Safety and Resilience Engineering in Saudi Arabian Industries

by

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Declaration

The work described in this thesis, carried out in the School of Engineering and Informatics, is that of the author and has not been submitted in any form for any other degree at this or any other university.

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Abstract

Large industrial accidents attract attention due to their catastrophic effects on human lives, economic growth, and the environment. Early studies on accident causations have concluded that 98% of all industrial accidents are preventable, and 88% can be prevented through the enforcement of a proper control system. There have been relentless efforts to develop models of accidents to understand this phenomenon and minimise the catastrophic outcomes of mishap events. These efforts have led to the development of systematic models of accident causations; in which accidents causations are viewed as dynamic processes that interact in a non-linear fashion. One of these systematic models is Resilience Engineering (RE), which takes a holistic view of the organisation and its natural abilities to maintain the system in a dynamically stable state under either stresses or normal operations.

This research attempts to explore safety of industrial corporations by evaluating resilience in the Saudi Arabian process industry. The Saudi Arabia context is

substantially different from the Western cultures where resilience concepts were developed and studied. The rapid expansion of the petroleum industries has had a major impact on the development of the Saudi socio-economic dynamics. The unique national culture dimensions of the Saudi Arabian society (power distance, uncertainty avoidance, and individualism) will help in understanding cultural influences on resilience and safety in general. Therefore, this research is conducted to identify the main contributing factors to resilience in the Saudi Arabian context.

The outcomes of the research help engineers and administrators in industrial organisations to engineer resilient systems that minimize the risks of mishaps and recover quickly to a normal state of operations. The findings support the influence of the national culture in different countries on organisational safety culture, which is extended to individuals' behaviour towards safety. Evidence has shown that collectivism, on the contrary to the common belief, has a positive impact on both resilience potential and safety culture in the process industry. In addition, the process industry in Saudi Arabia is characterised by resilience of the second type, where there is good ability to respond and monitor but a low ability to learn or anticipate. The main contributing factors to this resilience are: effective communication, information availability, control over work tasks, and dealing with external pressure. Lastly, the findings suggest an association between management commitment to safety and both resilience optimisation and organisational safety culture.

List of Acronyms

ACSNI	Advisory Committee on the Safety of Nuclear Installation
ARAMCO	Arabian-American Oil Company
BP	BP plc. Former name British Petroleum.
CIA	Central Intelligence Agency
ETTO	Efficiency-Thoroughness Trade-Off
FA	Factor Analysis
FRAM	Functional Resonance Accident Model
GDP	Gross Domestic Product
GNP	Gross National Product
HDI	Human Development Index
IBM	International Business Machines Corp.
ISO	International Organization for Standardization
KMO	Kaiser-Meyer-Olkin
KSA	Kingdom of Saudi Arabia
LTIF	Lost-time injuries per million man hours
MORT	Management Oversite and Risk Tree
OARU	Occupational Accident Research Unit
OPEC	Organization of Petroleum Export Countries
PA	Parallel Analysis
PCA	Principle Component Analysis
RAG	Resilience Analysis Grid
RE	Resilience Engineering
SABIC	Saudi Basic Industries Corporation
SEC	Saudi Electricity Company
SFA	Standard Factor Analysis
SMORT	Safety Management and Organisation Review Technique
Socal	Standard Oil of California
SPSS	Statistical Package for the Social Sciences
STAMP	System-Theoretic Accident Model and Process
STC	Saudi Telephone Company

SWCC	Saline Water Conversion Corporation
Texaco	Texas Company
TRIPOD	TRIPOD model of accident causation
UK	United Kingdom
UN	United Nations
US	United Sate
USD	United State Dollar
WTO	World Trade Organization

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1 Chapter One: Introduction

Overview:

Why do accidents occur? How can we prevent losing lives every year in large industrial complexes? Are recurrent catastrophic deaths and injuries indicators of failure to implement safety measures? What does that failure imply for safety management theorists, regulators, and administrators in the future? These questions have provoked several debates in the public and scientific literature. Large industrial accidents attract attention due to their catastrophic effects on human lives, economic growth, and the environment. A clear example of the tragic consequences of mishaps is the BP Macondo blowout and oil spill in the Gulf of Mexico 2010; where 11 people were killed and 17 other injured in the explosion, and over 8,000 animals (birds, turtles, mammals) were reported dead after 6 months of the oil spill. The oil spill had led to the loss of 4.9 million barrels of oil and 18.7 billion USD in fines. Some observers have blamed the issue on flawed practices by big companies who cut corners and favour production and profits over safety of their own employees. Others have argued that the governing bodies should step up and enforce tighter regulations on the industries. Investigations point towards failure of leadership and organisational commitment to safe operations.

The growing public concerns of accidents in industrial facilities have attracted scholars from various disciplines to further investigate this phenomenon. James T. Reason is one of the leading scholars who influenced the discussions on safety and risk management in human systems. Reason’s principal area of research has been human error and the way people and organisational processes contribute to accidents. His early work in the field of psychological error mechanism (Reason 1975; 1976; 1979) provided important insights into complexity as the cause of accidents [1], [2]. By 1990, he developed the accident causation model, which is quite distinct from the Pearson ‘active errors’ and system 'latent errors' approach to mishaps. The model has gained widespread acceptance and recognition by both scholars and experts. Before the Accident causation model, it was believed that accidents happened due to individual operator error solely (See: Heinrich, 1931 and Bird and Germain, 1985) [3], [4]. The significance of Reason's model (commonly known as the Swiss Cheese Model) is associating accidents to wider systematic organisational factors (latent conditions). In 'Managing the risks of organisational accidents' (1997), Reason developed a comprehensive model of system safety (see Figure 1.1) [5]. In practice, professional safety investigators adopted Reason's model and shifted their focus from blaming individuals at the sharp end of the system to a no-blame approach.

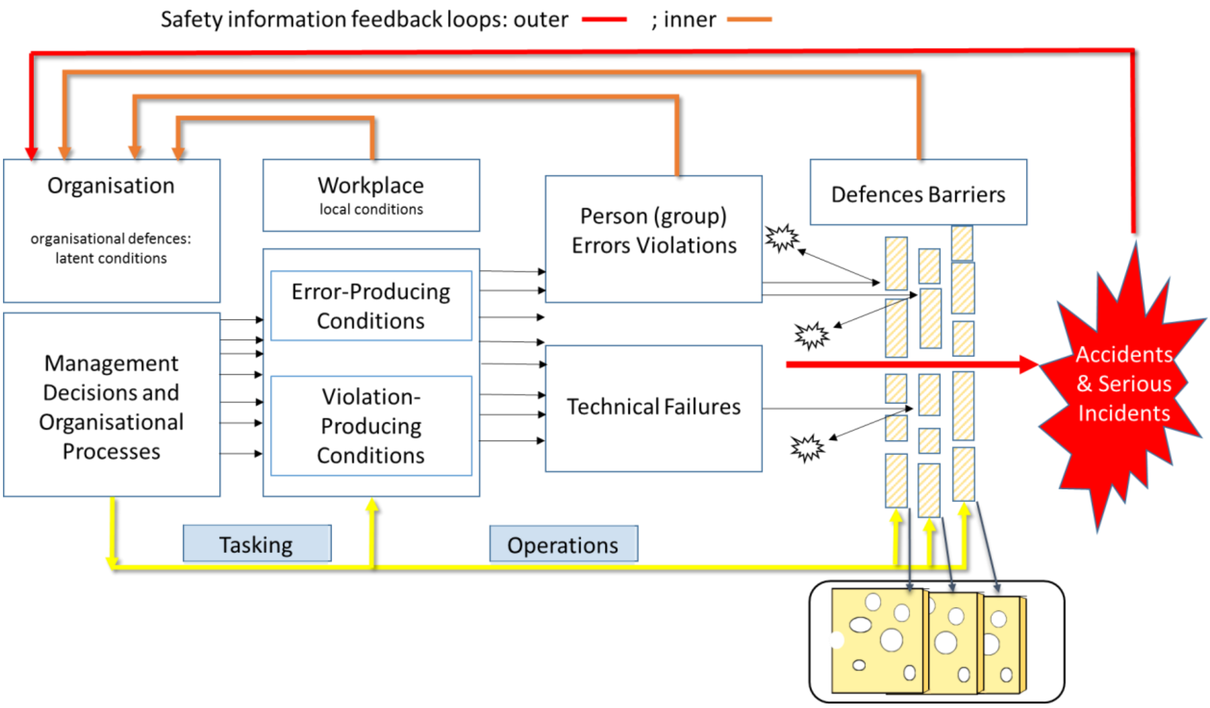

Figure 1-1 Reason Model of System Safety (Reason, 1997)

The realisation that systematic environmental factors contribute to mishap events have refocused the efforts to study these issues. This has led to the assumption that errors can be categorised and contained. More recently Erik Holnagel, who was focusing on human/cognitive reliability and the human/machine interface, introduced a new way of thinking about accident modelling. In his view, accidents were unforeseeable and thus the focus on setting more safety barriers and defences is misplaced. Organisations are complex systems, as they include a large number of subsystems and components that interact nonlinearly. Humans, technology, latent conditions, and safety barriers, each contribute with a little negative effect on the system as a whole. In his book ‘Barriers and Accident Prevention’ (2004), Hollnagel introduced the Functional Resonance Accident Model (FRAM) in an attempt to allow the organisations to be ‘error tolerant’ [6]. He transfered the organisational efforts from searching for more accident causes to monitor the whole system and control it instead. The FRAM model presents a view of how different functions within an organisation are linked or coupled in the normal state operation. By monitoring the variability in different functions within the organisations and how they interact nonlinearly, we could steer the system away from accidents.

In 2006, Hollnagel et al. introduced the concept of Resilience Engineering (RE) to overcome the limitations of existing approaches to system safety and risk assessment [7]. In the authors view, “safety is created through proactive resilience rather than reactive barriers and defences”. Resilience engineering relies on the system’s ability to anticipate surprises and adapt to potential failures. With the aim of making organisations safer, the resilience concept relies on providing workers and managers with information about changing vulnerabilities within the system to develop ways to avoid them. Several scholars were interested in this paradigm shift of viewing accident modelling and safety management systems, therefore; studies were conducted at railways, nuclear power plants, aviation, and in the petroleum industry. The Resilience Engineering concept is still relatively new and attracts researchers to study it in different industries or cultures.

1.1 Research Question:

This research attempts to understand further the safety of industrial corporations by evaluating resilience in the Saudi Arabian process industry. The Saudi Arabia context is substantially different from the Western cultures where resilience concepts were developed and studied. The rapid expansion of the petroleum industries has had a major impact on the development of socio-economic dynamics. The unique context of Saudi Arabia regarding power distance, uncertainty avoidance, and time orientation influences the safety climate including organisational practices and views on safety. Studying resilience engineering in such a context will help in understanding cultural influences on resilience and safety in general. Therefore, this research is conducted to identify the main contributing factors to resilience in the Saudi Arabian context.

Although the energy sector contributes 90% of export earnings to the Saudi economy, studies on safety are mostly concerned with the construction sector. Jannadi and Assaf (1998) have studied the level of safety as a function of the project size. Their study included items such as site safety administration, employee's health and welfare, trenching and excavation, power tool machines, and the use of heavy equipment [8]. The study results have indicated a variation of safety level in accordance with the project size. Safety scores were consistently high in large projects; whereas small projects score low in fire prevention, as well as health and welfare and safety administration. In another study, Jannadi and Bu-Khamsin (2002) have listed around 20 factors and 85 sub-factors of safety at industrial contractors in KSA [9]. The survey included 28 companies involved in constructing large industrial structures to determine the main causative factors to safety. The authors have identified management involvement, personal protective equipment, and emergency/disaster planning and preparation as the main contributing factors to safety. In a more recent study, Al Haadir and Panuwatwanich (2011) examined critical factors affecting the successful implementation of safety programs [10]. The study suggested seven factors that help in implementing safety programs for Saudi construction projects. Those factors are: (1) management support; (2) clear and reasonable objectives; (3) personal attitude; (4) teamwork; (5) effective enforcement; (6) safety training; and (7) suitable supervision. Other safety studies in KSA included road safety (Ansari et al., 2000; Bendak, 2005), health care sector (Walston et al., 2010), and a few other sectors [11]–[13].

Regarding the manufacturing sector, Noweir et al. (2013) evaluated the progress of occupational health and safety in Jeddah Industrial Estate (West of Saudi Arabia) [14]. With the aim of assessing the progress of safety, the paper compared results of two studies: the first study was conducted in 1990, and included data on 52 plants employing 5830 workers, while the second was conducted in 2010, and included 135 plants employing 18351 workers. Over that 20-year period, improvements to safety practices were much less than what was anticipated or required. However, improvements were made regarding exposure to physical and chemical factors, applying engineering controls, and occupational medical services. On the other hand, the 2010 data reveals a substantial drop in the safety performance in general. The authors have concluded the following remain as challenges in developing occupational health and safety programs in Saudi Arabia:

- General lack of understanding of occupational safety and health.
- Lack of information of occupational safety and health needs.
- Shortage of occupational safety and health specialists.

- Inadequate legislation or even inadequate enforcement of the existing safety laws.
- Diversity of agencies responsible for occupational safety and health.
- Lack of systematic appraisal of occupational safety and health.
- Plenty of small and medium-size plants.
- Diversity and rapid turnover of expatriate workers in industry from a wide spectrum of countries, language, ethnic groups and culture.

On the topic of resilience, Alshehri et al. (2013) have studied the sociological community resilience in Saudi Arabia after natural disasters [15]. Nevertheless, Hollnagel concepts of resilience engineering in industrial complexes have not been explored so far. This research attempts to explore resilience engineering in the Saudi context and will investigate Hollnagel concepts in the process industry all over the Kingdom. The overall quest of the research project can be formulated as follows:

What are the main contributing factors to resilience engineering in the Saudi Arabian Process industry?

The energy industry includes the following sectors: petroleum, natural gas, electric power production, and supporting industries to these sectors. The energy sector provides the country with its essential needs of fuel, electricity, basic materials, and water. According to the BP Statistical Review of World Energy 2014, Saudi Arabia was the world's 12th largest consumer of total primary energy in 2013. This is the motivation for the selection of the energy companies and contractors to be the subject to this project. In addition, the lack of literature on safety in that sector has created a knowledge gap that needs to be addressed. The leading companies in this sector are:

1- Saudi Aramco (formally, the Arabian-American Oil Company), is the Saudi Arabian national petroleum and natural gas company, which is based in Dhahran (East of Saudi Arabia). ARAMCO is the world's largest oil company in terms of oil reserves and production. The company owns many plants scattered around the country.

2- Saudi Basic Industries Corporation (SABIC): 70% of the company is owned by the government, and 30% by the private sector. SABIC businesses are broadly grouped into five primary sectors: basic chemicals, intermediates, polymers, chemical fertilizers, and metals.

