Safety working environment (SWE)	0.713	0.671	0.695	0.609	0.668	(0.727)

Note: N = 545; square-root of AVEs are on diagonal within parentheses

Table 19 Factor loadings, Reliability values, AVEs of Studied Variables

Dimension	**Items**	**Number of items**	**Factor loadings**	**AVE**	**Cronbach's Alpha**	**Composite reliability**
Employees' safety engagement (ESE)	ESE1	5	0.798	0.515	0.715	0.840
	ESE2		0.746			
	ESE3		0.768			
	ESE4		0.640			
	ESE5		0.620			
Employees' safety performance (ESP)	ESP1	3	0.648	0.526	0.723	0.768
	ESP2		0.782			
	ESP3		0.740			
Safe working environment (SWE)	SWE1	4	0.790	0.528	0.724	0.816
	SWE2		0.610			
	SWE3		0.775			
	SWE4		0.719			
Top management commitment to safety (TMCS)	TMCS1	5	0.790	0.530	0.726	0.848
	TMCS2		0.788			

	TMCS3		0.687			
	TMCS4		0.683			
	TMCS5		0.681			
Top management safety practices (TMSP)	TMSP1	5	0.767	0.515	0.717	0.841
	TMSP2		0.756			
	TMSP3		0.697			
	TMSP4		0.673			
	TMSP5		0.610			
Supervisory safety behaviour (SSB)	SSB1	5	0.734	0.512	0.714	0.839
	SSB2		0.674			
	SSB3		0.778			
	SSB4		0.678			
	SSB5		0.707			

5.2.6 BIFACTOR MODEL

Each indicator was loaded onto its subscale in the bifactor model, with top management commitment to safety (TMSP), top management safety practices (TMSP), supervisory safety behaviour (SSP), employee safety engagement (ESE), employee safety performance (ESP), and safe working environment (SWE) being orthogonal. As shown in Figure 13, the bifactor model was satisfactory but displayed a slight decrease in fit compared to the correlational model ($\chi 2$ = 1436.538; df = 324; $p < 0.01$; CFI = 0.961; TLI = 0.940; RMSEA = 0.041; SRMR = 0.040). The change in CFI ≤ 0.02 (ΔCFI = 0.003) and RMSEA were less than or equal to 0.03 (ΔRMSEA = 0.003); it indicated no significant differences between the models (Chen, 2007; Rutkowski and Svetina, 2014). The above models and their comparison between the CFI of different criteria that were less than 0.01 were consistent with Cheung and Rensvold (2002) suggestion: the correlational and bifactor models were not practically different. Fit indices suggested that all tested models had a satisfactory fit to the data, whereby the correlational model had a better fit than the correlational model.

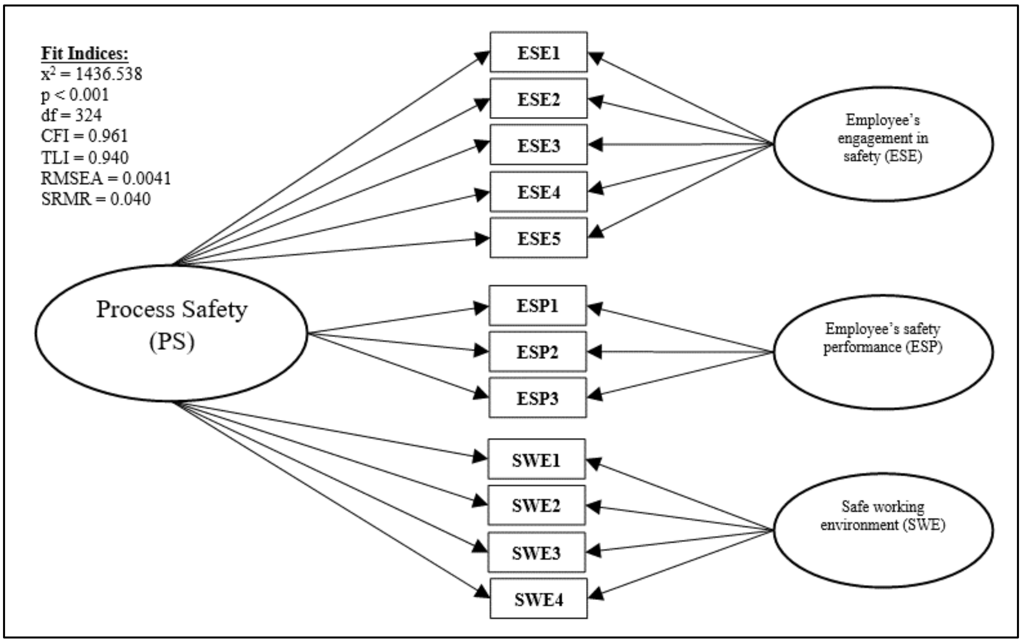


Figure 13. The Bifactor Model

5.2.7 MEASUREMENT INVARIANCE

The analysis ensued with the multi-group CFA to assess the measurement invariance—of whether the measurement model applies across groups (wave 1 = 292, wave 2 = 253, lower management level = 367, middle management level = 178). Through configurable invariance, metric invariance, and scalar invariance, measurement invariance reflects the extent of the underlying constructs measures across groups (Kline, 2015). In other words, it is expected that the model is similarly perceived across groups (i.e., despite the distinctiveness in terms of the level of management and timeline of data collection) through the testing for measurement invariance. Firstly, the indices observed revealed that the configurable model was satisfactorily fit the data across the management level and timeline of data collection accordingly. In particular, the indices for level of management were ($\chi2$ = 468.288; df = 282; p < 0.01; CFI = 0.963; TLI = 0.954; RMSEA = 0.048; SRMR = 0.0358), and timeline of data collection were ($\chi2$ = 215.691; df = 276; p < 0.01; CFI = 0.962; TLI = 0.950; RMSEA = 0.049; SRMR = 0.0396). The outcomes of the multi-group model assessment for configurable invariance thus concluded that the factor structure proposed in this study was constant across the management and timeline of data collection. Secondly, the indices reveal the metric model and its good fit for the gender, educational level, and employment status data. Changes in the fit are as follows: level of management (ΔCFI = 0.003, ΔRMSEA = 0.012, ΔSRMR = 0.0090); and timeline of data collection educational (ΔCFI = 0.004, ΔRMSEA = 0.003, ΔSRMR = 0.0016). Therefore, no changes of significance were seen in the fit for the configurable and metric models, whereby the indices demonstrated the factor loadings as consistent across the level of management and timeline in data collection. Thirdly, the metric and scalar invariance models comparison showed that the constant indices indicator intercepts across the level of management and timeline in data collection. The changes are as follows: level of management (ΔCFI = 0.001, ΔRMSEA = 0.001, ΔSRMR = 0.0002); and timeline of data collection educational (ΔCFI = 0.001, ΔRMSEA = 0.001, ΔSRMR = 0.0005). These results thus met the changes of CFI, RMSEA, and SRMR (ΔSRMR $\leq$ 0.015) values (Chen, 2007; Rutkowski and Svetina, 2014). Table 20 provides the summary of the model comparisons.

Table 20. Summary of the Model Comparisons

Model	χ^2	**df**	**CFI**	**TLI**	**RMSEA**	**SRMR**	**ΔCFI**	**ΔRMSEA**	**ΔSRMR**
Correlational model	509.000	282	0.964	0.955	0.038	0.033	-	-	-
Bifactor model	1436.538	324	0.961	0.940	0.041	0.040	0.003	0.007	-
Level of management									
M0 (configural)	468.288	282	0.963	0.954	0.048	0.0358	-	-	-
M1 (metric)	1292.100	564	0.960	0.950	0.036	0.0450	0.003	0.012	0.0090
M2 (scalar)	1292.101	564	0.959	0.950	0.035	0.0452	0.001	0.001	0.0002
Time line of data collection	215.691	276	0.962	0.950	0.049	0.0396	-	-	-
M0 (configural)	215.691	276	0.962	0.950	0.049	0.0396	-	-	-
M1 (metric)	281.288	552	0.958	0.946	0.046	0.0380	0.004	0.003	0.0016
M2 (scalar)	281.288	552	0.957	0.946	0.045	0.0385	0.001	0.001	0.0005

5.2.8 PHASE 5: NOMOLOGICAL VALIDITY OF STRUCTURAL MODEL

To evaluate the structural model's validity, the conceptualization of the safety climate scale is first averaged and computed from the scores of three dimensions (top management commitment, top management practices, and supervisory safety behaviour) by averaging the items under each dimension. As reported in Figure 14, path coefficients between safety climate and process safety in this structural model were positive and significant (β = 0.839; p < 0.001, R2 = 0.703). This model showed satisfactory model fit ($\chi 2$ = 212.934, *df* = 62; CFI = 0.947; TLI = 0.934; RMSEA = 0.067; SRMR = 0.0405). Safety climate also positively and significantly predicted employees' engagement in safety (β = 0.817, p < 0.001, R2 = 0.667), employees' safety performance (β = 0.683, p < 0.001, R2 = 0.467), and safe working environment (β = 0. 771, p < 0.001, R2 = 0.595). In addition, this nomological model indicated satisfactory model fit ($\chi 2$ = 249.957, *df* = 62; CFI = 0.934; TLI = 0.918; RMSEA = 0.075; SRMR = 0.0580). Thus, this study confirmed that safety climate has significant impact on process safety and its dimensions, supporting for H1. These relations are shown in Figure 15 and presented in Table 18 and being tested formatively (Maccallum et al. 1993).