3- Saudi Electricity Company (SEC): is mainly owned by the state (80%) and the public owns 20% of the shares. SEC is the largest provider of electricity in the Saudi Arabia, with a total available generating capacity of 65.5 GW (SEC Report, 2014) [16].

4- Saline Water Conversion Corporation (SWCC): government owned corporation provides most of the Saudi Arabia’s desalinated water as well as being the second-largest generator of electricity in the country. SWCC owned and maintained 28 desalination plants spread over 17 locations on the eastern and western coasts. The total desalinated production amounted to 3.6 million cubic meters a day which represent 60% of the Kingdom’s output (Bloomberg, 2014) [17].

These companies are major employers of Saudi nationals and have various partnerships with the private sector both nationally and internationally. Therefore, the safety of these industries is crucial for future planning and sustaining the growth in the country. For that reason, the energy sector is the subject of analysis in this study.

In order to answer the research questions presented above, the following stages are pursued:

1. Evaluate the safety climate in the Saudi Arabian energy industry.
2. Develop an appropriate methodological framework to measure the potential of resilience in the Saudi energy sectors.
3. Identify critical aspects influencing potential resilience in the energy sector.
4. Extract the main contributing factors to resilience in Saudi energy sectors.

Evaluating the safety climate will provide a starting point to understand the problem at hand and to recognise gaps of knowledge that need careful consideration. At this stage, reviewing the literature will provide a basic understanding of industrial safety and other related theories and concepts (organisation theory, culture, and behaviour). In the Saudi case, many researchers have indicated that there is a lack of publication on the topic (e.g. Noweir et al., 2013, Idris, 2007) [14], [18]. Therefore, the first part of this research includes exploratory methods (observation, interviews, case study). Regarding measuring the potential of resilience, Hollnagel et al. (2006, 2011) has outlined the methodological framework which will be implemented in this project [7], [19]. To identify what influences resilience in industrial complexes; a combination of literature review and the empirical work will help in qualifying most relevant factors to the Saudi energy sector. The filed work will also help in adjusting the original framework by Hollnagel to fit the Saudi context.

The second part of this study addresses developing a questionnaire based on the findings of the exploration stage. The questionnaire will assess the potential of resilience in Saudi's various companies working in the energy sector. The target sample of the questionnaire includes sharp-end operators, engineers, and managers at different levels of the organisations. The data collected will be analysed qualitatively by using factor analysis to extract the main contributing factors to resilience in the Saudi energy sectors.

1.2 Research outline:

So far in this chapter, an overview of safety status and the core research question has been presented. This section will guide the reader on the content flow of the thesis chapters with a brief introduction to each one.

Chapter One: Introduction

This chapter gives a brief introduction to the problem of safety in industrial facilities. Information about accident models and the development of safety management systems is provided. Some of the knowledge gaps were then briefly introduced, leading to the formulation of the research question as well as defining the steps to answer it.

Chapter Two: Literature Review

Discussions of safety often include a variety of related concepts and theories. With the aim of clarifying those theories, this chapter will provide the main theories about industrial organisation and safety. Moreover, resilience engineering and the development of safety and accident modelling will be introduced. The literature review will also discuss some aspects of the Saudi context, which will help the reader in understanding factors influencing the business environment there.

Chapter Three: Methodology

The methodology chapter will discuss the philosophical arguments to investigate the problem and detail the research strategy. The question of using a qualitative or quantitative approach will be debated to select the most appropriate approach to address the problem. Research methods, techniques, and procedures will be outlined as well as the development of the questionnaire, which will measure the potential of resilience in the Saudi energy sector.

Chapter Four: Results

The results chapter presents the data collection process including the preparation for the analyses (e.g. sampling adequacy tests). The results of the exploratory stage (on-site observation, informal interview, and case study) will be presented first. Afterwards, the main tables and figures will be highlighted.

Chapter Five: Analysis

This chapter discusses how to interpret the findings of the study in the light of the research question. The main contributing factors to resilience engineering in the Saudi energy industry will be introduced. The findings are then compared to other studies and the implication of the theory and practice is reviewed. The main contribution to knowledge, limitations, and future work will finally be examined.

Chapter Six: Conclusions

This chapter will bring together the arguments in the literature with the results of this research project, and the main extracted factors which influence resilience are decided. In the light of the findings, the chapter highlights the implications and suggests recommendations for practical and theoretical future work.

2 Chapter Two: Literature Review

Summary:

In today's world, managing businesses is influenced by the integration of various dynamics of social, technological, and environmental issues. Striking the right balance between production demands and safe operations is crucial and requires efficient management of resources and trade-offs. Over the last few decades, numerous efforts were dedicated to understand these challenges and examined ways for improving systems safety. Subsequently, significant advances have been made on various scientific fronts with promising potentials to address organisational performance and occupational health and safety. This thesis is an effort to investigate some of the new concepts related to that field. This study evaluates in particular the influences on the occupational health and safety in the Saudi process industries by testing resilience engineering concepts there. The aims of this research are summarised as follows:

1- **Explore safety development at industrial complexes in the light of the unique socio-economic culture.**

2- **Test RE concepts in a new context and highlight influences of cultural factors on it.**
3- **Identify the main contributing factors to resilience in the Saudi Arabian context.**

2.1 Introduction:

The historical development of societies and organisations have simultaneously presented numerous solutions to raise standards of living, and disclosed new challenges. The rapid growth of human societies urges industrial systems to become increasingly large and complex. Accordingly, mishaps turned out to be more tragic causing loss of lives, damage to the environment, and damaging economic growth. Thus far, a wide range of safety management approaches were developed to identify risks and prevent catastrophic consequences. These safety models, however, still fail in real complex socio-technical environments. Clear examples of such large-scale failures are the Chernobyl accident in 1996, the Deepwater Horizon rig in the Gulf of Mexico in 2010, and Fukushima power plant Japan 2011. Such disastrous accidents indicate a systematic failure and emphasize the need for more comprehensive models of risk assessments and safety management. Given the volume and variety of management approaches that deals with safety, it is important to recognise the theoretical roots of those tools to use them appropriately. The literature on organisational theory provides a suitable starting point to grasp how safety is viewed differently in management studies. The purpose of this chapter is to provide the reader with an overview of the significant literature on industrial organisation and the development of accident models. The overview will help in highlighting gaps of knowledge that motivated this enquiry. This study aims to contribute to the dissections on safety of industrial organisations through the following questions:

What are the main factors that influence organisational safety culture in the Kingdom of Saudi Arabia?

Is the Saudi Arabian process industry resilient? Under which category of ‘system-kind’?

Does the Saudi national culture affect resilience engineering within industrial organisations there?

What are the main contributing factors to resilience engineering in the Saudi Arabian process industry?

To answer these questions, this chapter starts by presenting the historical development of accident models. Since accident models are closely related to the development of management theory, the first section will introduce major ideas that form organisational and management studies. After that we will explore the development of accident models and their relation to management theories. A full section will be dedicated to explaining resilience engineering (RE) concepts as a new approach to view the problem of safety. Following that the chapter will go into more detail, presenting a literature review of organisational development and culture. The relationship between national, organisational, and safety cultures will be explored in order to understand the dynamics by which they affect each other. After that, safety culture will be described including previous studies on the matter. Lastly, since this thesis is concerned with the Saudi Arabian context, a portfolio on the country will be presented to understand the culture there in general. The portfolio will include historical, economical, geographical, and, most importantly, cultural details. This will help in highlighting gaps of knowledge regarding the macro influences on industrial establishments and the value systems of individuals working there. The following chapters will concentrate on testing RE concepts in KSA including methods to measure it, and analysing RE relations to national, organisational, and safety culture in the Kingdom. However, in order to understand how risks and safety are thought of in practice, the next section will present the development of accident models. Following this, the resilience engineering concept as new way of thinking about risks and safety will be revealed. The section on RE will respond to many of the debates and paradoxes that are presented in this chapter.

2.2 Models of accidents:

2.2.1 Organisations and management theories: historical overview

This section starts by presenting the historical context of safety and discusses the development of accident models. This will help in understanding accidents phenomenon and the challenges of managing systems safety in industrial context. Understanding the nature of accidents in complex industrial systems depends on the interaction of technical, human, social, organizational, managerial and environmental factors [20], [21]. The study of organisations was originated from the studies of social sciences, which are devoted to understanding social order and social change. The term sociology first appears around the beginning of the 19th century referring to the study of society and culture. The publications of Karl Marx (1848), Emile Durkheim (1897), and Max Weber (1905) have had major influence on forming basic theories of sociology [22]–[24]. Modern organization theory is rooted in concepts developed during that era. However, the importance of organization theory started with the industrial revolution.

Prior to the industrial revolution, people were either self-employed or working in small groups. The introduction of mechanised production processes instead of hand production transformed the industrial landscape. Since the industrial revolution (1760 - 1840) the science of management and organisation started to emerge. Frederick Taylor (1914) founded the scientific management by breaking down complex tasks into simpler steps [25]. Taylor was occupied with thinking of ways to organise work better and improve efficiency. The scientific theory of management postulated that increasing efficiency is achieved by measuring the time for industrial processes with the aim of eliminating wasteful motions. In 1922, Max Weber extended Taylor's work and developed the theory of bureaucracy by which the need for standardized organisations with hierarchical structure became evident [26]. Henri Fayol coined the first comprehensive theory of management in 1947 [27]. Fayol established the 'universal applicability' of management concept across all types of organizations. In addition, Fayol defined the five management functions as:

- Planning
- Organising
- Commanding
- Coordinating
- Controlling

This approach of organisational theory (Classical Organisation Theory) has the following major assumptions (perceptions) about the organisation:

- One 'best way' to carry out the task

- Specialisation and division of labour
- Workers are motivated by money

A great deal of criticism against this approach was due to the implication of the motivation of employees. Although these assumptions reflect the economic hardship at that time; many argue that classical theory of organisation consider the human worker as a ‘simple entity’ motivated only by means of financial rewards. Workers were thought of as another part (machine-like) of the organisational production process. The firm standardised control disregarding their individuality and suppressing creativity. The lack of ‘humanness’ within the classical organization theory had led to the ‘Human Relation Movement’ around 1930’s. A neoclassical approach to organization theory started to emerge acknowledging the importance of social aspects in motivating employees.

Elton Mayo (1933) was the first to link work environment to the efficiency of an organization [28]. Mayo investigated the workers efficiency in different intensities of the light at the ‘Hawthorne’ factory. The importance of his findings lays in challenging the classical approach of the organization theory. Workers efficiency seemed more complex than a linear process. In another study, Mayo asserts ‘solidarity’ between workgroups increased their satisfaction; therefore, he argues that the social aspect is prior to organizational structure. In addition, employees could be motivated by means other than money. In 1938, Chester Bernard published his book on the *Function of the Executive* in an attempt to form a notion of ‘behaviour’ in formal organizations. Bernard argued that the role of an executive is to provide a sense of purpose[29], and bring in the cooperation and ethical vision as the heart of the organizations. The author argues that employees should be stimulated to cooperate. The motivation issue appeared again in Abraham Maslow's work *A Theory of Motivation* in 1943[30]. Maslow introduced a hierarchical dynamic of human needs through his theory. The hierarchy of human needs model (figure 2.1) suggests that people tend to fulfil innate needs in priority one level at a time.

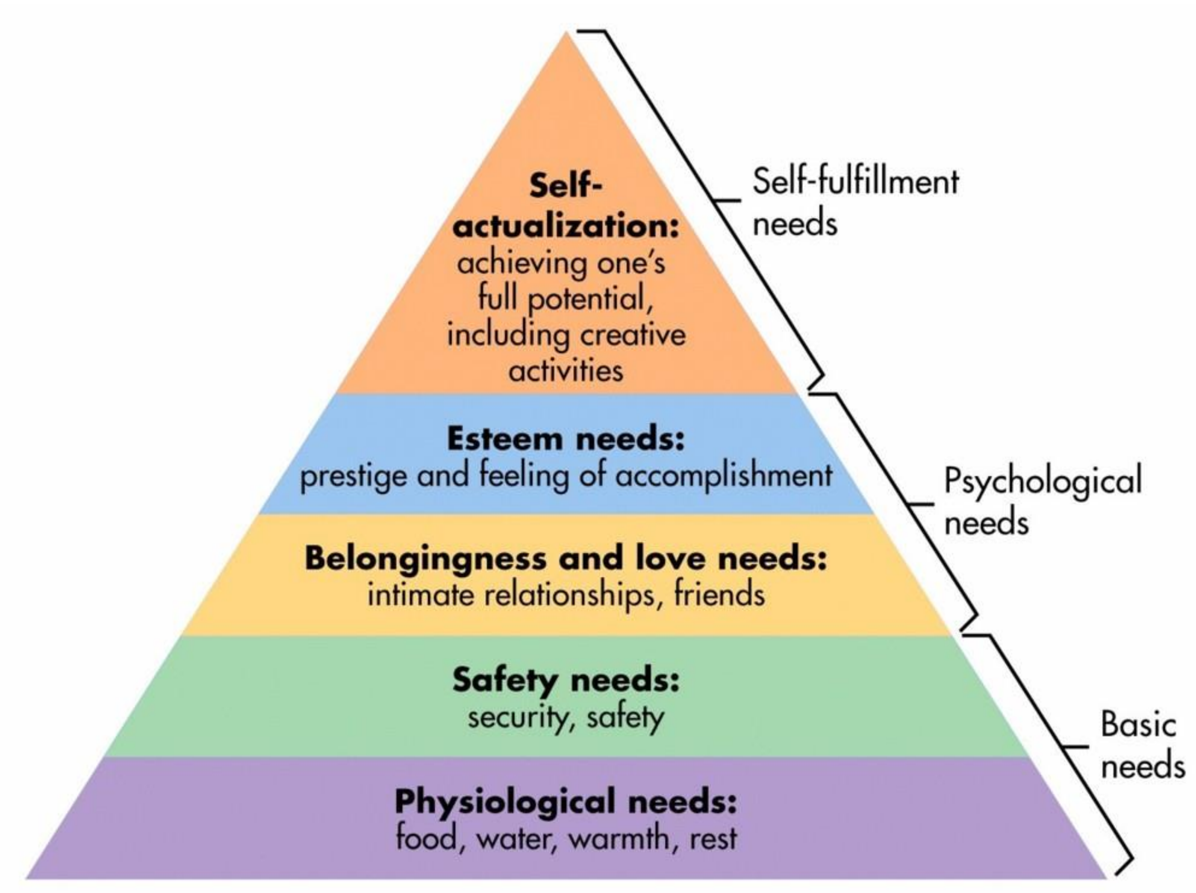

Figure 2-1 Maslow's hierarchy of needs, represented as a pyramid with the more basic needs at the bottom.