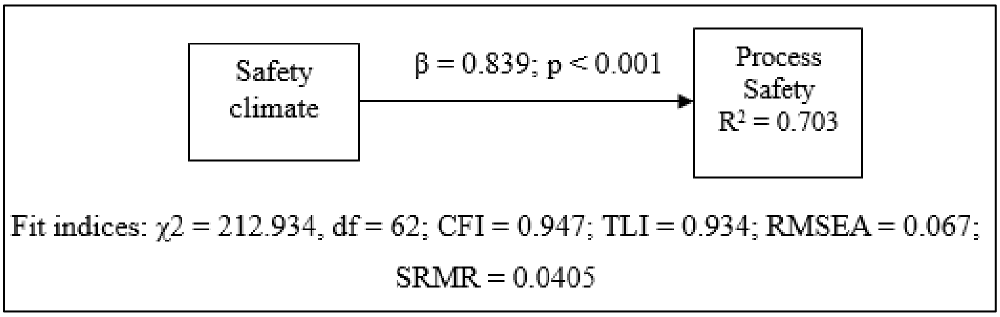


Figure 14. The relation between Safety Climate and Process Safety

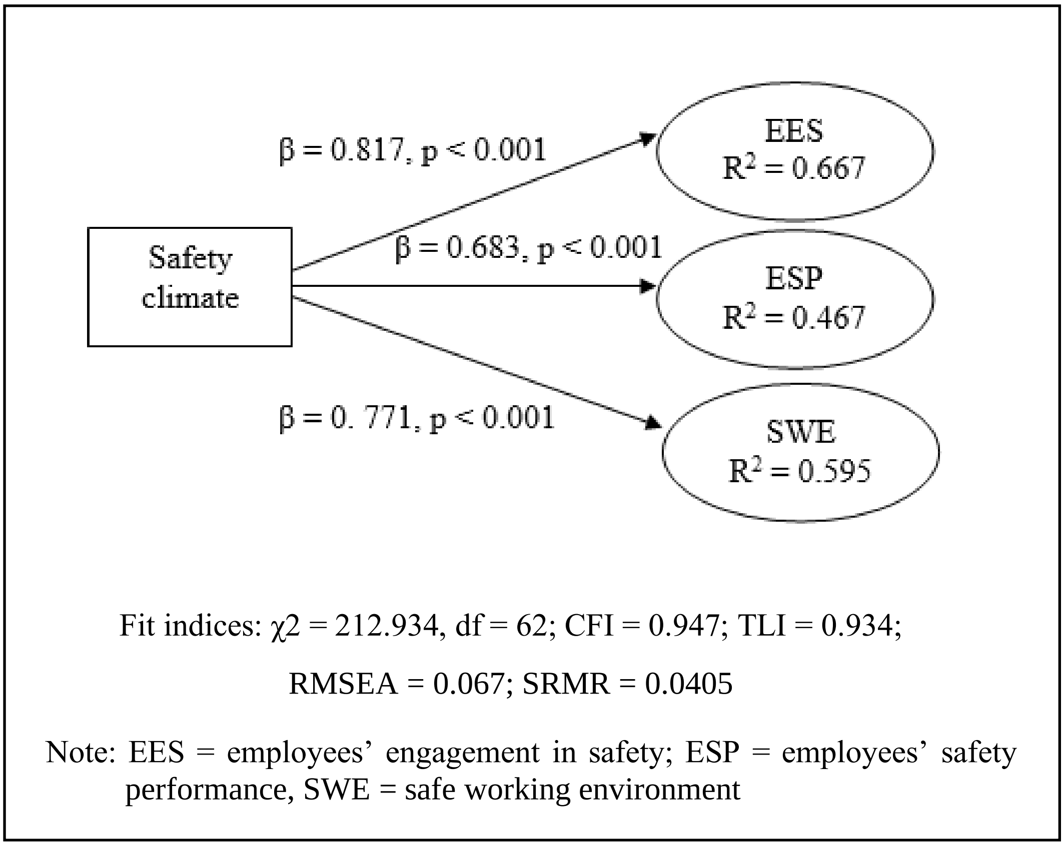
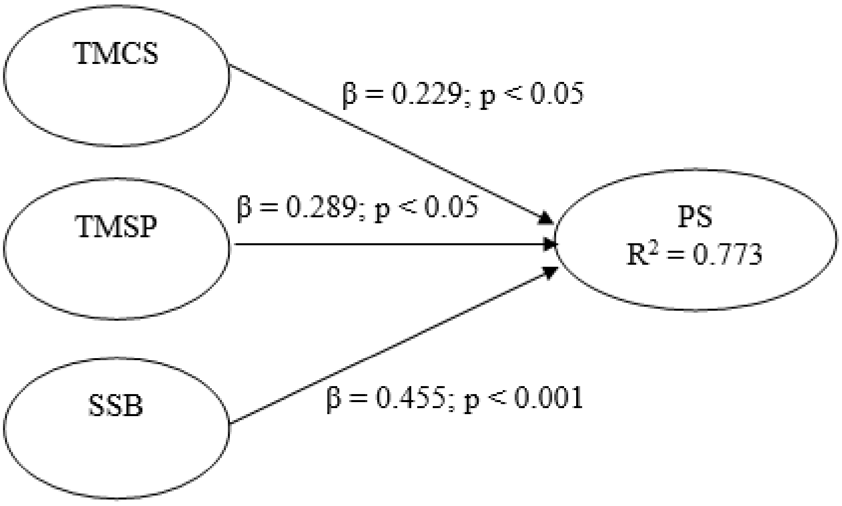


Figure 15. The relation between Safety Climate and Process Safety Dimensions

Similarly, the study estimated the relationship between top management commitment to safety (TMCS), top management safety practices (TMSP) and supervisory safety behaviour (SSB) on higher-order process safety (PS) confirmed that the path coefficients were significant at $p < 0.001$. Specifically, these arrayed constructs are theoretically related and highly influenced by safety climate factors, top management commitment, management practices, and supervisory safety behaviour. The extant literature has offered evidence supporting the links between safety climate and process safety (Dahl & Kongsvik, 2018; Saedi et al., 2020). As displayed in Figure 16, the result that the structural model is satisfactory fit the data ($\chi2$ = 719.965, df = 315; CFI = 0.935; TLI = 0.928; RMSEA = 0.049; SRMR = 0.0406). The results also presented top management commitment to safety (β = 0.229; $p < 0.05$), top management safety practices (β = 0.289; $p < 0.05$), and supervisory safety behaviour (β = 0.455; $p < 0.001$) significantly predicted process safety. Overall, top management commitment to safety, top management safety practices and supervisory safety behaviour explained 77% of the variance in process safety. The results demonstrate that the process safety scale is useful for explaining the effect of safety climate factors: top management commitment to safety, top management safety practices, and supervisory safety behaviour. These relations provide criterion-related evidence of nomological validity of the process safety scale. Thus, this study confirmed that top management commitment to safety, top management safety practices and supervisory safety behaviour significantly impact process safety, supporting H2, H3, and H4. All path coefficients are shown in Figure 12.



Fit indices: $\chi 2$ = 719.965, *df* = 315; *CFI* = 0.935; *TLI* = 0.928;

RMSEA = 0.049; *SRMR* = 0.0406

Note: TMCS = top management commitment to safety, TMSP = top management safety practices, SSB = supervisory safety behaviour, PS = process safety

Figure 16. The relation between top management commitment to safety, top management safety practices, and supervisory safety behaviour on process safety

5.3 RESULTS OF HYPOTHESES TESTING (MAIN EFFECTS MODEL)

The four hypotheses formulated on the research model were tested simultaneously in SEM-AMOS path modelling. The research model examined the path significance of hypothesised causality (beta coefficients), and variance (R2) explained by each path. The results confirmed the significant impact of presented top management commitment to safety management practices and supervisory safety behaviour on process safety, thus supporting all the hypotheses. The study synthesises all these findings in Table 21.

Table 21. Results of Structural Model

Structural model	**Path coefficient**	**Standard error**	**t statistics**	**Results**
HI: Safety climate → Process safety	0.839	0.049	17.844	Supported at $p < 0.001$
H2: Top management commitment to safety → Process safety	0.229	0.082	2.992	Supported at $p < 0.05$
H3: Top management safety practices → Process safety	0.289	0.087	3.140	Supported at $p < 0.05$
H4: Supervisory safety behaviour → Process safety	0.455	0.061	7.392	Supported at $p < 0.001$

H1: Safety climate has a significant positive impact on process safety in the context of the process industry

The relationship between safety climate and higher-order process safety (β = 0.839) was significant at $p < 0.001$) and explained 70.3% of process safety variance. Thus, safety climate satisfied the variance (see Tables 8.4 and 8.5) and emerged as a significant predictor of process safety in the ADNOC refinery.

H2: Top management commitment to safety has a significant positive impact on process safety in the process industry

The relationship between the top management commitment to safety and the higher-order process safety construct (β = 0.229) was significant at $p < 0.05$. Thus, top management commitment to safety was confirmed as a significant predictor of process safety in the ADNOC refinery context.

H3: Top management safety practices significantly impact process safety in the process industry context.

The relationship between top management safety practices significantly impacts process safety (β = 0.289) at $p < 0.05$. Thus, top management safety practices were confirmed as a significant predictor of process safety in the ADNOC refinery.

H4: Supervisory safety behaviour has a significant positive impact on process safety in the process industry

Supervisory safety behaviour displayed a significantly positive impact on process safety ($\beta = 0.455$) at $p < 0.001$. Process safety was predicted by top management commitment to safety, top management safety practices, and supervisory safety behaviour, which explained 77.3% of the overall variance. Supervisory safety behaviour is verified as a significant predictor of process safety in the context of ADNOC refinery.

Supervisory safety behaviour was a better predictor than top management commitment to safety and top management safety practices on process safety. These three safety climate factors were confirmed as predictors of process safety in the ADNOC refinery.

5.4 MODERATION ANALYSIS

The MSEM analysis was used to calculate the moderating effects of the safety climate on process safety performance. The MSEM is a method that compares the path coefficients of two groups (Ahmad & Khalid, 2017; Davidov et al., 2012). In this study, the respondents were split into two groups based on their safety training perceptions. Those with a high level of safety training were placed in the high trust group ($n = 403$), whereas those with a low level were classified into the low safety training group ($n = 142$). The significant estimation of the difference between the two groups by comparing the $\chi 2$ statistics of the cross-group equality constraint model and the unconstrained model. If there are meaningful differences between them, it is evidenced by the moderating effects of safety training on the correlations among top management commitment to safety, top management safety practices, and supervisory safety behaviour on process safety. The significance of the difference between the two models can be identified by $\chi2/df$ variation ($\Delta\chi2/ df$). When a df change is 1, the result is statistically significant at 0.05% significance level if the variation of $\chi2$ exceeds 3.841 (Preacher, Zhang, & Zyphur, 2016; Zyphur, Zhang, Preacher, & Bird, 2019). The relative importance of the coefficient can be determined using standardised path coefficients. In MSEM, standardised path coefficients are thus used to compare each group. Table 22 presents the results of the moderating effect of safety training. On the whole, the GFI met the recommended level (CFI = 0.946, *TFI* = 0.930, *RMSEA* = 0.030, *SRMR* = 0.0645). Simple slope analysis presented in Figure 17 shows the level of safety training between top management's commitment to safety, top management safety practices, and supervisory safety behaviour on process safety. Thus, H5 is rejected.

Table 22. Moderating Effects of Safety Training on Process Safety

Independent variable	**Dependent variable**	**Safety training**		**Unconstrained model**	**Constrained model**	**$\Delta\chi^2/df$**	**Result**
		Low ($N = 142$)	**High ($N = 403$)**				
All variables (Constrained)							
TMCS	PS	0.372	0.190*	χ^2 (545) = 818.976	χ^2 (542) = 815.705	$\Delta\chi^2(3) =$ 3.271; $p = 0.352$	Not moderated

Note: *** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level; regression weights are standardised estimates; TMCS = top management commitment to safety; TMSP = top management safety practices; SSB = supervisory safety practices

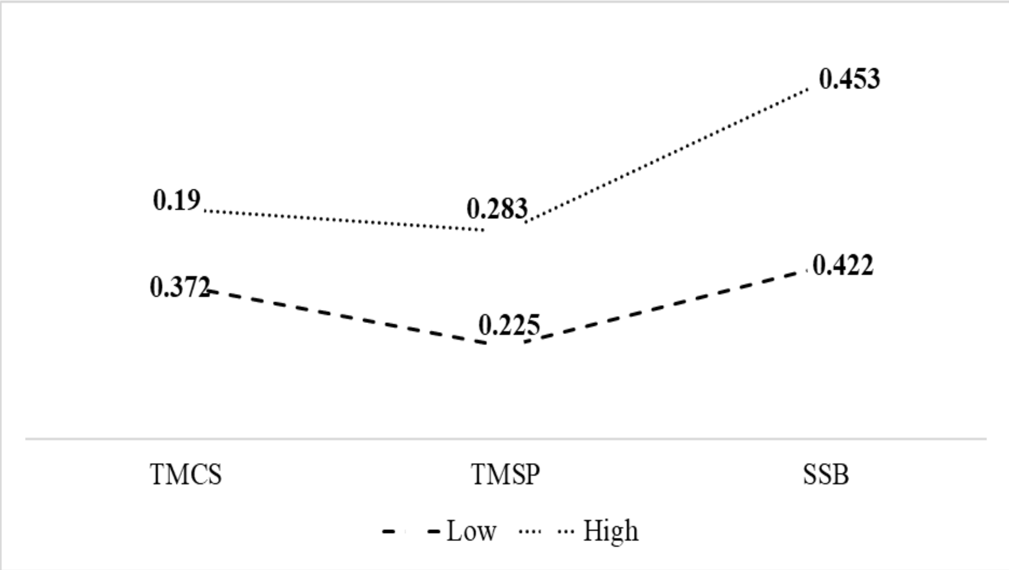


Figure 17. The Simple Slope Analysis of Moderation Effects

5.5 OVERALL FINDINGS OF HYPOTHESES TESTING

This study applied SEM-AMOS in estimating the hierarchical research model with moderating effects. The main effects model (i.e., top management commitment to safety, top management safety practices, and supervisory safety behaviour) was found to positively and significantly impact process safety. The overall findings of hypotheses testing are presented in Table 23.

Table 23. Results of Hypotheses Testing

Effects Model	Hypotheses	Results
Main effects	H1: Safety climate has a significant positive impact on process safety in the context of ADNOC refinery	Supported
	H2: Top management commitment to safety has a significant positive impact on process safety in the context of ADNOC refinery	Supported
	H3: Top management safety practices have a significant positive impact on process safety in the context of ADNOC refinery	Supported
	H4: Supervisory safety behaviour has a significant positive impact on process safety in the context of ADNOC refinery	Supported
Moderating effects	H5: The effects of top management commitment to safety, top management safety practices, and supervisory safety behaviour were different between the group with the high level of safety training and the group with the low level of safety training on process safety in the context of ADNOC refinery	Not Supported

Note: SC = Safety Climate; TMCS = Top Management's Commitment to Safety; TMSP = Top Management Safety Practices; SSB = Supervisory Safety Behaviour; ST = Safety Training

5.6 CHAPTER SUMMARY

The objective of this chapter was to confirm the measurement and structural properties of the research model by ensuring adequate reliability and validity. The study also aimed to assess the relationships among the model constructs and test four main hypotheses. Furthermore, the study aimed to examine the impact of safety training as a moderator in the relationship between top management commitment to safety, top management safety practices, and supervisory safety behaviour on process safety in the research model. To serve all these objectives, the study successfully applied SEM-AMOS modelling to estimate the parameters of the research model. The study's findings supported four main hypotheses (H1 - H4) and the main effects model's moderating hypothesis (H5). However, the results did not support the higher-order process safety construct (H5). An in-depth discussion of these results and their implications in terms of theory and practice are presented in the next chapter.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 OVERVIEW

This chapter aims to discuss the empirical findings of the previous chapter in terms of theoretical significance, methodological rigour, and practical contribution. The chapter briefly presents the findings addressing the two research questions of the study proposed in Chapter 1. The chapter also discusses how the results fill the existing knowledge gaps and contribute to process safety research in the ADNOC refinery context. Specifically, the contributions highlight that the study extends knowledge by reconceptualising safety theories theory, validating a hierarchical model and providing practitioners with a tool for integrated analysis and design process safety. The chapter also discusses limitations and future research directions with concluding remarks. Overall, the objective of this chapter is to elucidate the contributions of the study in terms of process safety in the process industry context.

This chapter is designed as follows: Section 6.2 reviews the research objectives of the study. Section 6.3 briefly presents research findings addressing the three research questions. Section 6.4 discusses the contributions of the study in terms of theory, method, and practice. Section 6.5 discusses the limitations of this study. Section 6.6 discussed future research directions. Finally, Section 6.7 provides concluding remarks for the entire study.

6.2 RESEARCH OBJECTIVE

The study's main goals were to investigate process safety dimensions and to assess the impact of top management safety commitment, top management safety practices, and supervisory safety behaviour on process safety. To pursue these objectives, this study utilised safety metaphors, models, and theories to test the hypothetical relationships among constructs. The following section goes over the empirical findings that support the theoretical relationships, the nature of the conceptual model, and relevant hypotheses. The entire discussion addresses the two research questions proposed in Chapter 1.

6.3 SUMMARY OF FINDINGS

This study answered two significant research questions that have been limitedly addressed in process safety research. The study developed and validated a context-specific, multi-dimensional, hierarchical process safety model in answering these questions. Later, the impact of top management commitment to safety (TMCS), top management safety practices (TMS) and supervisory safety behaviour (SSB) was modelled on process safety. The findings of the study are synthesised in the following sections, and its implications are discussed.

6.3.1 RESEARCH QUESTION 1: WHAT IS THE FACTOR STRUCTURE FOR PROCESS SAFETY?

To answer this question, this study provided an empirical illustration by developing a second-order, hierarchical-reflective process safety model using data from the process industry, ADNOC refinery. Consistent with the earlier studies, this study used repeated indicators (Taylor, et al., 2019; Zwetsloot, van Middelaar, & van der Beek, 2020) to estimate the higher-order latent variables and confirmed adequate measurement and structural properties.

To get a consistent and reliable result, engaging involved employees and working intensively with process safety was essential. The study sample comprised highly educated and skilled workers in a process industry, in which most of them had the minimum qualification of vocational diploma. Moreover, this study selected a large sample to produce more stable and reliable results to facilitate the generalisation of the outcomes

SEM-AMOS path modelling was used in the study to develop and validate the higher-order process construct (Casey, Neal, & Griffin, 2019; Roberts, Douglas, Overstreet, Ogden, & Schubert Kabban, 2018). The study showed that the process safety dimension was adequately reflected by three first-order dimensions (i.e., employees' safety engagement (ESE), employees' safety performance (ESP), and safe working environment (SWE)). The findings confirmed that employees' safety engagement had the greatest reflection of overall process safety, followed by a safe working environment and employees' safety performance. The relationship between process safety dimensions is discussed in the following sections with their empirical and theoretical insights.

6.3.1.1 EMPLOYEES' SAFETY ENGAGEMENT (ESE)

The empirical findings confirmed employees' safety engagement as a significant dimension of process safety to improve workplace safety in modern process industries. This relative importance of employees' safety engagement in process safety implies employees are expressing concern regarding health and safety hazards (e.g., provision of personal protective equipment, PPE, e.g., safety glasses and fall protection harnesses) (Cooper, 2015). The result is consistent with recent studies that highlighted employees' safety engagement as human factors affecting process safety (Prussia, Willis, & Rao, 2019). Thus, employees' safety engagement enables them to measure process safety by capturing the human factors and the non-technical factors of process safety (AlNabhani et al., 2016; Amyotte & Lupien, 2017; Jain et al., 2018). An association assessment indicated that 56.5% of overall variance (R2) in employees' safety engagement was explained by process safety, thus incorporating employees' safety engagement as an integral component of process safety. This association is supported by the models and theories that highlight that employee safety engagement explains a significant portion of overall process safety.