Bolmand and Deal (1991) summarize the major assumption of neoclassical organization theory as follows[31]:

- Organizations exist to serve human needs.
- People and organizations need each other.

- The ‘fit’ between individuals and the system affects the organizational wellbeing.

At the core of management science, increasing performance was what occupied managers (e.g. Frederick Taylor, 1914). The classical approach of management viewed accidents as a control problem, where many discussions led to the importance of standardizing tasks and procedures. It was commonly believed that employees’ performance could be controlled through supervisory role (authority). The supervision intends to reduce employee’s slackness and reward hard work. In the light of other studies (see Foyal 1948) performance seems to have more factors influencing employee’s efficiency. With the rise of the human relations movement, more attention was given to aspects that could compromise employee attention. The human relations movement studied the effect of workplace environment on employees’ performance. Better physical work environments seem to have a positive effect on the overall performance. This view became common, and more attention was given to employees working environment. Those conclusions give rise to consider many other factors that could influence performance. Those factors vary from the size of organization, structure, and type of industry, leadership style, and many more. The results of these studies seemed to lack consistency by which performance appears not to be a simple matter. Most of the studies and discussion led to consider different levels of performance being influenced by different contextual factors. Both classic and human relation approaches seemed not enough to understand performance. Organizations seemed to behave as open systems with complex interaction with the wider environment.

These ideas have formed the basis of management science and stimulated professionals and scientists to build up new thoughts on organisations and how to run industrial establishments. The development of occupational health and safety, and accident models is closely related with the rise of management science. The next section will view the chronological development of accident models.

2.2.2 Accident models' development:

Ever since the beginning of the industrial revolution, thousands of deaths and disabilities occurred because of occupational accidents. Accident consequences were (and still are) a strong motivator for tackling system safety and preventing mishap occurrence. Accident causation models attempt to understand the factors and processes involved in accidents in order to develop strategies for accident prevention. The different models are based on a different perception of the accident process. This section provides an overview of the main ideas on system safety and accident causation. Some fundamental concepts from the broad literature on these subjects is highlighted, as well as the ways these ideas have evolved over the last few decades.

Safety is closely related to other concepts such as injuries, errors, risk, and performance. Definitions of safety in the industrial context have evolved with the development of approaches that describe accidents. Over the years, there has been considerable overlap in the development of the various conceptual approaches to accident modelling. Therefore, it is essential to provide the reader with the historical context to indicate the origins of these views. Figure 2.2 illustrates a summary of the main development of accident modelling over the years. This section will introduce some important definitions of these concepts and provide background knowledge on the development of system safety.

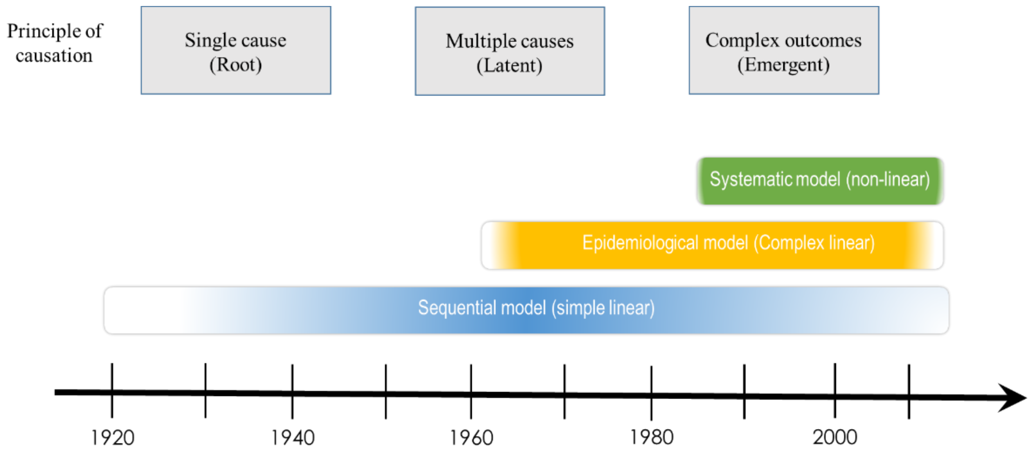

Figure 2-2 Summary of a history of accident modelling [19] (Hollnagel, 2010)

2.2.3 Sequential Models of Accidents:

Since the dawn of the industrial revolution, accident prevention was part of the culture in hazardous industries. Perhaps the earliest attempt to prevent accidents in the industrial context can be traced back to the 19th century at the Du Pont explosives factories. Klein (2009) documented consistent effort by Du Pont to understand the causes of the catastrophic explosions in order to prevent them [32]. Some of these efforts included creating a safety division to carry out inspections, special investigations, and analyse accidents. By 1915 Du Pont had established the idea of zero injuries by eliminating hazards. Accident research started with statistical analysis of injuries at industrial factories by Newbold in 1926. Other studies at that time have investigated working conditions such as working hours and absenteeism rate. During 1930s, researcher’s attention started to shift towards human output and individual accidents proneness. Accident causation modelling was a product of this shift.

The first major work on understanding accidents was developed by Herbert Heinrich in1931[3]. Under the title of *Industrial Accident Prevention*, Heinrich studied 75,000 injuries and illness as well as engineering reports from the 1930’s era. The findings indicated that 88% of the accidents were due to unsafe acts of workers, 10% were caused by unsafe mechanical or physical conditions, and only 2% were unpreventable. In other words, 98% of all industrial accidents are preventable, and 88% can be prevented through the enforcement of proper supervision. Heinrich was thinking of a scientific approach to avoid preventable injuries. His approach started with detecting causes of these injuries and eliminating them. In his view, accidents were merely a link in the chain, and injuries happen due to natural culmination of series of events. These events follow a fixed logical order. Therefore, his model for accident causation was also known as the ‘Domino theory’ which illustrates the idea of linear sequential factors that leads to injuries. Figure 2.3 illustrates the Heinrich domino model including the five sequential factors:

- Ancestry and social environment.
- Fault of person.
- Unsafe act or condition.
- Accidents.
- Injuries.

Figure 2-3 Heinrich domino model of accidents.

Domino theory hypothesises that removing one of these factors must be sufficient to break the knock-down effect and thus stop the preventable injuries. The theory is credited as the first scientific method of injury prevention. Safety professionals generally agree that Heinrich has had a significant impact on the practice of safety and his theory was widely accepted as a central concept of safety science for decades.

By the 1970's, and as a consequence of the advances in technologies, industrial production had become more complex. Industrial units grew in size, and mass production was necessary to meet societies' demands. Therefore, the coordination of efforts and resources was required to improve performance. It was evident, at that stage, for this complexity to be reflected on Heinrich's model. Building on the domino model, Bird and Germain (1986) developed a new model which incorporates management relationships as a cause of accident loss [4]. The 'Loss Causation Model' kept the notion of linear sequential factors but added multiple causes to the pattern. The model (Figure 2.4) was again represented by five blocks (dominos) in sequence, each included a range of factors. Although the loss causation model introduced the multiple cause's idea, the fundamental approach to prevent accidents remained the same. Sequential accident models rely on identifying causes of accidents, and either eliminate them or put barriers in place to encapsulate their effects.

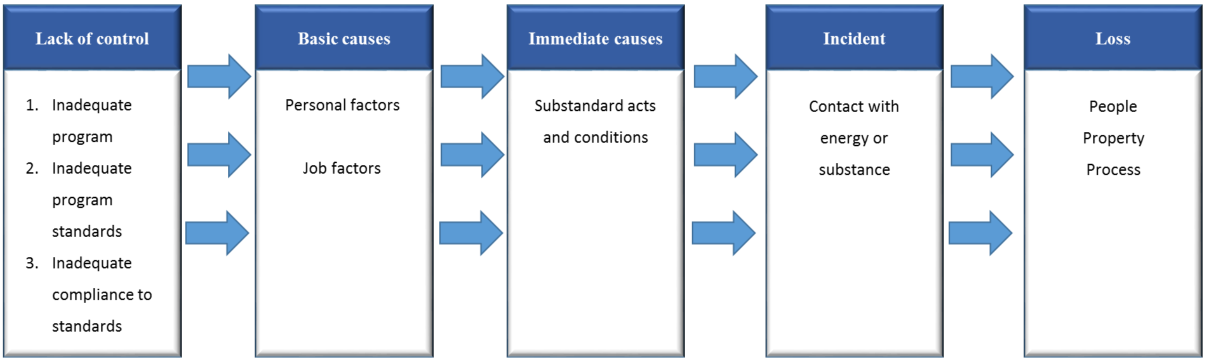

Figure 2-4 Loss Causation Mode by Brid and Germain (1985)[4].

2.2.4 Epidemiological Models of Accidents:

The causal series has influenced the development of several accident models during that period. Research was primarily focused on attribution of human characteristic and behaviour to injuries. An outstanding exception to the preoccupation of the behavioural approach was the result of Gibson's (1961) work. Under '*The contribution of experimental psychology to the formulation of the problem of safety*', Gibson adopted a natural science approach to safety issues [33]. For the first time, accidents were thought of in terms of energy within the system. This energy is transferred in a variety of ways and quantities, and at different rates, which damages inanimate or animate structures. In his view, injury problems are conceptualized to result from interactions among the host, agent, and environment. Gibson elaborated on this notion by classifying injury's agents with reference to various forms of energy. For an injury to occur, a person must be exposed to an injurious influence– a form of energy (mechanical, thermal, electrical, etc.). In the Energy-damage model, the hazard is a source of potentially damaging energy and accidents occur due to the failure to control it. Harmful objects were redefined as vectors/vehicles that carries potentially harmful energies. Therefore, a preventive mechanism had to be invented in order to control the harmful energies.

The Energy-damage model is closely related to epidemiological science where the focus is on the study of disease epidemics and the causal factors around their development. The relationship between epidemiology and accident prevention is traced back to the work of Gordon (1949) [34]. In *The Epidemiology of Accidents*; Gordon states that an accident "is a combination of forces from at least three sources, which are the host […], the agent itself, and the environment in which both the host and agent find themselves". This epidemiologic triangle (agent-host-environment) was transferred to accident prevention modelling. Gibson based his model on the idea that injuries are the result of energy transfer that exceed the body's threshold. In the same vain, Haddon (1980) introduced his matrix for injury prevention and control (Figure 2.5) [35]. The control mechanism includes physical, or structural containment including barriers, processes, and procedures. In addition, Haddon systemised the formerly known principles of accident prevention into the following ten strategies:

1. Prevent the creation of the hazard in the first place.
2. Reduce the amount of the hazard brought into being.
3. Prevent the release of the hazard that already exists.
4. Modify the rate or spatial distribution of release of the hazard from its source.
5. Separate, in time or space, the hazard and that which is to be protected.
6. Separate the hazard and that which is to be protected by interposition of a material barrier.
7. Modify the basic relevant qualities of the hazard.
8. Make what is to be protected more resistant to damage from the hazard.

9. Begin to counter the damage already done by the environmental hazard.

10. Stabilize, repair, and rehabilitate the object of the damage.

Haddon matrix			
Phase	Human	Equipment	Environment
Pre-Injury			
Injury			
Post-Injury			

Figure 2-5 Example of Haddon matrix for injury prevention and control.

The energy model and Haddon's strategies have had enormous impact on risk analysis and machinery safety. They are central components of developing other models such as: Occupational Accident Research Unit (OARU), Management Oversite and Risk Tree (MORT), Safety Management and Organisation Review Technique (SMORT), and TRIPOD models (Kjellen, 2000) [36]. Another contribution to the development of epidemiological accident modelling has been proposed by Benner (1975) [37]. Benner introduced the idea of 'multilinear events sequencing methods' as an alternative to the linear causal series that dominated accident investigations for decades. Benner emphasised the significance of understanding how multiple factors within a system combined contribute to an accident instead of identifying several causal factors. Based on his findings, Benner asserts that "a realistic accident model must reflect both a sequential and concurrent nonlinear course of events, and reflect event interactions over time". In his view, agents and environmental factors together could have negative impact on the hosting environment. This development has led the discussion towards the contextual factors of the organisation.

In the late 1970s and 1980s many catastrophic accidents occurred including Flixborough, Challenger, Three Mile Island, Bhopal, and Chernobyl. Each of these accidents have been extensively investigated by professionals. The investigation reports pointed towards local workplace conditions and upstream organisational factors as the underlying causes that led to human error. The contextual system argument were articulated by many researchers during that period including Charles Perrow (1984) and Barry Turner (1978), amongst others [38], [39]. Charles Perrow (1984) started to argue that technological advances have made industrial production inherently complex and tightly coupled. According to Perrow, tightly coupled systems have little tolerance to small disturbances, which makes the occurrence of accidents ‘normal’ in such systems. Therefore, Perrow’s normal accident theory postulates that tightly coupled systems are inherently unsafe. Complex system components are linked by multiple means, these parts interact and affect each other in unexpected ways; therefore, errors are inevitable. In Perrow’s view, large failures relate to organizational factors rather than operator errors. The system accident may begin with trivial events that cascade through the system to create a large event with severe outcomes. Furthermore, normal accident theory moved the attention to the weakness of using in-depth defences in complex systems. Such an approach adds to the complexity, tight coupling, and creates redundancies in the system. Other valuable accident models, during that period, were proposed by Rasmussen & Jensen (1974) [40]. The early work of Carl Rasmussen focused on studying how human error can be described and analysed in accident investigation. The product of this line of thought was the development of the skill-rule-knowledge model of human error. Further work of Rasmussen (1981; 1986) incorporated cognitive science with the aim of analysing human error in operations [41], [42].

In 1990, James Reason (1990) added crucial contribution to the understanding of human error role in accidents [43]. Reason distinguished between two types of human error: active errors (the consequence immediately follows the cause) and latent errors. Reason used the term 'latent'–borrowed from the epidemiological studies- to indicate similarities between 'pathogen' related diseases and the catastrophic accident in complex organisations [43]. The resident pathogens are biological agents in the body that causes disease or illness to its host when combined with external triggering factors. Reason used the term to indicate that the cause of some errors exists naturally in the system, however when they interact with other factors they could breach system defences. To illustrate this idea, the model uses the 'Swiss Cheese' analogy, where each safety barrier has some holes in it (Figure 2.6). The breach of defences occurs due to interaction between inherent features of the system (resident pathogens) and external triggering events. The resident pathogens, in the author view, are more open to detection than local triggering events. Therefore, concentrating on detecting these pathogens and neutralizing them is more likely to minimize the risk of accidents. In his book, *Human Error*, Reason asserts "simple human error can be foreseen and contained by built-in defences, but theses engineered defences offer little protection against certain compensation of system pathogens and local triggers". Therefore, efforts should concentrate on hazards, defences, and losses, instead of searching for an individual's contribution to errors. Opposing the underlying concept that dominated accident investigations for decades, Reason drew attention to the failure to recognize hazards within the system. Such a shift from human behaviour contribution to the error mechanism has created a no-blame approach to safety investigations. Regarding human error, he continued the discussion from a managerial perspective. Reason recognised the impracticality of total eradication of human error. Therefore, barriers design must take into account the normality of human operation error. The study of humans in the system moved away from the individual to groups of individuals working in that system. More emphasis was given to studying normal human behaviour and decision making in relation to the environment. By 1997, Reason introduced his model for system safety which incorporated the Swiss Cheese model to the whole system (Figure 2.7) [44]. In Reason's view, an accident could be prevented by building up a variety of defences to the effects of upstream organisational factors.