The study's findings also provided strong evidence that understanding the extent of employees’ safety engagement in process safety may assist in implementing PSM and reduce the adversity of incidents compared to previous performance. This finding is consistent with the literature, which suggests that employee safety engagement may advocate for the incorporation of human factors and other contextual factors likely to influence process safety (Behari, 2019; Hendershot, Herber, & King, 2011; Mearns, 2017; Ostroff, Kinicki, & Muhammad, 2012; Swuste et al., 2020a; 2020b).

Overall, the findings confirm employees’ safety engagement as a significant dimension of overall process safety in the process industry, particularly ADNOC refinery. This finding is also consistent with the suggestion by the Canadian Society for Chemical Engineering (CSChE), Organisational Safety and Health (OSH), and Energy Institute to incorporate human factors into process safety regulations and to set assessment standards.

As such, the findings suggest process industry should give much attention and include employees’ safety engagement factors in process safety risk assessment.

6.3.1.2 EMPLOYEES' SAFETY PERFORMANCE (ESP)

The empirical findings confirmed employee safety performance as a significant dimension of process safety, which explained 65.2% of overall process safety variance (R2). This relative importance of employees' safety performance in process safety implies safety-related behaviour at work (e.g., wearing PPE and encouraging co-workers to wear PPE (Neal & Griffin, 2006). This association highlights that employees' safety performance is the essential component among the three first-order components. The findings indicate that the process industry must focus on employees' voluntary safety behaviour perspective rather than ensuring employee safety behaviour compliance. This finding reflects recent research that employees' safety performance assumed in the interaction between the top management, immediate supervisor and employees – the interpersonal process is crucial to employee's safety performance, affected more on voluntary participative behaviour than compliance (Paolillo, Silva, Carvalho, & Pasini, 2020; Shamim, Buang, Anjum, Khan, & Athar, 2019; Winge, Albrechtsen, & Arnesen, 2019).

This finding is consistent with the literature indicating that employees' perception of overall process safety is mainly influenced by the degree of behavioural psychology to drive safety-related behaviour at work (Aryee & Hsiung, 2016; Hendershot 2012; Huang et al., 2016). It also indicates that the understandability of the employee's needs and the ability to provide collaborative environment attention are critical to improving process safety in the process industry environment.

Overall, the findings support employees' safety performance as a significant dimension of overall process safety in the context of the ADNOC refinery. These findings are consistent with the suggestion from extant literature, which indicate that employee's safety performance measurement is necessary for accident prevention in organisations with complex technological systems (Gao et al., 2019; Liaw, 2019; Naqvi et al., 2019). Further, it fulfils the gap in the current PSM that was argued to insufficiently touch on the human psychological context in mitigating risk (Anwar et al., 2019; Theophilus et al., 2017). The findings also suggest that this element of process safety is an essential component between safety risk management-employee psychology interaction, which deserve equal attention in the context of risk mitigation and analysis, identification and analysis of hazards, accident modelling, and analysis of repercussions for PSM.

6.3.1.3 SAFE WORKING ENVIRONMENT (SWE)

Results of the study supported a safe working environment as a significant dimension of process safety by explaining 56.7% of the variance (*R2*). This relative importance of a safe working environment in process safety implies working conditions that do not harm employees and instead protect their well-being (e.g., routine healthcare check-ups and PPE tests and inspections) Sieberhagen, Rothmann, & Pienaar, 2009). The findings also indicated that a safe working environment benefits process safety are critical in forming overall PSM. These findings support earlier research that argued the critical role of employees' perception between a safe workplace and decent working environment (Naqvi et al., 2019) and the critical role of human factors in managing key process safety risks (Behari, 2019).

This finding is consistent with the literature indicating that a safe working environment is one of the critical elements that can improve process safety maturity (Halim & Mannan, 2018; Liaw, 2019; Swuste et al., 2016). Safety working environment will encourage a willingness to accept accountability and enhanced trust - linked with adequate process safety incident reporting and organisational learning. It also indicates a clear association with human conditions in process safety in the process industry environment (Aziz & Mohd Shariff, 2017; Swuste et al., 2016). Overall, the findings confirm a safe working environment as a significant dimension of overall process safety.

In sum, the findings suggest that three second-order dimensions (i.e., employees' safety engagement (ESE), employees' safety performance (ESP), and safe working environment (SWE)) are critical components of process safety in the process industry environment. Although the results show the varying impact of these dimensions, it is noteworthy that the differences in magnitude were minor, and all the components were proven significant. Thus, the results confirm that the process safety should be based on a robust platform, dynamic interaction, and meaningful outcomes to satisfy the PSM - advocate integrating human factors and additional contextual factors likely to influence process safety (Behari, 2019; Hendershot, Herber, & King, 2011; Mearns, 2017; Ostroff, Kinicki, & Muhammad, 2012; Swuste et al., 2020a; 2020b).

6.3.2 RESEARCH QUESTION 2: DOES SAFETY CLIMATE INFLUENCE PROCESS SAFETY?

6.3.2.1 THE RELATIONSHIP BETWEEN SAFETY CLIMATE AND PROCESS SAFETY (H1)

This study modelled the impact of overall safety climate factors (i.e., top management commitment to safety, top management safety practices, and supervisory safety behaviour) on the overall safety process model to answer this question. The study results confirmed a strong significant, and positive relationship between safety climate and process safety ($\beta = 0.839$; $p < 0.001$, R2 = 0.703) in the structural model. This result also consistent with the relation between safety climate and the first order dimension of process safety; employees' engagement in safety ($\beta = 0.817$; $p < 0.001$, $R2 = 0.667$), employees' safety performance ($\beta = 0.683$; $p < 0.001$, $R2 = 0.467$), and safe working environment ($\beta = 0.771$; $p < 0.001$, $R2 = 0.595$). The finding indicated that process safety is heavily influenced by organisational safety climate. Safety climate affects employees' engagement in safety followed by a safe working environment, and the least on employees' safety performance. This finding supports earlier research that argued positive contributions of safety climate effects on the employees' process safety (de Almeida & Vinnem, 2020).

This finding is consistent with the literature that proposes action theory as a framework for understanding why safety climate and process safety are causally related (Dekker et al., 2011; Griffin & Neal, 2000; Kiani & Khodabakhsh, 2013; Kouabenan et al., 2015). According to action theory, objective situational factors such as top management commitment to safety, top management safety practices, and supervisory safety behaviour are social actions that must be considered within organisational systems of action orientation (Griffin & Neal, 2000). According to this theory, safety climate is an emergent model because of complex reciprocal interactions and relationships about safety priority based on how safety climate factors influence action (Dekker, Cilliers, & Hofmeyr, 2011). Other research also supports action theory's suggestion about the relationship between safety climate factors and process safety (Kiani & Khodabakhsh, 2013; Kouabenan, Ngueutsa, & Mbaye, 2015). As a result, various multilevel top management roles tend to have strong relationships with process safety. Overall, the findings confirm safety climate as a significant factor of overall process safety.

In sum, this finding provides a based line analysis for the following three hypotheses nested in the base model. Furthermore, the study examined and reported critical results on the moderating effects of safety training on the research model. In the following sections, the significance of all these findings is discussed.

6.3.2.2 THE RELATIONSHIP BETWEEN TOP MANAGEMENT COMMITMENT TO SAFETY AND PROCESS SAFETY (H2)

The findings confirmed top management commitment to safety as a significant predictor of process safety ($\beta = 0.229$; $p < 0.05$, $R2 = 0.773$). This association indicates that top management commitment to safety is one of the major drivers of process safety. Thus a high level of top management commitment to safety is critically important to employees. Besides, this association proves that employees' concern about top management commitment to safety directly impacts process safety in the process industry setting. The findings suggest that the process safety in the process industry will depend on employees' perception of the level of top management commitment to safety, and their attitudes will be depending on whether they believed that their top management is committed to effectively managing safety at the workplace (Kashwani & Nielsen, 2017; Khdair et al., 2011; Vongvitayapirom & Phusavat, 2013). Thus, in the context of safety risk management, it is necessary to assure adequate safety commitment by the top management to increase the employees' perceptions and then lead to positive process safety attitudes and behaviour.

This finding is consistent with the literature, which proposes action theory as a framework for understanding why top management commitment and process safety are causally related (Dahl & Kongsvik, 2018; Ho et al., 2018; Saedi et al., 2020). The result supports action theory that suggests social action reciprocates between what employees perceived, attitudes and behaviour. At the organisational level, social interaction at the workplace must be considered within systems of safety-action orientation (Vinodkumar & Bhasi, 2011). According to this theory, top management commitment to safety is an important driver in the complex reciprocal interactions and relationships between levels of management in the organisation. If these interactions and relationships are not perceived as necessary by the employees, priority on safety based might be compromised (Horbah et al., 2017). Other research backs up action theory's claim that the relationship between top management commitment to safety and process safety reflects on organisational levels of safety values (Dahl & Kongsvik, 2018; Musa et al., 2015; Vongvitayapirom & Phusavat, 2013). Thus, top management commitment to safety roles tends to have robust relationships with process safety. Overall, the findings confirm top management commitment to safety as a significant factor of overall process safety.

6.3.2.3 THE RELATIONSHIP BETWEEN TOP MANAGEMENT SAFETY PRACTICES AND PROCESS SAFETY (H3)

The results found satisfaction as a significant predictor of continuance intentions ($\beta = 0.289$; $p < 0.05$, $R^2 = 0.773$). This finding indicates that a higher level of top management safety practices among the employees creates greater process safety at the workplace (Gao et al., 2019; Saedi et al., 2020). In other words, this relationship implies that the level of employees' process safety depends on the top management role in efficiently practising safety at the workplace. The existing literature also supports safety formation through top management safety practices that foster continuous intentions and conscious safety, which influence the safety climate and overall workplace safety culture. (Kashwani & Nielsen, 2017). This relationship is particularly relevant in the process industry, where the interactive safety climate influences the process safety experience. The findings also suggest that the process industry should develop a positive safety environment to create a positive perception of safety attitudes and voluntary behaviour on safety activities. As such, the study results identified top management safety practices as a necessary factor to impact process safety at the workplace. Thus, process safety should consider their roles – in demonstrating good safety behaviour and practices as important strategic objectives to scale and sustain process safety in high-risk industries such as the O&G industry.