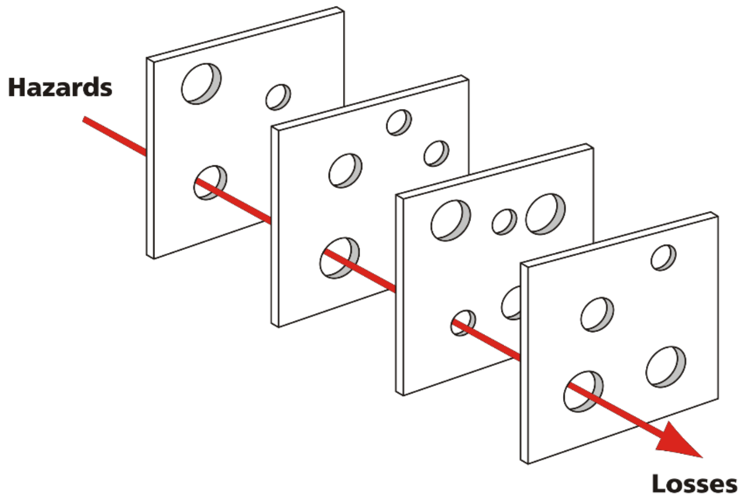

Figure 2-6 Reason's 'Swiss Cheese' Model.

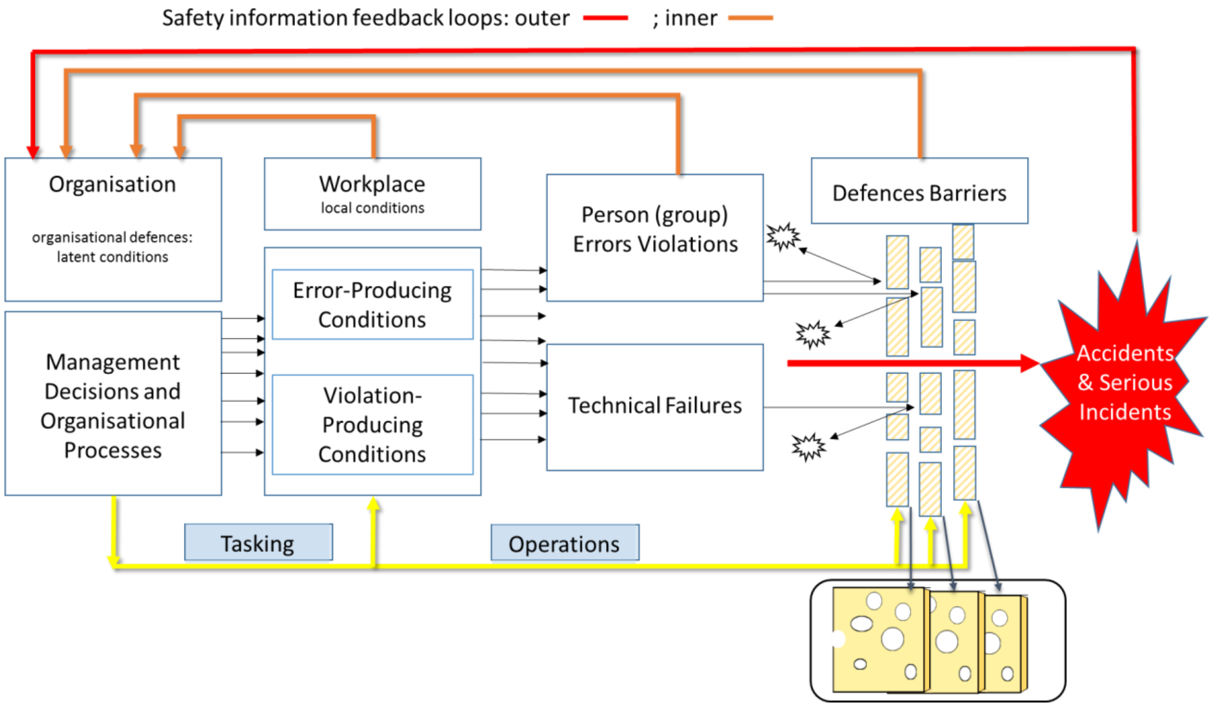

Figure 2-7 The Reason Model of System Safety (Reason, 1997)

2.2.5 Systematic Models of Accidents:

Reason's work demonstrated the complexity of accident causation and moved away from the emphasis on human error. The discussion on the complexity of accident causation has led researchers to think of effective ways to overcome growing complexity in industrial systems. Leveson (2004), an expert on system and software safety, introduced a paper titled '*A New Accident Model for Engineering Safer Systems*' [45]. The new model uses system theory to divide the organisation into hierarchical levels with control processes operating at the interfaces between levels (Figure 2.8). Her model 'System-Theoretic Accident Model and Process' (STAMP) views accidents as a control problem. The model builds on the no-blame approach and views systems as interrelated components in a dynamic equilibrium state. The systems remain in that state through feedback loops of information and control. Accidents occur due to a failure in an adaptive feedback function to meet a complex set of goals and values. The STAMP model advocates investigation of system control failures to detect or prevent accident triggers. Leveson states “instead of defining safety management in terms of preventing component failure events, it is defined as a continuous control task to impose the constraints necessary to limit system behaviour to safe changes and adaptations”. Leveson’s model introduced a dynamic proactive approach to safety through safety performance indicators. The basic concepts in STAMP are: constraints, control loops and process models, and levels of control. Although the STAMP model provides a new approach to safety, it had little success in the safety community (OHS, 2012) [46]. Roelen et al. (2011) questioned the usefulness of such an approach because it does not fit with the current practice of safety data collection and analysis [47]. Although Leveson’s model was not popular in practice, a new paradigm started to emerge challenging the fundamental view of accident modelling. A novel systematic view to accident modelling, which considers the performance of the system as a whole.

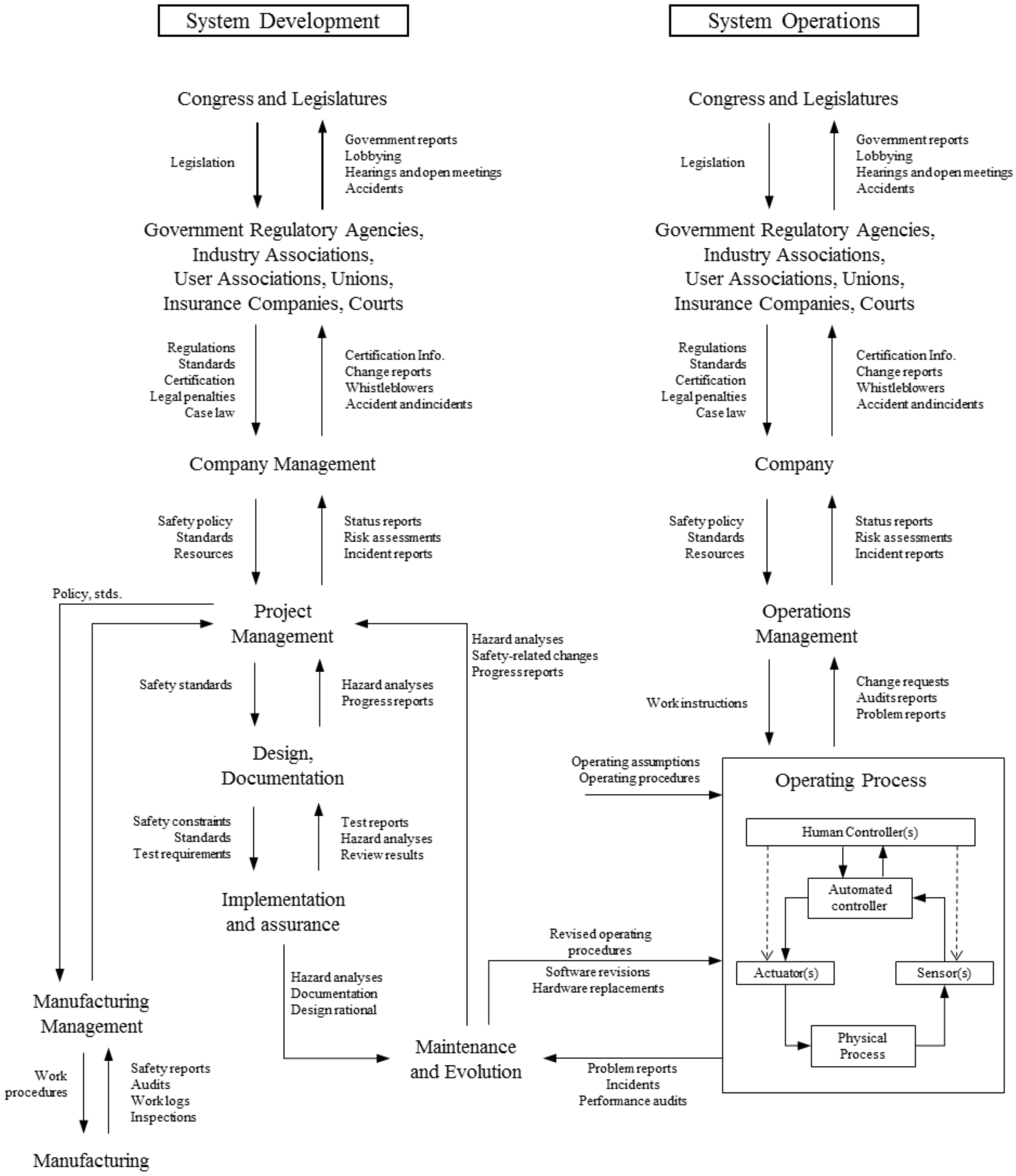

Figure 2-8 General form of a model of socio-technical control (Leveson, 2004)

Erik Hollnagel, a cognitive systems engineer, proposed a new approach to safety analysis and accident modelling. In *Barriers and Accident Prevention* (2004), he challenged the idea of linear cause-effect sequences, which was a core concept of accident modelling since its development by Heinrich in1931 [6]. Hollnagel's non-linear systematic approach to safety views accidents as an emergent phenomenon. Using the resonance (frequency) analogy, Hollnagel distinguishes between control signal as a property of the system and noise as a property of the environment. Although noise may seem completely random (stochastic resonance), it is determined to a large extent by the variability of the functions of the system. In this regard, accidents could be viewed as ‘functional resonance’ which is a consequence of functional couplings in the system. Based on this concept, the author suggested the Functional Resonance Analysis Method (FRAM) as an accident analysis model and risk assessment tool. The model uses the idea of resonance arising from the variability of everyday performance to describe system’s outcomes. Both failures and successes are emergent. The accident occurs when variability from multiple functions combines in unexpected ways. FRAM basic analysis principles are as follows:

- Identify and characterise essential system functions; the characterisation can be based on the six connectors of the hexagonal representation (figure 2.9).
- Characterise the potential (context dependent) for variability using a checklist.
- Define functional resonance based on identified dependencies among functions.
- Identify barriers for variability (damping factors) and specify required performance monitoring.

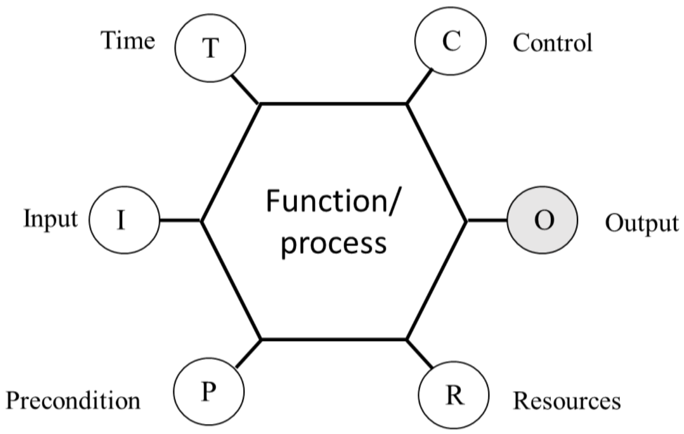

Figure 2-9 A graphical representation of a generic functional entity.

FRAM take a ‘breadth-before-depth’ approach in order to build organisational functional model. The breadth-first principle relies on the understanding of the everyday functioning of a system (the breadth). As a first step of developing the FRAM, all the functions within the system must be identified. The aim of this step is to recognise organisational functions in an everyday situation and its variability (instead of going directly to identify root causes of risks) to understand what may go wrong. This is a fundamental difference from the traditional safety analysis method. The breadth-first principle shifts the focus to identifying all functions and considers how activities are usually carried out. The next step is to describe essential aspects of each function. At this step, each function could be described in terms of the following criteria (see figure 2.7):

- Inputs (I): what is needed to perform the function?
- Outputs (O): what is produced by the function?
- Resources (R): what is needed to process the inputs?
- Controls (C): what are the restrictions?
- Preconditions (P): what conditions must be fulfilled before a function can start?
- Time (T): What is the duration of the function?

Since FRAM adopts the breadth-first principle, the simplest description of a function could be made through its input(s) and output(s). This helps in focusing the efforts on understanding the system as a whole, while avoids complexity and redundancies of going into too much detail. The inputs and outputs of each function helps in understanding the interactions of organisational subsystems and tasks. It is necessary to iterate the former two steps (if needed) until an acceptable FRAM is achieved.

A year after that, Hollnagel (2005) identified a fundamental characteristic of human and organisational performance which is responsible for balancing demands and resources [48]. The author refers to this ability as a trade-off between efficiency and thoroughness to reach performance goals. The Efficiency-Thoroughness Trade-Off (ETTO) principle states that “in their daily activities, at work or at leisure, people (and organisations) routinely make a choice between being effective and being thorough, since it rarely is possible to be both at the same time. If demands for productivity or performance are high, thoroughness is reduced until the productivity goals are met. If demands for safety are high, efficiency is reduced until the safety goals are met” (Hollnagel and Goteman, 2004) [49]. Therefore, the author advocates the notion of resilient performance to maintain a dynamically stable state under normal operation or stress.

2.2.6 Resilience Engineering:

The term ‘resilience’ was used in different disciplines with similar meanings. The early use of the term described the ability of materials to withstand severe conditions. Many years later, the term was used in ecology to express the ecosystem capacity to resist damage and recover quickly in response to turbulences. Psychologists used the term in the 1970’s to refer to an individual’s ability to properly adapt to stress and adversity. By the year 2000, it was used in economics to maintain continuous business operations by rapidly adapting and responding to business disruptions. Hollnagel (2011) defines Resilience Engineering as "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" [19]. Resilience Engineering takes a holistic view of the organisational functions by looking at the intersection of people, technology, and how they function together as a system. According to the former definition, the goal of a resilient organisation is to attain resilience performance that avoids undesirable risks and catastrophic outcomes. In order to achieve resilience, Hollnagel propose the following four basic abilities (Figure 2.10):

- Anticipate: how an organisation anticipates risks/opportunities, potential changes, and their consciences in the future. The author calls this the ability to address the ‘potential’.
- Respond: how an organisation reacts to disruption (normal and abnormal) earthier by a planned response or by adjusting its function to the disturbances. This factor looks at the organisational ability to address the ‘actual’.
- Monitor: how to observe and assess threats within the system itself or the environment. In other words, organisational ability to address the ‘critical’.
- Learn: how to extract knowledge from previous failures and successes. The ability to address the ‘factual’.

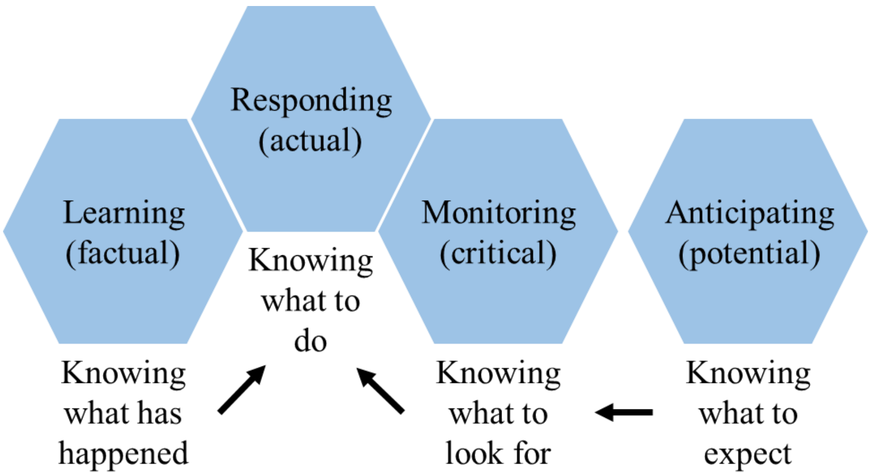

Figure 2-10 The four cornerstones of resilience (Hollnagel, 2011)

Safety under resilient systems goes beyond the traditional view of zero mishaps risks. The traditional view entails an inverse correlation between the level of safety and the number of undesirable outcomes (accidents, incidents, work time injury, work related illnesses, etc.). Under this view, organisations take a ‘protective’ approach to safety to protect and prevent the system from adverse outcomes. Hollnagel (2014) refers to this type of safety as ‘Safety-I’ to distinguish it from how safety is defined in a resilient system [50]. RE defines safety as “the ability to succeed under varying conditions” (Hollnagel, 2015) [51]. In the author’s view, the ability to succeed under varying conditions will produce fewer undesirable events and robust performance in general. This view of safety is called ‘Safety-II’ where safety is ‘productive’ instead of ‘protective’. Resilience is something the organisation ‘does’ rather than something the organisation ‘has’. Thus, resilience helps organisations to avoid failures and losses, and responds effectively after these have occurred. The proposed four abilities provide the basis for resilient performance. This discussion leads us to the question of how to develop these four abilities within a system.

Engineering resilience into a system in practice is all about constructing the former four capacities into the system. RE and systemic models in general have their roots in control theory (Sheridan, 1992) and emphasise the need to base accident analysis on an understanding of the functional characteristics of the system [52]. Unlike sequential and epidemiological models, the systematic models consider a holistic view of the system’s performance. Therefore, instead of putting barriers and defences in place, efforts must focus on a system’s ability to monitor and control any variances in its basic abilities (monitoring, anticipating, responding, and learning) of the organisation. Accidents happen when the system is unable to tolerate variances in its operating mode. Humans and their social systems is also a source of variability in the system. Thus, there is a particular emphasis on the human to adjust and manage demands on time and efficiency. It is managers' responsibility to implement safety management and ensure an adequate performance level in the organisations. By evaluating the organisation's ability to monitor, anticipate, respond, and learn, the managers' role is crucial to ensure resilient performance.

In order to evaluate the extent of each ability that provide the basis for resilient performance, Hollnagel (2011) proposed a Resilience Analysis Grid (RAG) [19]. The RAG uses a quantitative method in the form of sets of generic questions to determine how well a system performs on each of the four basic abilities. These questions can be tailored to be used in specific application to build a profile of the system's potential for resilient performance. The RAG profile provides managers with the state of resilience and safety in specific groups or departments. Several RAG profiles can be analysed and used as the basis for managing the organisation and following the consequences of planned intervention. By analysing the RE four abilities the organisation can fall into one of the following system-types proposed by Hollnagel (2016) [51]:

- *Systems of the First Kind*: these types of organisations rely heavily on reacting when something unexpected happens. Failure to react appropriately to unexpected events will lead (sooner or later) to the 'death' of the system. Managers in such system must take action to develop a more active approach to safety. In such organisations, it is necessary to improve the learning and monitor the ability of the organisation in order to be resilient. While the ability to respond is fundamental, systems of the first kind are not really resilient.

- *Systems of the Second Kind*: are organisations that can learn from previous response experiences. An organisation under this type can respond to unexpected events and adjust what it does in the future. Learning what to look for in the future and how to manage it is necessary to survive in an unstable environment. Managers should use the learning ability in order to improve monitoring and response abilities in the future.

- *Systems of the Third Kind*: are able to detect situations before they become too serious. By analysing the developments in the environment around, these organisations can anticipate changes and prepare themselves as well as possible. Anticipation is used to make predictions about the future, which allows managers to take actions before mishaps occur. Organisations that plan in advance and organise recourses efficiently have better chances of surviving dynamic environments.

- *Systems of the Fourth Kind*: meets all the criteria of resilient performance. They are able to respond, monitor, learn, and anticipate therefore able to succeed under varying conditions. Organisations of the fourth kind are resilient and could improve by considering what happens within the system and between the system and its environment.

Resilience as a concept for safety engineering is in the early development stages and has not been used much formally, although informally many of the ideas have existed within safety management circles under different rubrics (Sheridan, 2008). Resilience

Engineering is still an evolving concept that attracts many professionals and scholars to test it. Testing RE in various organisations and industries continues to develop our understanding of accident causation and organisational performance in general. The rapid continued growth in complexity and the development of technology adopted by the process industry offer a good case to test the concept.

On the account of these new developments in viewing safety and RE four kinds of system, this research asks the following questions:

- **Is the Saudi Arabian process industry resilient? Under which category of 'System-kind' does it fit?**

- **What are the main contributing factors to resilience engineering in the Saudi Arabian energy industry?**

So far, this section reviewed the development of industrial organisation in management studies. The main schools that influences organisation theory and hidden assumptions about management roles and employees were discussed. The development of accident models was closely influenced by the development of management theory. The views on safety started with the sequential casual model where accident prevention was linear and simple. The mounting evidence of influences of the environment led to the development of more complex linear models of accidents. However, a new school of thought has challenged the linear view of accidents and moved towards adopting a non-linear systematic model. Resilience Engineering adopted that view and offered a different way of thinking about safety. RE approaches to safety and risk assessment advocate a holistic view of the organisation and all it functions. Within RE, safety is defined as the freedom of mishap risk. The goal of a resilient organisation is to keep all its interrelated functions in a state of dynamic equilibrium. This can be achieved through developing and supporting for basic processes: monitoring, anticipating, responding, and learning. In the light of these four abilities an organisation can fall under four different classes that were defined by Hollnagel. This research attempts to examine the concepts of RE in a new culture, which will review new strengths and weaknesses of the theory. In addition, this will help in understanding cultural influences on RE and the main contributing factors to the Saudi Arabian process industry. The next section will view the literature on organisational and safety cultures and explore the influences of national culture on them.

2.3 Organisational Culture and Safety Culture:

This section will introduce the concept of culture and its relations with organisations and safety. In addition to the development of the concept in organisational and management studies, we will present debates concerning the relationship of national, organisational, and subcultures in the literature. Safety culture will then be defined and discussed.

2.3.1 Organisational Culture

Organisational culture as a concept has been used by psychologists for a long time. Psychologists studied the norms within certain groups and sometimes referred to it as 'climate' (e.g. Lewin et. al., 1939) [53]. The concept was transferred to organisational studies when organisational psychologists began to study work groups and whole organisations instead of focusing on individuals as the analysis unit. Schein and Bennis (1965) noticed a pattern of norms and attitudes that cut across a social group [54]. With this shift from individuals to groups it was essential to think of organisations in terms of 'systems'. System theory and system dynamics provided important theoretical foundations for the development of organisational and cultural studies (Schein, 1990) [55]. The Tavistock Institute developed the concept of 'socio-technical systems' as a concept that includes the new unit of analysis. Katz and Kahn (1978) has used this unit of analysis to study organisations [56]. In The Social Psychology of Organisations, the authors discussed the existence of roles, norms and values that are present within organisations. The application of 'culture' as a concept within certain societies and organisations was developed during the 1980's. That period witnessed growing interest in organizational culture and management. Several books were published, such as: In Search of Excellence (Peters et al. 1982) and Corporate Cultures (Deal & Kennedy 1982), where they advocate the role of culture to improve performance [57], [58]. 'Strong culture' was found to be of great importance particularly if management emphasized basic values and common goals. It was suggested that culture can be used as a control instrument and as an alternative to other forms of control in organizations (such as bureaucratic control). However, a great part of what was written about organizational culture and management in the 1980s was influenced by Japanese organizational philosophy, but it is relatively obvious that many of the measures implemented in Japanese industry would not be desirable or even possible in Europe, specifically because of cultural differences (Haukelid 2008) [59]. In the same vain, Ouchi (1981) tried to study differences between organisational performances cross-cultures (Japanese and US companies) [60]. It was noticed that organisational performance was also different within a society, which indicates that national culture was not enough of an explanation. Therefore, organisational culture was developed mainly to explain variation in patterns of organisational behaviour; and levels of stability in groups. In other words, measures that are implemented to improve organizational culture neither can, nor should, be considered in isolation from the national culture.

Schine (2004) defines organisational culture as “The pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration, and that have worked well enough to be considered valid; therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to these problems” [55]. Hofsted’s approach to organisational culture is a derivative of the idea that organisations are subcultures of a larger cultural system. His study of work related values indicated distinctive patterns of the collective value systems in different countries. Whereas Schein’s work highlighted that these differences derived from core assumptions held by members of an organisation and represent what they believe to be reality. Socially constructed reality is more complex because it consists of sub-world contexts, therefore these assumptions are running deep and manifested as values and behaviours. Culture, however, is taken for granted and remains unquestionable. Members of an organisation tend to confirm to the existing culture and do not challenge it. Members adapt to the value system of the organisation and act accordingly. One significant influence of values on cultural members takes place through defining norms for behaviour. Values can be defined as the social principle, goals and standards that cultural members believe have intrinsic worth. It dictates their priorities and guides them to distinguish what is right and wrong. On the other hand, norms are the expression of the values. They are the unwritten rules that allow members to know what is expected from them. In reality, this is translated into variety of social behaviours, such as dress code, the formality of communication, and ways to resolve conflicts. In short, norms outline what is conceded to be normal or abnormal behaviour. According to Schein's theory, the underlining assumptions held by members nurture their values and norm; in turn, values and norms support activities that produce cultural artefacts.

Further studies on the impact of culture on organisational performance have indicated a significant relationship between cultural strength and organisational performance (Kotter and Heskett, 1992) [61]. In addition, this relation is much stronger when cultural values are supported by organisational adoption to the environment. In a different study, Denison (1990) argued the importance of aligning the environment not only with the national culture but also to the strategy of the organisation. In his findings, Denison emphases the rule of value flexibility, organisational adaptability, and organisational commitment to succeed in a rapidly changing environment [62]. The debate on the relationship between organisations and the environment leads us to the larger discussion about boundaries of the organisations. Prior to the general system theory, a close system view dominated management theories where influences of work environment were neglected. General system theory introduced the notion of level of analysis not only in terms of national and organisational levels but also in terms of hierarchical subsystems within an organisation. Although this debate falls beyond the scope of this thesis (for more see Hatch and Cunliffe, 2013), we undertake a symbolic-interpretive view to determine the level of analysis [63]. Symbolic-interpretive organisational theorists are concerned with studying cultural symbols to understand groups and group dynamics. Within this view, institutional theorists typically take the position that institutions are relatively durable social systems where actors can be individuals, groups (as in this study) or organisations. Within this group individual actions and interactions produce a distinctive pattern of relationships. These relationships when analysed at organisational level appear as structure. In this thesis, we will investigate working groups (operators, managers), and analyse the result from an organisational point of view. Within such a group we will investigate the pattern of behaviour regarding safety including their view on top management commitment to safety, beliefs about the value of safety, reporting accidents, risk taking tendencies, and patterns of behaviour when a mishap event occurs. This will provide us with a general feeling of the safety culture in the process industry in Saudi Arabia.

2.3.2 Safety Culture

Just as you can analyse an organisational culture as a subsystem of national culture context, you can examine safety culture as subculture of the organisational culture context (Hatch and Cunliffe, 2013) [63]. Accordingly, Van Maanen and Barley (1984) articulate that subcultures exist within organisations harbouring segments of relative diversity within a generally approved organisational plan [64]. Subcultures may form around similar interests (e.g. professional, gendered, and occupational) or sheared place or equipment (e.g. cafeteria, photocopiers, and toilets). These subcultures may compete with the organisational plan by offering alternative priorities or goals to its members. Therefore, Siehl and Martin (1984) label subcultures according to their relationship with organisational culture to enhancing: subculture, orthogonal subculture, and counterculture [65]. Enhancing subcultures are supportive of the organisational culture, while orthogonal subcultures are neutral where they neither boost nor stand against organisational culture, and countercultures actively challenge values and beliefs of the organisational culture. Safety culture could challenge some production goals or compete with organisational resources, subsequently it could create a paradox for top management in some cases. This issue has major implications for implementing an effective safety culture.

The main purpose of any business is to create more value to the shareholders. Consequently, organizations constantly aim to cut their expenses to increase the revenues. As a result, managers, as well as employees, feels pressured more and more to execute projects with limited resources and to a tight schedule. The investment in one area, usually, creates greater squeezes in other areas. Thus, operators, usually, decide to take short cuts to save time or resources. More often than not, they consider safety practices redundant or even an obstruction to carry out tasks. Safety under such an atmosphere is considered as something that acts against efficiency and productivity. Certainly, this reduces (if not provoks) safety margins and puts at risk the integrity of system processes.