This finding is consistent with the literature suggesting action theory as a framework to understand why top management safety practices and process safety are causally related (Dahl & Kongsvik, 2018; Ho et al., 2018; Saedi et al., 2020). The result supports action theory that suggests social action reciprocates between what employees perceived, attitudes and behaviour. The social interaction at the workplace must be considered within systems of safety-action orientation at the organisation level (Vinodkumar & Bhasi, 2011). According to this theory, top management safety practices are an important driver in the complex reciprocal interactions and relationships between levels of management in the organisation. If these interactions and relationships are not perceived as necessary by the employees, priority on safety based might be compromised (Saedi et al., 2020). Other research also supports action theory's suggestion about the relationship between top management safety practices and process safety reflects on employee development on safety values (Dahl & Kongsvik, 2018; Horbah et al., 2017; Kashwani and Nielsen, 2017). Thus, top management safety practices tend to have robust relationships with process safety. Overall, the findings confirm top management safety practices as a significant factor of overall process safety.

6.3.2.4 THE RELATIONSHIP BETWEEN SUPERVISORY SAFETY BEHAVIOUR AND PROCESS SAFETY (H4)

The findings confirmed that supervisory safety behaviour was a significantly predictor of the higher-order process safety construct ($\beta = 0.455$; $p < 0.001$, R2 = 0.773). This finding indicates that perceptions of supervisory safety behaviour contribute to employees' process safety or process safety in the O&G environment. This relationship is significant in the O&G context, where the interactive nature of the immediate supervisor, middle, and lower-level employees influences the process safety experience. Since supervisory safety behaviour was a stronger predictor of process safety in the context of the process industry, employees with a high perception of safety behaviour of their supervisor tend to change their attitudes and behaviour accordingly to align to their supervisors' safety behaviour. Mutual understanding of social contract between immediate supervisor and middle and lower-level employees may firmly control and influence employees' attitude and action on process safety. This study identifies supervisory safety behaviour as the main predictor of process safety. It confirms the instrumental role of supervisory safety behaviours' role in positively shaping this outcome. As immediate social relation between supervisor, middle, and lower-level employees at the workplace is mutually exclusive, this study also confirms that association by linking supervisory safety behaviour and process safety in the context of process safety (Saedi et al., 2020). Therefore, a positive reflection on day-to-day human relations at the workplace plays a huge role in creating and optimising process safety to control operations by assessing and mitigating human error between supervisor, middle and lower-level employees (Naqvi et al., 2019). Therefore, the findings confirm a richer understanding of the role of supervisory safety behaviour in improving process safety among middle and lower-level employees at the workplace.

This finding is intriguing because supervisory safety behaviour has a positive bivariate correlation with process safety. Earlier studies have also found that workers tend to violate process safety procedures and behave unsafely due to work pressure from supervisors and managers, rather than a lack of awareness of the risks involved (e.g., Choudhry & Fang, 2008; Kiani & Khodabakhsh, 2013; Luria et al., 2008). Workers may take shortcuts in work processes to avoid negative consequences and to satisfy their bosses. As a result, production pressure tends to lead to unsafe processes by decreasing workers' safety motivation. Moreover, production pressure may cause managers and supervisors to temporarily prioritise production over safety and, thus, ignore some process safety indicators to stay on schedule.

Consequently, supervisory safety behaviour can negatively affect workers' safety processes. Wachter and Yorio (2014) indicate that PSM systems and practices depend on the levels of safety focus and workers' cognitive and emotional states. Workers' perceptions may affect an organisation's process safety even within an environment of highly structured safety management systems. These findings support previous research findings that process safety should extend beyond engineering and technical elements (Hendershot, 2012;

Hofmann et al., 2017; Wurst & Cornelisen, 2013) by also aiming to influence the psyches and personalities of employees (Cooper, 2003).

The value of social support in process safety has long been recognised in the process industry. This result is consistent with recent studies arguing that supervisory safety behaviour creates positive safety behaviour among workers. Top management commitment to safety also influences workers' process safety in the workplace (Ladewski & Al-Bayati, 2019; Yu et al., 2019). Previous research has shown that frontline supervisors significantly influence their employees' safety behaviour, directly affecting process safety (Behari, 2019; Gao et al., 2019). Social support has played an essential role because frontline workers are more likely to be influenced by their daily interactions with supervisors and co-workers (Oah, Na, & Moon, 2018; Xu, Qin, Dust, & DiRenzo, 2019).

In comparison to top management safety commitment and top management safety practices, social support plays a unique role in the workplace and is perceived differently by different employees (Amponsah-Tawiah & Mensah, 2016). Social support is understood as a factor that shapes behaviour at the group level. At the same time, top management safety commitment and safety practices mainly influence the upper-level management of an organisation (Huang, Lee, McFadden, Rineer, & Robertson, 2017). Past studies have proved that the social support of supervisory safety behaviour facilitates process safety and, thus, is vital to improving the safety climate (Hanvold et al., 2019; Liang & Zhang, 2019).

This finding is consistent with the literature suggesting action theory as a framework to understand why supervisory safety behaviour and process safety are causally related (Behari, 2019; Saedi et al., 2020). The result supports action theory that suggests social action reciprocates between what employees perceived, attitudes and behaviour. The social interaction at the workplace must be considered within systems of safety-action orientation at the organisation level (Vinodkumar & Bhasi, 2011). According to this theory, supervisory safety behaviour is essential in the complex reciprocal interactions and relationships between management levels. If these interactions and relationships are not perceived as necessary by the employees, priority on safety based might be compromised (Lu & Chen, 2015). Other research supports action theory's suggestion about the relationship between supervisory safety behaviour and process safety immediately impacting employees' safety values (Brandhorst & Kluge, 2018). Thus, the role of supervisory safety behaviour tends to have robust relationships with process safety. Overall, the findings confirm supervisory safety behaviour as a significant predictor of overall process safety.

6.3.2.5 THE MODERATING ROLE OF SAFETY TRAINING (H5)

Although recent studies have argued that the moderation role of safety training is important for measuring the link between safety climate and process safety, future research is warranted due to its fragmented findings (Butler et al., 2019; Gao et al., 2019; Iqbal et al., 2019; Naqvi et al., 2019; Zhang et al., 2019), the results of the study did not support the moderating effects of safety training on top management commitment to safety, top management safety practices, supervisory safety behaviour on process safety relation. The moderating role of inadequate safety training between top management commitment to safety and process safety is insignificant ($\beta = 0.372$, $p > 0.05$). A similar relationship was found between top management safety practices and process safety when moderated by inadequate safety training ($\beta = 0.225$, $p > 0.05$). However, the moderation effects in the relation between supervisory safety behaviour and process safety for inadequate safety training was found significant ($\beta = 0.422$, $p < 0.001$). The effect of high safety training that moderated the relation between top management commitment to safety ($\beta = 0.190$, $p < 0.05$), top management safety practices ($\beta = 0.283$, $p < 0.01$), supervisory safety behaviour ($\beta = 0.453$, $p < 0.001$), and process safety was found significant. The results showed that the sizes of the interaction effects were small ($\Delta\chi 2$ (3) = 3.271, $p = 0.352$), thus insignificant moderated. One plausible explanation of the reason safety training is not significantly influenced by an effect (process safety) rather than cognitive beliefs (safety climate factors: top management commitment to safety, top management safety practices, and supervisory safety behaviour); therefore, the moderation power of safety training as a theory is less pronounced (Loosemore & Malouf, 2019; Taofeeq, Adeleke, & Lee, 2020). The negative attitudinal-behavioural outcome of top management commitment to safety, top management safety practices, supervisory safety behaviour, and process safety link indicates that safety training is unavoidable as a separate construct in the research model to prove top management commitment to safety, top management safety practices, supervisory safety behaviour, and process safety link. In this study level of safety training does not affecting the employees' perceptions, attitudes, and participation in process safety, as well as develop a safe working environment through their safety, cognitive and psychological needs at the workplace. Swuste and colleagues (2020) contended that the organisations' process safety is largely dependent on workers and management skills and knowledge and skills from the training. In contrast, Saedi and colleagues (2020) suggested that it is, therefore, necessary to investigate employee perception on the level of safety training in connection with the entire structure of process safety. This argument aligns with Mkpat, Reniers, and Cozzani (2018) findings on process safety that revealed safety training remained grey in safety literature. A common background emerged, although possibilities for human optimisation of process safety are subjected to a meaningful experience of safety training among the employees (Naqvi et al., 2019). Thus, this study implies that the subjectivity of experience between employees does not depend on their perception of the effectiveness of the given training for accident prevention.

Though this study found the insignificant role of safety training in the relationship between safety climates factors of process safety, this study suggests the plausible safety climate to be an additional factor in safety climate to measure process safety. This suggestion is consistent with recent studies that revealed safety training has become compulsory in most process safety industries. However, workers may still perceive safety differently (Bhandari et al., 2019; Leder et al., 2019; Zhang et al., 2019). Old-fashioned learning methods were becoming outdated and useless for skills development because safety requires employees to develop from repetition training and real-life experiences (Vinodkumar & Bhasi, 2011). As a result, safety training identifies conveying information through written descriptions, which can only provide low levels of engagement. In contrast, simulations should provide a high degree of engagement because learning in a simulation is based on interactive elements, which allow for active participation and the opportunity to experience the consequences of one's actions.