In such an environment, when accidents occur, investigators view these short cuts from sharp-end operators as one of the main reasons for the event (if not the prime one). From an organisational level, the existence of short cuts by the operators is viewed as an unsafe culture. Top managers who believe in the causal model tend to react by introducing tougher regulations. However, many empirical studies have shown that a considerable number of employees had not followed the standard procedures to carry out their tasks. McDonald (2005) asserts that most commonly technicians reported that the alternative methods were better and faster [66]. Perhaps more surprisingly, is that such practice is widely accepted among employees and managers. Researchers might highlight the gap between formal requirements and what happens.

Operational managers usually think of safety in terms of LTIF (lost-time injuries per million man hours) as the centre of their attention. For them, around 90 percent of accidents are due to 'human error' (Reason, 1997) [44]. Given the range of human involvement in a complex environment, front-line operators are usually considered as the prime reason for accidents. Therefore, the majority of managers treat employees with the 'carrot and stick' rule. However, such a view lacks the proper understanding of accidents or the dynamics of a safety culture. Resilience engineering pursues safety as a value to the system (process or output). Safety measures must involve the product as well as the processes that made it. This could be achieved by linking error management with the total Quality Management. RE takes a holistic view of the wider issues that leads to such pattern of behaviours. Instead of thinking of short cuts taken by operators, RE takes account of the reasons that lead to the need for these short cuts. Pressure on employees to meet deadlines and resources conditions are understood, and managers should think of how to balance production goals and safety efforts of the operators. Hollnagel (2009) emphasized the importance of achieving balance between the organisational goals and safety requirement in order to ensure safe operation [67]. Resilience engineering incorporates the ETTO (efficiency-thoroughness trade-off) principle as a tactic to overcome such paradoxes.

Much of this discussion on safety management echoes the interest in organizational culture in the 1980s. The debates within safety management literature focuses greatly on the connection between the organizational cultural and safety performance in the organization. Among these debates: what do we mean by 'safety culture'? Do we deal with one unitary culture within an organisation, or many subcultures? Can it be managed or controlled? The academic interest in the relationship between culture and safety dates back to Barry Turner's (1978) influential book Man-Made Disasters [39].

However, the concept of safety culture was not introduced into the mainstream until 1986 with the International Atomic Energy Agency's investigation into the Chernobyl accident (International Atomic Energy Agency, 1986) [68]. Since then, many safety researchers and practitioners have turned to the concept (Vaughan 1996; Reason 1997; Pidgeon 1998; Cooper 2000; Cox & Cheyne 2000; Hale 2000; Richter & Koch 2004; Schaufeliet al. 2006) [44], [69]–[75]. Here, we accept the general definition proposed by the Advisory Committee on the Safety of a Nuclear Installation (ACSNI) which is "the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organization's health and safety management" (ACSNI, 1993) [76]. Under this definition, safety culture is multidimensional and closely related to the management. Generally speaking, culture can influence safety in two ways: first, by providing the frames of reference through which information about risk is interpreted (Turner, 1978) [39]. Second, culture influences safety by constituting conventions for behaviour, interaction and communication.

On the question of can managers control safety culture in organisations, Frost (1985) asserts that "Culture cannot be managed; it emerges. Leaders don't create cultures; members of the culture do. Culture is an expression of people's deepest needs, a means of endowing their experiences with meaning. Even if culture in this sense could be managed, it shouldn't be (. . .) it is naive and perhaps unethical to speak of managing culture" [77]. A number of organizational studies support this view. The problem, however, is that several subcultures compete within a single company, and those who work on the shop floor will often have a 'counterculture' that conflicts with management's goals and values (e.g. Krackhardt & Kilduff 1990; and Thompson & McHugh 2002) [78], [79]. These studies conclude that culture cannot be managed or controlled, but that to a certain degree, it may be influenced. On the contrary, Reason (1997) takes the view that safety culture can be socially engineered [44]. He argued that gradual and persistence by top managers are essential for successful implementation of an 'effective' safety culture. This approach suggests a sequential model of safety where identifying, fabricating, and assembling essential components of safety culture is possible. In contrast, a control theory view does not see organisations as a static design of components. It rather accepts that a system is a set of constantly changing and adaptive processes to achieve multiple goals (Dekker, 2011) [80]. Of course, there are many interesting studies of organizational culture in which culture is treated like the complex phenomenon that it is. What is worth emphasizing here is that safety culture is a useful concept, but much of the management literature (and some organization theory) often takes an instrumental and superficial approach to it. To achieve a deeper understanding of this complex phenomenon, the analysis should be holistically oriented and cover various levels from the manifest and discursive to the more essential 'taken for granted'. Resilience engineering takes a holistic view of the organisation and attempts to keep all its interrelated functions in a state of dynamic equilibrium. Therefore, managers must make sure that safety culture is adaptive to the organisational culture and flexible to differences between subcultures that exist in the organisation. Such an approach can result in an effective safety culture across the organisation.

Assessing organization culture should provide some basis for making judgments about how safe or unsafe an organization is, as well as some sort of 'prediction' as to whether the organization is prone to having accidents in the future. The predictive value of culture surveys has not been the subject of much discussion or empirical investigation in the literature. Although some authors have addressed the topic (e.g., Zohar 2000; Kathryn Mearns et al. 2003; Cooper & Phillips 2004; Hofmann & Mark 2006), publication of the relationship between culture surveys and safety is rather limited [81]–[84]. On a more theoretical level, culture may influence safety in two ways: first, by providing the frames of reference through which information about risk is interpreted. This is a view on culture that is influenced by the views of Turner (1978) [39]. An organization's culture involves a field of vision, where some risks are visible, but where there may be blind spots regarding others. Second, culture influences safety by constituting conventions for behaviour, interaction and communication. This aspect of culture pertains to the informal work practices that usually exist alongside the formally prescribed structures of work. Finding appropriate ways to 'measure' different aspects of culture has been a recurrent problem for both practitioners and researchers interested in safety culture. Several researchers and institutions have developed questionnaires containing items that are meant to be indicators of cultural traits regarded as important for safety. Examples of existing survey tools include the 'A guide to measuring health & safety performance' (Health Safety Executive 2001), the 'Safety Culture Assessment Toolkit' (Cox &

Cheyne 2000), and 'Risk Level on the Norwegian Continental Shelf' (Tharaldsen et al. 2008) [72], [85], [86]. The apparent hope is that the use of such assessment tools will provide the basis for a proactive analysis of risk. The need for such proactive assessments has been emphasized by high liability theorists (e.g. Roberts 1993), and more recently by (Hollnagel et al. 2006) in their book *Resilience Engineering* [87], [88]. The first step towards building resilience is 'to analyse, measure, and monitor the resilience of organizations in their operative environments' (Hollnagel et al. 2006) [88]. This has to do with an organizations' ability to recognize when situations fall outside the limits of acceptable risk, and thus has the organizational foresight that is an important part of resilience engineering. How one is to analyse and monitor the social part of socio-technical systems is, however, not explicitly discussed. As the practical value of safety monitoring rests on its ability to describe current and 'predict' future performance, this is a very important question for safety research.

2.4 Saudi Arabia:

This profile on Saudi Arabia aims to guide the reader on some cultural context and business environment in the country. The profile will introduce historical, geographical, economical aspects of the Saudi context; which helps in understanding the psychological and social influences on employees working in the Kingdom. In addition, a review of the business environment and labour market regulations is presented to understand the contextual macro influence on organisations operating there. The Kingdom of Saudi Arabia (KSA) was chosen because:

- It is the largest producer of oil in the world.
- One of the top 25% best environments for business in the world (World Bank report, 2015) [89].
- A new cultural context to implement a Resilience Engineering framework.

Since the aim of this research is to test resilience in the Saudi context and identify the main contributing factors to resilient performance in the process industry. This section will provide contextual aspects of the Saudi Arabian values and behaviours.

2.4.1 Overview of Saudi Arabia:

The Kingdom of Saudi Arabia (KSA) is the largest Arab state in Western Asia and the second-largest geographically in the Arab world. It occupies an area of 2,149,690 square kilometres and have a population of more than 27,752,316 people with 1.46% growth rate. Since its foundation (modern Saudi state), in 1932, the economy of the country relied mainly on its natural resources. The export of fossil fuels has led the country to become one of the fastest growing economies in the world (CIA, 2016) [90]. The kingdom is categorized as a high income economy with a high Human Development Index (HDI) (Human Development Report, 2014) [91]. Islam is the main religion in the country with over twenty-five million population most of them are young. In 2014, Saudi Arabia’s gross domestic product (GDP) was estimated to be $1.6 trillion, which make the Kingdom’s rank the 15th in the world (CIA, 2016). Recently, the Kingdom has been undergoing a series of social and economic changes in order to diversify its economy and to employ more Saudi nationals. Initiatives are proposed by the government to attract foreign investment, encouraging the growth of the private sector, and there is great investment in power generation, telecommunications, natural gas exploration, and petrochemical sectors. There are over 6 million foreign nationals living in the country and they play an important role in country’s economy, particularly in the oil and service sectors (CIA, 2016) [90].

Saudi Arabia is proud of its Islamic heritage, where it devotes a large effort to Islam's two holiest mosques in Mecca and Medina. Mecca is the birthplace of Islam and hosts around 2 million people from all over the world per year to complete their pilgrim rituals (Hajj). Islam has a great influence on all aspects of life in the country. This influence was reflected in the country’s first article of the basic law of the governance which states:

“*The Kingdom of Saudi Arabia is a fully sovereign Arab Islamic State. Its religion shall be Islam and its constitution shall be the Book of God and the Sunnah (Traditions) of His Messenger, may God’s blessings and peace be upon him (PBUH). Its language shall be Arabic and its capital shall be the city of Riyadh.*”.

The influence of Islam on the Saudi society was observed by studies on culture and business in the Kingdom. Idris (2007), for instance, describes the Saudi culture as ‘fairly homogenous’ due to Islamic teachings [18]. The author argues that Islam influences all aspect of Saudi’s life including business decisions. Additionally, Cassell (2012) cited the importance of understanding the Saudi culture for businesses to thrive in that culture [92].

Besides the influence of Islamic teaching, the Saudi society is also bonded by tribal traditions inherited over the years. Tribes in the Arab world used to be the basic form of organisations -way before Islam- therefore, tribal traditions influence the Saudi culture in a profound way. As Kostiner (1990) asserts “Tribes were also important as a source of the Saudi values system, which stemmed from the tribal segmentary organization that dominated the chieftaincy [93]. Political decentralization, minimal administration, kin-related political behaviour, social solidarity and economic cooperation [….]”. The tribal traditions are still incorporated to the power structure of the Saudi society.

2.4.2 Geography of Saudi Arabia:

The Kingdom of Saudi Arabia is in the south-west of the continent of Asia bordering the Arabian Gulf in the east and the Red Sea in the west, with shared borders with Yemen in the south (Figure 2.11). The main cities in Saudi Arabia are:

- Riyadh - the capital and seat of government and located in the centre of the Kingdom. The estimated population is more than five million people.
- Jeddah - the second largest city of Saudi Arabia and considered the economic capital of the country as well as the gate to the two holy mosques. The estimated population of Jeddah is more than three million people.
- Dammam is located on the east coast. It is a port for the country's east, overlooking the Arabian Gulf. After discovering the first oil filed there, Dammam became the centre of the oil exploration and extraction operations.
- Mecca – holy city and the birthplace of Islam, is located in the western province of the Kingdom. Its population is estimated at more than 1.5 million people.
- Medina – is also a holy city located in the west of the country. It is the incubator for the 2nd holy Mosque of the Prophet Mohammed. The population of Medina is estimated at more than one million people with thousands of visitors.

Figure 2-11 Map of Saudi Arabia illustrating geographical location and main cities (maps.google.co.uk)

2.4.3 Saudi Culture:

The culture of a country has a major implication on individuals, organisations, and the laws of that country. In order to explore the cultural context in Saudi Arabia, this profile refers to the Hofstede framework for cultural dimensions. Geert Hofstede's initial work started around the 70's to study employees behaviour in large organisations [94]. As the manager of the personnel research department at IBM, Hofstede introduced employee opinion surveys to understand individual personalities. The cross-cultural study covered over 70 national branches of IBM around the world. After a few years of collecting and analysing data Hofstede released the effect of contextual factors on individuals. The focus of the study was then shifted from studying individual personalities to the effect of national cultures on individuals. The cultural diminution model was introduced in 1980 to illustrate the cultural influence on work-related values. The original theory of cultural dimensions proposed four dimensions (power distance, uncertainty avoidance, individualism, and masculinity) that affected the value system within a society and behaviours of its members. Further research revealed an additional two dimensions (time-orientation and indulgence). Hofstede's work is widely accepted by researchers and consultants in many fields related to organisations and international management. Hofstede's six dimensions include:

- Power Distance: this dimension is the power distribution within members and organisations of that culture.
- Individualism: indicates individuals' degree of interdependence from the local society.
- Masculinity: reveals motivation within the collective value system. It measures a culture of competition verses the quality of life.
- Uncertainty Avoidance: measures social ability to deal with ambiguity through the value system and people's intuitions.
- Long Term Orientation: the time-orientation of a society describes how people maintain links with their past to face challenges of the present and the future.
- Indulgence: measures the extent of controlling individual desires and impulses.

Hofstede's model is used in this research to understand the characteristics of Saudi national culture. Understanding the contextual effects of the Saudi's value system and behaviours provides a starting point to develop knowledge on employees and organisations working in Saudi Arabia. The characteristic of Saudi national culture is illustrated in figure 2.12. As the figure shows, Saudi society is a collectivist nation, and

Saudi's exhibit great respect for customs and traditions. This is manifested in a strong commitment to family, work groups, and friendships. The society is, also, highly hierarchical and tends to have centralised organisations by which roles are well defined and accepted by the majority. People within such a culture value security, and hard work is applauded. Hence, competition and performance are highly prized. Saudi society, also, promotes an assertive decisive management style and personnel feel an emotional need for rules. Generally, employer/employee relationships are perceived in moral terms and managers take responsibilities for fellow members of their group. The downside of such a society includes inherent inequalities and uphold autocratic leadership. This can yield rigid codes of belief and behaviour and brings about resistance to change and new ideas. Therefore, normative thinking is not criticised and the focus is devoted to accomplishing quick results. Comparing the Saudi Arabian context to European cultures (where Hollnagel's (2006) resilience engineering concepts were developed and tested) can reveal significant insights.