6.4 CONTRIBUTIONS OF THE STUDY

The study discusses its contributions in terms of theory and practice. Theoretically, the study extends safety research and process safety research by reframing the concept as a reflective hierarchical construct of process safety and modelling its impact with top management commitment to safety, top management safety practices and supervisory safety behaviour in the context of the process industry in the UAE. In practice, the study provides managers with a process safety model for conducting integrated analysis and risk management analysis to prevent injury and accidents. Overall, the study makes a significant contribution to achieving support for the process industry, specifically, O&G industry generally and other high-risk sectors at significant context, above all, an improved understanding of the quality of human factor in process safety that has been consumed as engineering and technical domain.

6.4.1 CONTRIBUTION TO THEORY

This study extends process safety research in the safety domain by developing and validating a higher-order process safety model on three primary dimensions (i.e., employees' safety engagement, employees' safety performance and safe working environment). By encompassing the combined explanatory power of each component, the process safety model advances action theories in safety research while presenting an economic structure. The research argues that the approach conducted in this study adds the qualities of completeness and thoroughness to the theoretical work (Thunnissen & Gallardo-Gallardo, 2019; Whetten, 1989). In this manner, both the research process and results can be assured of high rigour and robustness. Specifically, the study contributes in several ways to process safety research in the O&G sector. Firstly, the study has defined the domain of three process safety constructs and their associated measurement instruments against the backdrop of safety research in the O&G context. Secondly, the study has identified a comprehensive, yet parsimonious, set of dimensions that help predict the interactive quality of human reliability factors in safety process safety research that have been limitedly studied and their association with safety climate constructs (i.e., top management commitment to safety, top management safety practices and supervisory safety practices). Thirdly, the study has explored characteristics specific to the human reliability factors, which provides a solution to the new and complex challenges in controlling the relation to process safety in optimising human performance and reducing human failure using diverse safety management strategies (Shqairat & Sundarakani, 2018).

The study adds novelty to the theory by modelling the association between overall process safety with the three most significant safety climate factors of top management commitment to safety, top management safety practices and supervisory safety practices, which have been limitedly investigated and unclear, especially in process safety research. Previous research has suggested that safety climate factors may have different effects on specific dimensions of process safety. Therefore, this study has focused on human factors variables rather than system maintenance and technical issues (i.e., Hendershot, 2012; Mearns et al., 2010; Pousette et al., 2017). These conceptualisations and evaluations are critical in understanding the role of process safety and its financial benefits when measured in terms of safety climate in establishing psychological investment for employees and return of investment for the organisation, supported by action theories. Firstly, given the infancy stage of process safety, it is necessary to evaluate safety climate to identify and replicate the best practices worldwide. This evaluation can ensure acceptable economic returns to process safety platforms in the process industry and high-risk industries, which is necessary for scalability and sustainability. This assessment is a direct contribution to theory as it examines the factors that influence human performance optimisation and reduces human failure using diverse safety management strategies in the context of the process industry in the O&G. Secondly, conceptualisation and evaluation of safety climate are significant because safety climate employs person, behaviour and situational factors that influenced the environmental causes of incidents. Although safety climate is well understood as a predictor of safety behaviour, its effect on process safety was limitedly researched. It was primarily related to psychological and observable factors that may differentiate the perceived safety value driven by motivation, emotion, attitudes, and other individual traits.

The study's findings thus address the concerns that regulators should pay much more attention to human factors to manage hazards in the process industries (Theophilus et al., 2018; Swuste et al., 2020). A unique feature of process safety in the process industries is that the framework for managing operating systems integrity and processes to handle hazardous petrochemical substances are affected by the human factors of workers' emotions, commitment, and cognitive biases, with potentially negative consequences for the resilience of safety systems and procedures. Since process safety research is a new area, scholars still strive to frame its impact on critical financial and psychological outcomes. Thus, this study extends the scope of process safety research in this new domain by modelling the effect of safety climate.

The uniqueness of the theory also lies in assessing the process safety of innovative safety research and can be considered a new research setting in high-risk industries based on the logical evidence of human reliability factors. Although in this study process safety research has proven to be instrumental for the safety research, there are few studies in safety research that have attempt to identify the human and psychological factors that lead to reliability in safety at the workplace (e.g., Amaya-Gómez et al., 2019; Anwar et al., 2019). However, these studies focused on process safety management (PSM) systems dedicated to the absence of PSM regulations and awareness. It is worth noting that process safety development had gain intention based on the appreciation of its history while drawing attention to the imminent failure to learn from previous events that contributed to the decrease of reputations, profitability, and sustainability, both economic and human loss (Kerin, 2017). Thus, in focusing on safety management, loss prevention, and occupational hazards in high-risk industries, especially the process industry in the O&G context, this study developed and validated the process safety model for a new setting. Whetten (1989) concurs the common elements in advancing theory development by applying it in contemporary settings as an improved tool rather than reaffirming its utility. Thus, the study believes that the proposed theoretical framework contributes to knowledge as most of its constructs and their relationships have not been the subject of prior theorising in this context. Thus, process safety research in the safety management domain opens up a new horizon that will bring fascinating new perspectives to the field. As Swuste and colleagues (2020) state, once the idea has been introduced, the concept's significance within the field encourages new work.

Because process safety is a core construct in safety research and action theory, the findings have critically impacted the theoretical contribution for safety research. Companies in UAE process industries can use our reliable and validated, non-technical, and non-engineering construct to measure process safety. This measure is essential in assessing workers’ receptivity to safety rules and regulations because they can better understand the processes, hazards, and consequences than other workers. Further, the complexity of the psychological–behavioural safety relationship can be further understood, recognised, and valued as an integral part of process safety efforts (Geller, 1997). The results are consistent with the suggestion by earlier studies that cognitive psychological factors are vital in safety research because they have multiple causal effects on safety governance, thoughts, and actions (Johari, Alam, & Said, 2018). The implication for the motivation of individual workers to expend efforts endorsing safety-related process behaviour is evidenced. Thus, many questions are raised concerning the role of human psychological factors in modifying and altering the dysfunctional condition between safety climate factors and psychological factors, which are mutually exclusive. Although human error is regarded as an essential component in action theory, the causative effect of human psychology on process safety failure is critically important in predicting reinforced attitudes and behaviour modification toward reducing safety-related accidents.

6.4.2 CONTRIBUTION TO PRACTICE

The scene-setting of this research is very important as it’s an eye-opener for the management of Abu Dhabi National Oil Company on the process safety aspects. This research is the first to investigate done this subject within ADNOC. After the unfortunate explosion in 2017, ADNOC had started seriously investing in many ways to mitigate all process safety accidents. Top management had participated in this research heavily, which made it unique. The implications of this research are highly relevant to process safety practices, the process industry and O&G sector in general. The findings indicate that middle and lower-level employees evaluate the process safety at an overall and dimensional level (employees’ safety engagement, employees’ safety performance and safe working environment). These findings improve the understanding of a manager and management level of the organisation on how employees evaluate process safety and relate this factor with safety climate in particular and safety culture in the general workplace environment. In particular, the establishment of safety institutions and the safety state of equipment among organisations ultimately depend on their managers and leaders. Therefore, the organisation's managers are particularly essential in building the employees’ trust in organisational safety. Employees' trust in managers and their daily safety management practices can directly improve their psychological and attitudinal decisions for process safety. The managers of organisations should pay attention to employees' safety of life and occupational health in the daily management process for employees to believe that the safety managers of their organisations are genuinely concerned about their safety and welfare. Hence, this study was focused on employees having management roles (i.e., lower management level of 55.6% and 44.4% middle management level).

Moreover, it’s worth mentioning that most of the participants are young and educated. Research finds that older respondents tend to give less precise signs of the attitudes, actions or other attributes being surveyed than do information received from younger respondents. Hence the selection of respondents makes this research is exceptional.

A fixed form and primary carrier of organisational safety culture is an institution. Thus, formulating a people-oriented yet practical safety institution and affectively implementing safety standards is crucial because the safety institution is one of the essential means to standardise the employees' intention to engage in process safety. An excellent organisational safety institution can promote the employees’ satisfaction and trust in the safety process. Employees can feel psychological safety and support during actual work. Therefore, the organisation should consider developing people-oriented safety participation rules that satisfy the middle and lower-level employees' existing working environment to encourage them to participate in process safety activities. Thus, organisational safety policies and institutions can be implemented well, motivating the employees’ sense of belonging.

Similarly, rules and regulations that guided the employee’s safety at the workplace should be established to allow employees to gradually internalise their process safety into the daily job at the workplace. In addition, institutional support should be provided and guaranteed for enabling employees to be psychological engage in safety management. Ensuring the establishment of safety institutions and rules can improve the enthusiasm and passion of employees to participate in safety activities. At the same time, employers can also provide them with peace of mind, bold suggestions, and further assistance. Moreover, the organisation should also open communication channels for allowing employees to engage in process safety activities. At the same time, managers can keep abreast of the employees' thoughts and ideas and facilitate the timely update and improvement of relevant safety institutional documents and rules. Based on the demographics of the respondents, this focused on employees with a significant amount of experience in process safety. Most of the respondents (40%) have between 16 to 30 years of experience, facilitating engagement with the fewer experience employees. The physiological state of experienced employees plays a significant role in passing expertise and confidence to deal with a different situation to avoid process safety accidents. One of the main reasons that caused the unfortunate explosion in one of ADNOC facilities in 2017 was lack of experience and a psychological state of mind.

Management of the process industry must also focus on employees' psychological state to create a positive process safety atmosphere. When employees trust the organisational safety management, their inner feelings generate a sense of psychological safety. This kind of psychological safety motivates the employees' safety engagement, safety performance and safe working environment. To establish trust in organisational safety management, the organisation should pay attention to the psychological state of middle and lower-level employees in daily safety management affairs and encourage them to participate in safety activities. Only when employees believe that the organisation can protect their safety and managers promote employees' safety will they reciprocate this mutual psychological contract with strong safety concerns and actively engage in process safety.