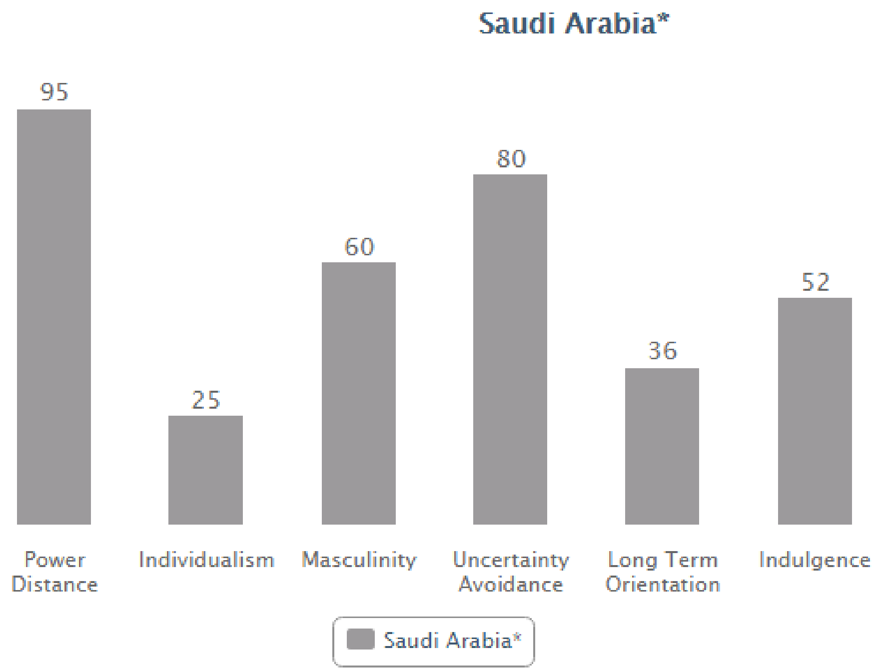

Figure 2-12 Hofstede six dimensional characteristic of Saudi national culture [95].

These indications of cultural features are unique to each country; therefore, we could hypothesise the existence of different behaviour towards resilience in Saudi Arabia in comparison with other western cultures. In fact, the edition of the Time-orientation, for instance, was a result of cross-cultural study of the Hofested model. This research attempts to test resilience constructs in non-western culture using the example of Saudi Arabia. Therefore, the following questions needed to be answered before testing and extracting main contributing factors to resilience in the Saudi industries.

What are the general features of safety climate in Saudi Arabia?

What are the factors that influences organisational safety culture in the Kingdom?

Does Saudi national culture effect resilience engineering within industrial organisations there?

So far, studies on resilience have been conducted mainly in western societies (e.g. Hansson et al., 2009 in North Sea, Albrechtsen and Besnard, 2014 in Norway, Gomes et al., 2009 in Brazil) [96]–[98]. Within the Middle East, Shirali et al. (2012) conducted a similar study on chemical plants in the Islamic Republic of Iran. The study indicated gaps of knowledge in system safety and challenges in building resilience there [99]. Therefore, the current work aims to assess the potential of resilience in the manufacturing and process industry in the Kingdom of Saudi Arabia. The formation of process and manufacturing in the Kingdom, however, is closely related to the discovery of the oil. Most of the industries in the country rely primarily on oil and its derivatives.

Hence the next section will explore the discovery of oil and how it relates to industries and the economy of the country.

2.4.4 Saudi Arabian Economy and Oil discovery:

The development of industries in Saudi Arabia is strictly connected to the discovery of oil in the country. Thus, in this section the history of this development is presented. The story of the oil in Arabian Peninsula started in 1930's. Oil was discovered in nearby Bahrain in 1931. During that period, the country was struggling to recover from the great recession of global markets. The Kingdom had given exclusive rights to the American company Standard Oil of California (Socal) (later renamed Chevron) to explore and extract petroleum from the eastern province. In 1938, further exploration and test wells revealed additional discoveries of oil deposits north of Dammam and in Abqaiq. With the outbreak of the Second World War, the development had set-backs due to shortages of personnel and materials (steel in particular) (McHale, 1980) [100]. In 1944, Socal formed a partnership with The Texas Company (Texaco) and established the Arabian American Oil Company (ARAMCO). The realisation that the large and increasing magnitudes of the Saudi Arabian oil deposits required capital investment, ARAMCO decided to invite Standard Oil of New Jersey (now Exxon) and Standard Vacuum Oil (now Mobil) to share development costs and become part owners (McHale, 1980). With time, ARAMCO crude oil production increased to reach nearly a million barrels a day in 1955. The successful exploration of oil reserves in Saudi continued rapidly to become the backbone of the Saudi economy. In the 60's, Saudi Arabia formed the Organization of Petroleum Export Countries (OPEC) with cooperation with other countries (Venezuela, Iraq, Iran, and Kuwait) to secure the best price available from the major oil corporations. OPEC aimed to ensure stability and eliminate fluctuations in oil prices by unifying petroleum policies among its members.

After the Second World War ended, oil income exceeded all other sources of government revenue. The oil sector provided the government with over three-quarters of its revenue and foreign exchange earnings, in addition to two-thirds of the gross national product (GNP). Saudi Arabia were producing around 3.5 million barrels a day by 1960. During that period, the country were recognised as the world's largest exporters of oil (McHale, 1980) [100]. Saudi Arabia has taken steps to expand the energy sector and encourage greater investment, especially by foreign companies. The government had made an effort to expand its exportation capacity. By 1980, the Kingdom had been producing oil at the rate of 95 million barrels a day to the international market. This investment has paid off generously where Oil exports contributed 98% of all the Kingdom's export earnings, and 90% of the total government revenue (CIA, 2015) [90]. In terms of national income, revenues from oil production have transformed the Saudi cash economy completely. On a GNP per capita basis, Saudis during that period have doubled the income of the Americans and almost five times the income of the average Briton. Currently, Saudi Arabia is the world’s largest producer and exporter of oil, and has one quarter of the world’s known oil reserves. Although there are different ways to measure oil reserves, experts have estimated the Saudi oil reserves to be more than 260 billion barrels. Most of the oil deposits are located in the Eastern Province, including the large onshore field in Ghawar and the large offshore field at Safaniya in the Arabian Gulf. Due to technical factors involving field size, well-production rates, and reservoir, pressure have made the cost of extracting the oil in Saudi Arabia competitive by comparison to any other place in the world. Moreover, the close proximity of the production areas facilitates the transportation and save costs.

Currently, Saudi Arabia possesses about 16% of the world's proven petroleum reserves, ranks as the largest exporter of petroleum, and plays a leading role in OPEC (CIA, 2015) [90]. The BP Statistical Review of World Energy (2015) estimates Saudi oil reserves are around 267 trillion barrels with 63.6 Reserves-to-production ratio [101]. In 2014, Saudi Arabia produced around 11.5 thousand barrels/day, and consumed about 3.4% of what it produces (three thousand barrels/day). The revenues from this production contributes the majority of the $1.616 trillion estimated budget in 2014 (CIA, 2015). During the past five years, Saudi Arabia has seen remarkable growth, which included the growth or the proportion of the urbanized areas to more than 40%. Furthermore, roughly 70% of the population of Saudi Arabia are under the age of 30.

On the downside of relying on oil and oil derivatives, the Saudi economy is threatened by the fluctuation of oil prices. As Kemp (1999) stated, the problem the Saudi economy is facing is “buoyed by oil, bound by its uncertainty” [102]. The drop of oil prices since the mid-1980’s, for instance, has hindered the country’s economic growth and has had a direct effect on job creation (Budhwar and Debrah, 2001) [103]. A more recent example of world oil prices affecting the Kingdom’s economy has happened in 2014. World oil prices were fairly stable at $110 a barrel. In mid-2014 the price of Brent crude oil dropped to below $48 a barrel. The Saudi economy has suffered and it ran into its first budget deficit since 2009 (CIA, 2015). The effect of the drop in oil prices was also reflected on the unemployment figures in the country. According to Trading Economics (2015), unemployment figures have risen from 5.5% in early 2014 to reach around 6% near the end of the year. In order to lessen its dependence on oil, the Saudi government has committed since the mid-1990’s to diversify sources of income. The government has joined the World Trade Organization (WTO), invited foreign investors and encouraged the private sector to take responsibility in developing the economy. Despite the government efforts, large state corporations still contribute the majority of the GDP. These firms include Saudi ARAMCO, the Saudi Basic Industries Corporation (SABIC), The Saudi Telephone Company (STC) and several other large firms (Budhwar and Debrah, 2001) [103].

Besides oil exports, Saudi Arabia is also developing its additional energy resources, sauch as the natural gas that once flared off oil wells is collected and used; and the Kingdom has become a producer of refined oil products and petrochemicals such as kerosene, diesel oil and gasoline. In addition, the country has other mineral deposits. Gold, silver, copper, iron-ore, phosphate and chrome mining has been carried out in the past and there are plans restart this sometime in the future. However, due to scarce supplies of water in the country, mining such materials in commercial quantities is problematic.

Since 1970, the kingdom adopted a 5-year planning approach to set out the general guideline of socio-economic development. The plan addresses the political strategy, government funded programmes, resources required, expected major challenges and how to meet those challenges. The United Nations (2015) lists the following issues that hinder the development of the country:

- Raising standard of living and improving quality of life.
- Diversification of economic base.
- Enhancing non-oil revenues.
- Balanced regional development.
- The move to a knowledge-based economy.
- Enhancing competitiveness.

- Development and productive employment of human resources.
- Sustainability of natural resources.

Despite those challenges, the country has achieved 3.4% annual growth rate over the period 1999-2010. Concerning forging alternative trading sectors, the non-oil merchandise exports share in total exports increased from around 8.5% in 2000 to some 14.3% in 2010 (UN, 2016) [104]. The government commitment to resolve these challenges appear to have had positive outcomes and the integration with the global market will help in creating a healthy socio-economic environment.

2.4.5 Business environment

The World Bank (2015) has released the annual report that evaluates the effect of regulations on the business environment in different countries [89]. Under the annual "Doing Business" report series, the World Bank Group presents quantitative indicators that measure the effect of regulation on the business life cycle in 189 economies. Saudi Arabia is ranked at 49, which is considered high with comparison to the regional average. For instance, when comparing the Saudi business environment to other regional oil producing countries such as Iraq or the Islamic Republic of Iran, we find those countries are ranked at 156th and 130th, respectively. Figure 2.13 illustrates the ease of doing business in Saudi Arabia with comparison to other regional countries. According to the report, Saudi Arabia is committed to improve the business environment and encourages new businesses to open. For instance, in 2010 the government introduced a one-stop centre at the Ministry of Commerce that merged registration procedures and simplified publication requirements. Regarding trading across borders, most indicators point to governmental efforts to introduce tools to facilitate trade and boost firms' international competitiveness. On the labour market regulation, employees are required to work around 50-hours/week (6 days/week) with the right of health insurance paid by the employers. The trends in the Saudi business environment are improving, and government efforts appear to cut bureaucracy and encourage new businesses to flourish. The overall effect of governmental regulations stands to support a healthy environment for both organisations and employees to perform well in the market (World Bank, 2015) [105].

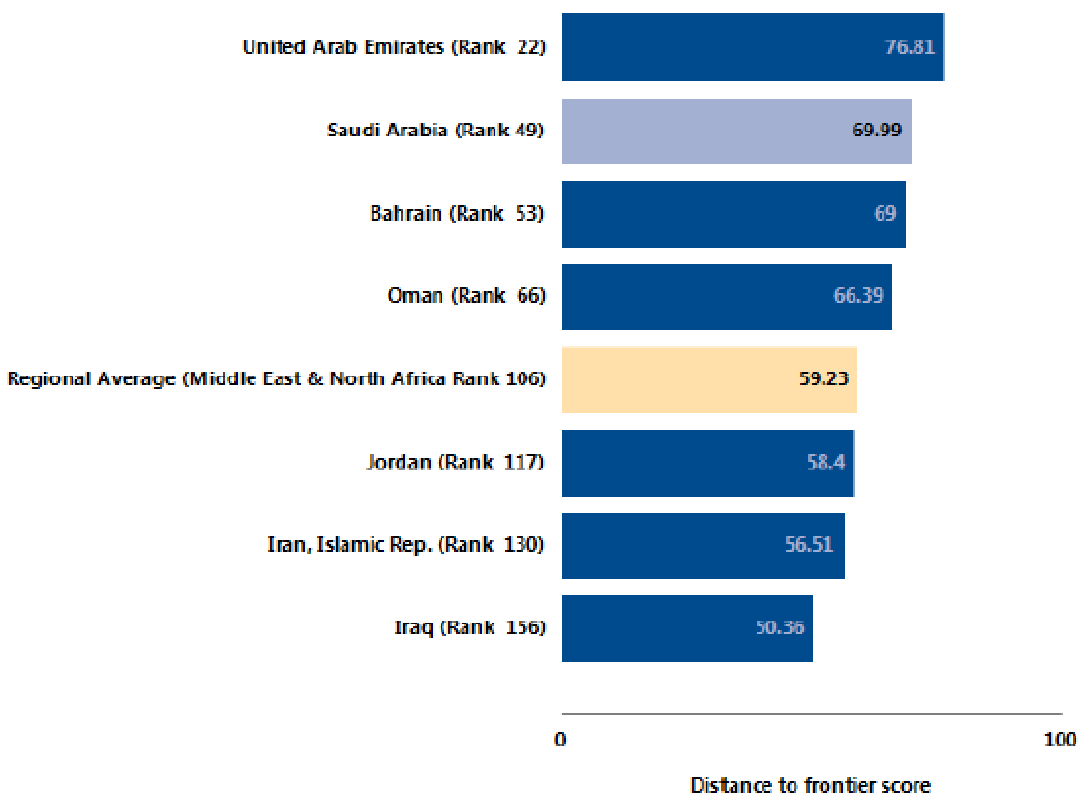

Figure 2-13 Saudi Arabia ease of doing business compared with regional economies (World Bank, 2015).

To sum up, Saudi Arabia has a distinctive cultural, geographical and economic environment. The country is among the richest in the world, and has a lot of experience in producing oil and industries that relay in large on its derivative; however, this industrial progress was not accompanied by legislative and regulatory reforms. In addition, the distinctive cultural dimensions regarding high power distance, uncertainty avoidance, collectivism and short-time orientation makes an interesting case in which to assess the safety climate and culture. Thus, this research can contribute considerably to the body of knowledge regarding safety culture, safety management and cross-cultural organisational studies.

The next chapter will present the research methodology, which will present a general discussion of research philosophy and how to choose appropriate experimental design. This will include types of data and data collecting methods in addition to the pre-analysis criteria and how data is processed. After that, we will look at the way to assess the results and the method chosen to analyse the results.