Furthermore, suppose middle, and lower-level employees believe that managers will respect and treat them equally in terms of process safety. In that case, the former will invest more in safety advice and assistance. By contrast, if the managers cannot respect middle and lower-level employees in the process safety of adopting employees' safety engagement, safety performance and safe working environment, or ignore the latter’s proposed safety advice or even abandon, the employees will feel frustrated. Thus, safety risks remain unsolved, and employees' enthusiasm to engage in process safety in keeping their safety affairs intact is inevitably affected.

This study finds that process safety's sense of psychological safety may translate into the employees’ emotional need for belongingness. When their needs are satisfied, employees adopt employees' safety engagement, performance, and a safe working environment. Therefore, managers should encourage middle and lower-level employees to engage in process safety to help them connect the realisation of self-worth with the prospects and development of organisational safety level. Thus, they can hold a sense of belonging to the organisation during the psychological process to actively engage in the organisation's safety activities with mastery to improve the organisational safety level. Managers should simultaneously create a harmonious and friendly environment where employees can feel their primary position in the organisation and managers' concerns. Managers can appropriately authorise some highly educated and competent employees to express recognition and trust, thereby stimulating the employees’ initiative to engage in process safety affairs, improving the employees’ responsibility to their co-worker’s safety, and enhancing the employees’ enthusiasm for improving organisational safety.

The study's findings extend the scope of process safety research for practitioners by offering insights for top management development. Top management is the leader in the organisation and thus, must be self-aware and speak positively regarding workplace safety initiatives. They, too, need to walk the talk and not be cynical towards safety initiatives, as their behaviours model what subordinates will emulate, for better or worse. This study also introduces a new perspective on safety commitment in top management. The repositioning of the concept via a focus on leaders provides an understanding of safety commitment beyond employee perceptions. By examining how top management experiences and demonstrates their commitment to safety, the roots of subsequent employee perceptions of safety commitment can be uncovered. Currently, most top management will have been made aware of the importance of their safety commitment but receive little guidance on what it means to be committed to safety and how to demonstrate it best. Top management can use the insights presented in this study to reflect on their safety commitment and how it affects how they convey the importance of safety. In particular, a more detailed reflection about their safety commitment may support them in developing stronger visions for safety rooted in their mindset for making safety a priority. This can also be considered in the design of key performance indicators (KPIs) and reward structures and the formulation of organisational safety values. The results also show that how organisations communicate the importance of safety for their operations can be critical in shaping the extent to which top managements' safety commitment translates into psychological engagement demonstrated through process safety.

6.5 LIMITATIONS

Several limitations are worth noting. Firstly, this research was conducted within the specific domain of process safety and in one country. Although process safety and safety research by its nature is context-specific, replications in other contexts would increase confidence in the research model. Secondly, all the variable measures taken from previous studies better fit our study's context, which might have influenced their reliability and validity. However, the positive relationships between these measures and their positive associations demonstrate the construct validity of these measures. Thirdly, constructs labelling is entirely based on the research context of the study, that is, process safety in the ADNOC refinery context in the UAE. Future research can further explore and differentiate such constructs from other related constructs (e.g., proactive safety participation) or add some new constructs based on the dynamics of the research context. Fourthly, this study was designed in a multicultural organisation context, without differentiating workers' educational and positional backgrounds. Thus, cross-sectional causality conclusions cannot be drawn. For instance, the relationships among process safety and its indicators among different levels of management remain unknown. Future longitudinal and experimental research is needed to explore the multi-group relationships between top management commitment to safety, top management safety practices, supervisory safety behaviour, and process safety. Finally, the sample only represents lower and middle management levels from a specific sector of high-risk industries (O&G industry) in the UAE; thereby, there is a limitation regarding the generalizability of findings to other employees in other high-risk industries and countries. There might be variations in the perceptions of the components and consequences of safety climate and process safety in Eastern and Western countries, developing and developed nations, and individualistic and collectivist communities.

6.6 FUTURE RESEARCH DIRECTIONS

The success of an occupational health and safety risk management system (OHSMS) depends on (1) an informed culture in which those who manage and operate the system have current knowledge about the human, technical, organisational and environmental factors that determine the safety of the system as a whole; (2) a reporting culture in which people are willing to report errors and near misses; and (3) a just culture with 'no blame' where an atmosphere of trust is present, and people in the organisation are encouraged to provide essential safety-related information. As a result, human factors are considered a crucial element for organisational safety and health management review (National Emergency Crisis and Disasters Management Authority (NCEMA), 2016). Aligned with the same spirit for better implementation of OHSMS through better human factors process safety, future research could take several new directions:

1. Future work may investigate cross-cultural settings by incorporating respondents from all three levels of management, the top-level, middle-level and lower-level management. There is always a different perception regarding process safety between the levels of management in the

organisation concerning the level of education, cultural background, communication systems, and the level of near-missed or safety incident experiences (Behari, 2019; Zwetsloot et al., 2020). Information on these differences in organisational context might be of considerable interest and significance to both researchers and practitioners for critical managerial decision making (Al Mazrouei et al., 2019). However, some issues should be considered, such as consistency in instrument development and validation, response bias about measurement equivalence, respondents' demographic profile, and response style.

2. Although the variance explained by the research model is relatively high for the study, future work should attempt to identify and test additional boundary conditions of the model to present an even richer understanding of process safety and safety climate factors. This extension might be shaped by different contextual variables, moderating influences (e.g., safety monitoring and control), and other high-risk industries contexts (e.g., mining, chemicals – commodities such as fertilisers or primary plastics settings). Findings from such studies might enhance the overall generalizability of process safety to explain further variance in human psychological factors that affect employees' emotions, attitudes, and behaviour.

3. Future work could take a different approach, taking into account management and employee perceptions. By evaluating perceptions of process safety across other groups in a single study, this approach may yield some interesting results.

4. Subsequent studies need to assess the antecedents of process safety (i.e., leadership, trust, transparency, skills and ability, knowledge, motivation, and personal characteristics) and other consequential latent variables (i.e., near-missed accidents, injury rates, audit reports) (Vierendeels, Reniers, van Nunen, & Ponnet, 2018).
5. Future studies can extend the present research model by adding more perceptual factors into safety climate (i.e., leadership, trust, transparency), personal-psychological factors (i.e., skills and ability, knowledge, motivation and personal characteristics), and observable factors (i.e., technology, training, procedures) to address the concern of human factors in process safety. It would be interesting to compare the results of such an approach with other established process safety models in process industry domains.
6. Future studies can extend the present research model by adding the nature of training as an independent variable and its effect on process safety. The current research had explored movement as a moderator to explore the strength, reduce, refute, or otherwise modify the association between the safety climate variables and the process safety.

6.7 CONCLUSION

The objective of this study was to identify the dimensions of process safety and model the impact of safety climate factor of top management commitment to safety, top management safety practices and supervisory safety behaviour impact on overall process safety in the context of ADNOC refinery in the UAE.

A systematic literature review of the process, safety, and process industries were undertaken in meeting the objective. Using the literature on process safety, safety climate and safety training, a conceptual framework and a set of hypotheses were developed. The research model was specified as a hierarchical-reflective model and was tested in an O&G refining company in the UAE. A total of 180 samples were analysed to develop and validate an instrument, and 545 samples were analysed to test the conceptual model. The study applied AMOS path modelling to estimate the hierarchical model and test the relationships among constructs. The findings confirmed the research model's adequate measurement and structural properties, proving four hypotheses. This study did not support the safety training construct as a moderator between safety climate factors and process safety relations.

The most significant contribution of the study lies in providing critical insights in process safety research in the process industry and high-risk sectors by reframing process safety as a second-order, hierarchical-reflective construct and modelling its overall effects with total management commitment on safety, top management safety practices and supervisory safety behaviour as the antecedents in their relationships. The main dimensions and items in the questionnaire have an impact on the process safety factor structure. This study showed that the process safety construct has good psychometric properties and can measure essential safety outcomes. Specifically, the measure is highly reliable and enables distinction between the three process safety dimensions, which can, in turn, be combined into a higher-order process safety factor. The relationships of the research model are based on adequate logical (i.e., the theory is internally consistent), epistemological (i.e., rigour in research design) and empirical (i.e., robust findings) evidence. The study outcomes are precious to managers to capture employees' process safety perceptions, evidenced as hierarchical, multidimensional and context-specific. This knowledge offers an integral step to providing conceptual clarity and practical solutions to the process safety challenges of the process industry, such as the O&G refining company in the UAE. Despite the context of the O&G process industry, this model may be of interest to other settings of high-risk organisations that involve the process industry, such as the chemical industry and mining industry.

Overall, the findings show that process safety factors exist and that the complexity of process industries affects the safety climate. In addition, the factors that influence safety climate within one industry might not be relevant in another industry due to differences in multilevel management styles and safety regulations. These factors result in different safety perceptions, which are reflected in varied factors structures. Overall, the findings showed that this instrument could assess process safety in the process industry and conduct future research on safety culture.

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APPENDIXES

APPENDIX A

Impact of Organizational Culture on Perceived Process Safety in the UAE Oil and Gas Industry

Dear Potential Respondent,
My name is Mohamed and I am a Doctoral candidate at the University of Abu Dhabi. In partial fulfillment for the award of this degree, I am conducting research on the impact of organizational culture on perceived process safety in the UAE oil and gas industry. I am therefore requesting you kindly take 25-30 minutes of your time to complete this online questionnaire. By completing this questionnaire, you are assured:

- of total confidentiality, privacy, and anonymity
- that, although I hope it is not the case, you can refuse to complete this questionnaire without any penalty
- that your participation is voluntary and attracts no material incentive
- that you will not be exposed to any harm
- that you are not required to provide any information that is linkable to you whether directly or indirectly
- that all your responses will be kept safely under password protection
- that all raw data shall be trashed permanently upon submission of the final work to the university

To proceed to the next section of the questionnaire, kindly check the box below to confirm that you are satisfied with the information provided about this research and agree to participate voluntarily and click next.

* Required

1.

Check all that apply.

- [ ] I am satisfied with the information provided and hereby give my informed consent to participate in this research voluntarily

A. Demographic Information

2. 1. What is your gender? *

Mark only one oval.

- Male
- Female

3. 2. What is your age group? *

Mark only one oval.

- 22 - 30 years old
- 31 - 40 years old
- 41 - 50 years old
- 51 - 60 years old

4. 3. Which nationality best describes you? *

Mark only one oval.

- Emirati
- Gulf Cooperation Council States (except Emirati)
- Middle Eastern or North African Nations
- North American
- Asian
- African
- Other: ____________

5. 4. Job Tenure? *

Mark only one oval.

- 6 months to a Year
- One year to 5 years
- 6 years to 15 years
- 16 years to 30 years

6. 5. Education Level? *

Mark only one oval.

- High School Diploma or Technical Certificate
- Undergraduate University Degree
- Graduate University Degree

7. 6. Job Level? *

Mark only one oval.

- Lower Management Level
- Middle Management Level

B. Top Management Commitment to Safety

In your opinion, to what extend do you agree with the following stateme about the management and organization you work for?

8. 1. Safety is given high priority by the top management *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

9. 2. Safety rules and procedures are strictly followed by the top management *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

10. 3. Top Managements consider safety to be equally important as production *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

11. 4. When near-miss accidents are reported, my top management acts quickly to solve the problems *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

12. 5. My company provides sufficient personal protective equipments for the workers *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

C. Top Management Safety Practices

Think about your management. Do you agree or disagree that each of the following words or phrases describes your management?

13. 1. Top Management conducts frequent safety inspections *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

14. 2. Top Management investigates safety problems quickly *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

15. 3. Top Management provides safe equipment *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

16. 4. Top Management responds quickly to safety concerns *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

17. 5. Top Management provides safety information *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

D. Supervisory Safety Behaviour

Think about your immediate supervisor. Do you agree or disagree that each of the following words or phrases describes your immediate supervisor?

18. 1. My immediate supervisor involves workers in setting safety goals *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

19. 2. My immediate supervisor discusses safety issues with others *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

20. 3. My immediate supervisor updates safety rules *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

21. 4. My immediate supervisor trains workers to be safe *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

22. 5. My immediate supervisor enforces safety rules *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

E. Employee Safety Performance

In your opinion, to what extend do you agree with the following statements about your performance as an employee?

23. 1. My performance is better than my colleagues with similar qualifications *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

24. 2. My performance is better than the other employees with similar qualifications *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

25. 3. The performance of my department is better than the other departments *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

F. Employee Engagement on Safety

In your opinion, to what extend do you agree with the following statements about your organization you work for?

26. 1. I feel that employee organization values my contributions on promoting process safety *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

27. 2. I feel that my organization values employee suggestions on improving safety *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

28. 3. I feel my organization values employee adherence to process safety procedures *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

29. 4. My organization promotes communication on process safety among employees regularly to enhance process safety *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

30. 5. I believe that it is possible to achieve zero process safety events/incidents in my organization *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

G. Safety of Working Environment

In your opinion, to what extend do you agree with the following statements about your organization you work for?

31. 1.I feel that my organization is keen on eliminating process safety incidents *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

32. 2. The leadership in my organization reviews process safety procedures when an accident/incident happens *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

33. 3. My organization ensures regular checks to ensure process safety standards are maintained *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

34. 4. I feel safe when working in my organization *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

H. Employee Safety Training

In your opinion, to what extend do you agree with the following statements about your organization you work for?

35. 1. My company gives comprehensive training to the employees in work place health and safety issues *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

36. 2. New recruits are trained adequately to learn safety rules and procedures *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

37. 3. Safety issues are given high priority in training programmes *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

38. 4. I am not adequately trained to respond to emergency situation in my work place *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

39. 5. Management encourages the workers to attend safety training programmes *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

40. 6. Safety training given to me is adequate to enable me to assess hazards in work place *

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strongly Agree

Thank you for your participation.

APPENDIX B

IRB Approval

RE: IRB FORM

ED Essam Dabbour
To Mohamed Ali Almazrouei
Cc Khalizani Khalid

Reply | Reply All | Forward | ...

Wed 3/6/2019 5:54 PM

Follow up. Start by Wednesday, March 6, 2019. Due by Wednesday, March 6, 2019.

IRB Close Out Form.doc
73 KB

IRB Protocol Modification Form (Final).doc
78 KB

Dear Mr. Mohamed

Based on the expedited review of your IRB application, I am pleased to inform you that the application is now approved. Please make sure that you adheres to the policy as well as to the approved protocols and questionnaire forms that were submitted. In case if you will need to make any changes to the protocols or the questionnaire forms, please fill out the attached change form and send it to me for approval prior to making those changes. Once the data collection process is completed, please fill out the attached closing form and return to me. Thank you and good luck in your research

Regards,

-----Original Message-----
From: Mohamed Ali Almazrouei <1064240@students.adu.ac.ae>
Sent: Tuesday, February 26, 2019 11:48 PM
To: Essam Dabbour <essam.dabbour@adu.ac.ae>
Cc: Khalizani Khalid <khalizani.khalid@adu.ac.ae>
Subject: IRB FORM

Dear Dr. Essam,

Please find herein attached the IRB form and the survey for your further process.

Regards,

Mohamed Almazrouei
cohort-8
ID 1064240

APPENDIX C

-------- Original message --------
From: "Jasem Ali Al Sayegh (ADNOC Refining - HQ)" <jasem.alsayegh@adnoc.ae>
Date: 22/04/2018 13:47 (GMT+04:00)
To: "Mohamed Ali AL-Mazrouei (ADNOC Refining - RRE)" <maalmazrouei@adnoc.ae>
Cc: "Ali Mohamed Al Jaberi (ADNOC Refining - HQ)" <alialjaberi@adnoc.ae>, "Dr. Hasan Karam (ADNOC Refining - RRE)" <karam@adnoc.ae>, "Fadi Khalid Tawfiq Malak (ADNOC Refining - HQ)" <fmalak@adnoc.ae>
Subject: RE: perception of process safety

Dear Mohamed,

Ok with me and I wish you all the best.

However, please coordinate with our GC, Mr. Fadi Malak to ensure all legalities are covered before you can start the survey.

Best regards,

أدنـوك
ADNOC

Jasem Ali Al Sayegh
Chief Executive Officer

PO Box 3593, Abu Dhabi, UAE
T (+971) 2 60 27201
jasem.alsayegh@adnoc.ae

adnoc.ae ADNOC Refining

100% HSE أنا أصنع الفرق 100% HSE I AM THE DIFFERENCE

APPENDIX D

Dimension	Items	Reference	Operational Definition
Employees' safety engagement	- My organisation values my contribution to promoting process safety. - My organisation values employees' suggestions on improving safety. - My organisation values employees' adherence to process safety procedures. - My organisation regularly promotes process safety - My organisation can achieve zero process safety events/incidents.	Al Mazrouei, M. A., Khalid, K., & Davidson, R. (2019). Modeling the impact of safety climate on process safety in a modern process industry: The case of the UAE's oil-refining industry. *Cogent Business & Management*, *6*(1),1647591.	Employee's safety engagement is how much is the individual is engaging with the organisation values in safety culture, and safety climate.
Employees safety performance	- I use all of the necessary safety equipment when doing my job - I ensure the highest levels of safety when carrying out my job - I know how to use safety equipment and understand standard work procedures	Al Mazrouei, M. A., Khalid, K., & Davidson, R. (2019). Modeling the impact of safety climate on process safety in a modern process industry: The case of the UAE's oil-refining industry. *Cogent Business & Management*, *6*(1),1647591.	Employee's safety performance is measured by how much near misses he or she is accounted for.

Safe working environment	- My organisation wants to eliminate process safety incidents - The leadership at my organisation reviews process safety procedures after an event/incident occurs - My organisation conducts regular checks to ensure that process safety standards are maintained - I feel safe when working at my organisation	Al Mazrouei, M. A., Khalid, K., & Davidson, R. (2019). Modelling the impact of safety climate on process safety in a modern process industry: The case of the UAE's oil-refining industry. *Cogent Business & Management*, *6*(1),1647591.	Safety working environment is the overall setup in the workplace itself to eliminate all process safety incidents.
Top management commitment to safety	- Safety is given high priority by the management. - Safety rules and procedures are strictly followed by the management. - Corrective action is always taken when the management is told about unsafe practices. - In my workplace managers/supervisors do not show interest in the safety of workers. - Management considers safety to be equally important as production. - Members of the management do not attend safety meetings. - I feel that management is willing to compromise on safety for increasing production. - When near-miss accidents are reported, my management acts quickly to solve the problem. - My company provides sufficient personal protective equipment's for the workers.	Vinodkumar, M. N., & Bhasi, M. (2011). A study on the impact of management system certification on safety management. Safety Science, 49, 659–667.	Top management commitment to safety is leading by example.

Top management safety practices	- Top management conduct frequent safety inspection. - Top management investigate safety problem quickly. - Top management provide safety equipment’s. - Top management responds quickly to safety concern. - Top management provides safety information.	Hayes, B. E., Perander, J., Smecko, T., & Trask, J. (1998). Measuring perceptions of workplace safety: Development and validation of the work safety scale. Journal of Safety Research, 29(3), 145–161.	Top management safety practices is the leadership commitment and promoting safety.
Supervisory safety behaviour	- My immediate supervisor involves workers in setting safety goals. - My supervisor discusses safety issues with others. - My immediate supervisor updates safety rules. - My immediate supervisor trains workers to be safe. - My immediate supervisor enforces safety rules.	Hayes, B. E., Perander, J., Smecko, T., & Trask, J. (1998). Measuring perceptions of workplace safety: Development and validation of the work safety scale.	Supervisory safety behaviour is commitment on site actives with full ownership to safety.