3 Chapter Three: Methodology

Summary:

The problem of safety cannot be understood without combining social, managerial, and organisational factors. Therefore, this study uses an inductive approach in order to achieve the research objectives. In the first part, exploratory methods were employed to gain deeper understanding of the safety problem in the Saudi context. Those methods include literature review, on-site observation and unstructured interview. The information obtained from the exploratory approach was used to develop a survey that measures the potential of resilience. The aim of this step is to test and validate basic resilience in a new cultural context. The survey method was suggested by the Hollnagel et al. (2011) framework [10]. The questionnaire was tailored to suite process factories working in the Saudi context. The survey included twenty-two contributing factors to resilience. It measured factors that characterise resilient and non-resilient systems. The results from the survey are used to determine the system-types that dominate the process industry in the Kingdom. The questionnaire has 5 sections representing the key aspects of potential resilience within organisational processes. The data were collected and analysed using a statistical method that describes correlation among the contributing factors. By assessing the underlying correlation between those factors, the most relevant factors to our data set could then be extracted. The next chapter will present the way the data were analysed and shows the main results of the survey.

3.1 Introduction:

Research can be defined as a systematic effort in the search for pertinent information on a particular topic to gain new knowledge (Kothari, 2004) [106]. The systematic way of answering research questions is the methodology of the research. Each research study has its own purpose; therefore, the test of hypotheses and discovering answers relies on choosing an adequate means of conducting the research. The occurrence of accidents with adverse outcomes has inspired many scholars to investigate this phenomenon in order to prevent loss of lives and damage to the environment. The Saudi context is of special interest to this study as it lacks proper regulations regarding occupational health and safety (see chapter two). The lack of studies investigating safety of industrial complexes in this country has motivated this study as it may reveal new insights. The outcome of this enquiry contributes to the literature of safety in Saudi Arabia, besides providing recommendations on how to engineer resilience in that specific context. The objectives of this research can be summarised as follow:

- To gain familiarity with the status of safety at industrial corporations working in Saudi Arabia in order to identify core difficulties with safety there.
- Test and validate resilience engineering concepts cross-culturally.
- Characterise resilience (system-type) in the Saudi Arabian process industries.
- Identify the main contributing factors to resilience in the Saudi Arabian process industries.

In order to achieve these objectives, this chapter will start by presenting the research philosophy which guides the choice of investigation methods and tools. Many writers have emphasised the role of the chosen ‘paradigm’ [research philosophy] as being more important than the research methodology itself (Guba and Lincoln, 1994) [107].

The chosen research philosophy provides some assumptions about the nature of knowledge and its development. Those assumptions assist in forming a research strategy that underpins practical considerations of the methods used. It influences the relationship between knowledge and the process by which it is developed. The differences between those assumptions are mainly in the region of the nature of reality (Ontology) and the nature and scope of knowledge (Epistemology). These differences will be discussed in the next section as well as the development of research philosophies from a management and industrial organisation’s perspective. The philosophical discussion highlights the strength and weakness of each paradigm in addition to justifying the adequacy of the chosen methods. The research methods will be discussed in section 3.2 followed by the procedures to be implemented in the context of this study. Since the main enquiry of this study is to assess resilience of the KSA process industry, the development of measurement tools will be explained in section 3.4. Furthermore, details on data collecting and preparation for analysis will be established.

3.2 Philosophical Perspective:

Paradigm as a term is commonly used in the literature with multiple meanings and contexts. It is the concept that incorporates the distinct pattern of knowledge or thoughts. Therefore, it is important to present some of its different manifestations within the scope of this research. The literature underlying organisation research methods can be divided into two main approaches. The first was developed in the natural sciences, which looked into the objective truth of a natural phenomenon. Therefore, there is great focus on experiments to measure quantifiable observables. Experiments help to discover relations between variables and their interactions. Those relations are, then, generalized to form the universal principles or laws (Brewerton and Millward, 2001, p. 7). This method, generally known as ‘Positivism’, has had great successes and therefore considered the best practice model available for a long time. Influenced by natural science, Frederick Taylor (1914) published ‘*The Principles of Scientific Management*’ as a study of time and motion [25]. Time and motion studies continue to mature with the work of Frank and Lillian Gilbreth (1919) who constructed techniques to implement the ideas on the shop floor [108]. Those studies are now the cornerstone of business efficiency measurement.

Challenging this view, the second approach originated in social science using the study of psychological and sociological phenomena. Elton Mayo (1945), a human relations scholar, emphasised the importance of the non-rational aspects of employees [109]. The human relation movement believes that individuals should not be thought of as economic entities, and contextual factors must be taken into account. Thus, studies of social phenomena are better to be conducted subjectively relying on induction from quantitative data. Surveys and interviews are instruments used to collect data; and subjective interpretation helps in analyzing it. Attached to this method is the assumption that reality cannot be explained by direct reference (cause-effect) to universal laws. This approach is generally known as ‘Interpretivism’ and it has gained considerable momentum, especially among social scientists and organisation theorists. Table (3.1) shows the main emphasis of each approach.

Table 3-1 Major differences between deductive and inductive approaches to research.

Deductive emphases	Inductive emphases
• Scientific principles.	• Gaining an understanding of the meanings humans attach to events.
• Moving from theory to data.	• A close understanding of the research context.
• The need to explain causal relationship between variables.	• The collection of qualitative data
• The collection of quantitative data.	• A more flexible structure to permit changes of research emphasis as the research progresses.
• The application of controls to ensure validity of data.	• A realisation that the researcher is part of the research process.
• The operationalisation of concepts to ensure clarity of definition	• Less concern with the need to generalise.
• A highly-structured approach.	
• Researcher independent of what is being researched.	
• The necessity to select samples of sufficient size to generalise conclusions.	

Another point of debate emerged from studying the relationship between systems and their environments. Classical management theory, for instance, devotes effort to the internal design of organisations. Therefore, organisations are viewed as 'closed' mechanical systems, paying little attention to interactions with the contextual environment. The classical view, originating from the natural sciences, tends to divide a system into its simple component parts, each to be examined in detail. Understanding and then integrating those parts should be sufficient to control and predict the system behavior. This view, however, ran into difficulties, as organizations became more complex working in ever changing environments. The close system view was challenged by the study of Ludwig von Bertalanffy (1957) on biological organisms [110]. Bertalanffy noticed that for an organism (or organisation) to survive, it must sustain an appropriate relation with its environment. Therefore, organisms must be 'open' to interaction with their environments. Based on his findings, Bertalanffy developed the principles of General System Theory as a new way of thinking about systems of all kinds.

The open-system approach focuses on the environment in which organisations exist. Social scientists have always recognised the importance of the contextual environment. The relationships between systems' internal functions and variations in the surroundings are major subjects of their research (e.g. Weiner, 1985) [111]. In order to sustain an effective relation with the environment, Morgan (2006) describes the living organism as "… 'open systems' characterised by a continuous cycle of inputs, internal transformation (throughout), output, and feedback (whereby one element of the experience influences the next). []… A living organism, organisation, or social group is a fully open system." [112].

Drawing from these debates, both approaches highlight different features to assess by researchers in dealing with scientific enquiries. Although those philosophies may seem intuitively contradictory, the fact is that many studies stress the resourcefulness of integrating both paradigms. Saunders *et al*., (2009) argue that "choosing between one position and the other is some-what unrealistic in practice" [113]. Therefore, it is more appropriate to think of the philosophy adopted as a "continuum rather than opposite positions". A pragmatic position promotes a mixed method of positivist and interpretive philosophies. Therefore, mixing both deductive and inductive approaches is highly appropriate within one study. Saunders *et al*., (2007) suggests a continuum (Fig 3.1) illustrating the nature of business and management research projects [113].

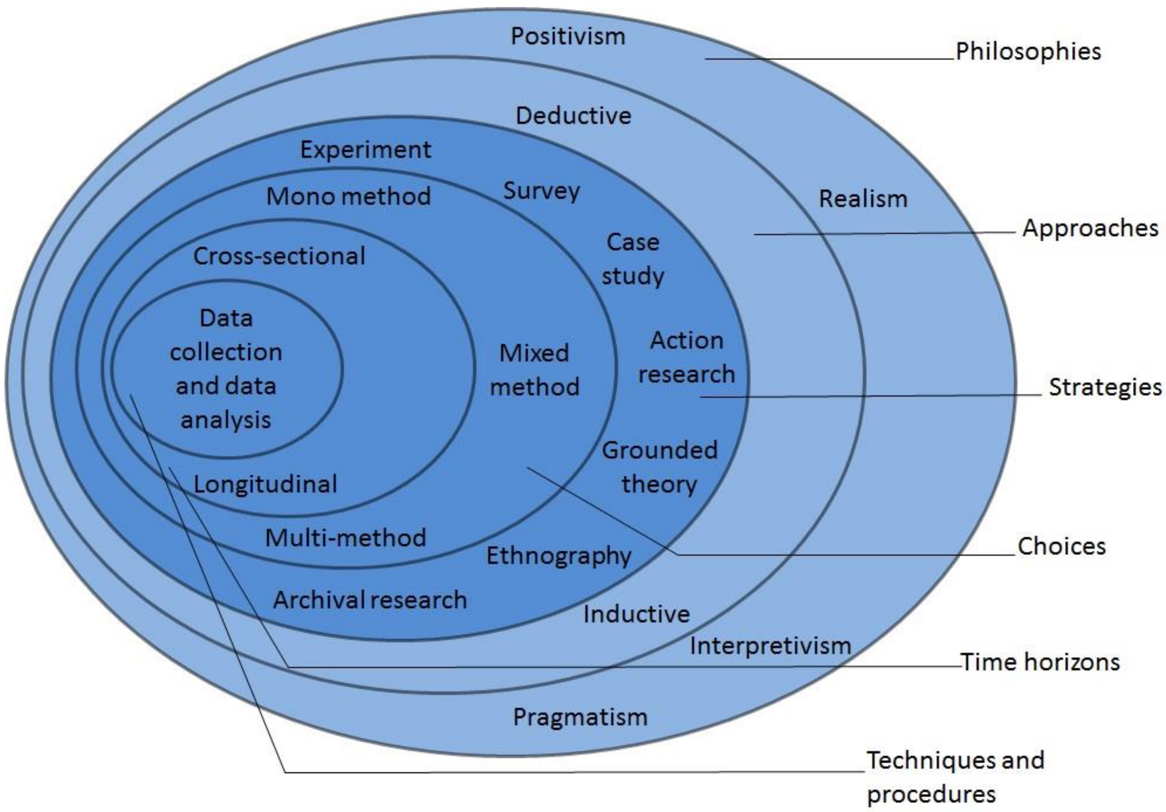

Figure 3-1 The research 'onion': layers underlying the choice of research philosophies.

This research acknowledges the multidisciplinary nature of the questions in hand. Keeping in mind each philosophy's strength and weakness, this research adopts an inductive approach where the nature of the data is qualitative. Therefore, in order to gain knowledge on safety in Saudi Arabia exploratory methods are used including reviewing the literature, observation, and interviews. The qualitative data will be collected using a survey; however inductive and deductive tools are used to analyse the data collected (See section 3.3). Table 3.2 illustrates the design of research approaches to achieve the research objectives. The mixed method approach is common in complex social phenomena such as organisation, business, and management literature. The next section will provide more details on the specific methods used at different stages on this study.

Table 3-2 Research tools used to achieve research objectives.

Research Questions	Research Objectives	Research Tools
What are the general features of the safety climate in Saudi Arabia? **What are the factors that influences the organisational safety culture in the Kingdom?** **Does Saudi national culture affect resilience engineering within industrial organisations there?**	Explore the safety climate in Saudi Arabian industrial organisations.	Deductive (literature review, observation, interview)
Is the Saudi Arabian process industry resilient? Under which category of 'System-type'?	Examine resilience concepts and identify the system-type in the Saudi Arabian process industries.	Deductive (survey)
What are the main contributing factors to resilience engineering in the Saudi Arabian energy industry?	Identify the main contributing factors in the Saudi Arabian process industry.	Inductive (factor analysis)

3.3 Research Methods:

Quantitative and qualitative methods have different ways of collecting data and have analysis processes. This thesis uses a mixed method approach to collect and analyse data. This approach is increasingly advocated within the business and management literature. With the intention of answering the questions of this research, this investigation starts with exploratory research to identify core difficulties with safety in complex organisations working in KSA. Secondary data, in the form of literature review, is also used. The source of these data includes books, academic journals, and academic theses. Different data bases are used to explore occupational health and safety in Saudi Arabia, such as: Google Scholar, Science Direct, JSTOR, IEEE and SCOPUS. The literature review (Chapter 2) includes a brief outline of accident model development as well as the main theories that are in-use to analyse the phenomena. In addition, a background on management and organisational theory was presented in the literature review to understand the complexities within the process industry. The main focus of the review illustrates the relationship between the organisation and its environment, including the challenges of quantifying the social (human) aspects of complex organisations.

In order to achieve the first objective of this research and gain knowledge on safety in the Saudi context, an explanatory approach is used. A combination of on-site observation and unstructured interviews were used. Both methods provide insights into the organisational culture and dynamics of the employee/manager relationship. Furthermore, it permits explanation of the relationships between the organisations at different levels within its environment. Primary quantitative data on employees is linked to the state of the organisational safety system. To test concepts of resilience within industrial complexes and identify the type of resilience, the study uses a generic survey that was proposed by Hollnagel (2011) [19]. The survey was tailored and translated into Arabic for the process industry in the Kingdom. Surveying is the most commonly used deductive approach. It allows the collection of large amounts of data from a sizeable sample. In addition, it helps in answering a wide range of questions which makes it appropriate to analyse complex phenomena such as the one in hand. The data is then analysed quantitatively using inferential statistical tools. The following paragraphs will introduce the methods used in more details.

3.3.1 Observations:

In an attempt to collect primary data on site, observation was required to get a feeling for safety in the Saudi context. There are qualitative and quantitative types of observations; both involve systematic observation of people in order to analyse and interpret their behaviour. The participant observation is a qualitative method that emphasises discovering meanings that people attach to their actions; whereas structure observation put the emphasis on the frequency of those actions. Participant observations enabled the researcher to acquire insight into the organisational culture. The data is collected through sharing the experience with people within targeted organisations which helps in designing the experiment (survey), and in interpreting their answers afterwards. Participant observation has deep roots in social anthropology but this method is not commonly used in management and business research. However, Resilience Engineering relies on the breadth-before-depth principle which emphasises the understanding of the system as a whole (see Section 2.2.3). Therefore, Hollnagel (2006; 2011) advocates the use of this method at an early stage [7], [19]. This will help in forming general ideas on how the system works and what to look for when designing the survey.

The participant observation method is a valuable tool, especially when used in combination with other methods. In this research, the observation method was used besides a literature review and informal interviews as an exploratory method. All these methods serve the intended exploration process of safety in the Saudi context. Additionally, since there is little published in the literature about safety and organisational culture in the Saudi context, participant observation is applied to obtain knowledge about people working in the process industry and learn their symbolic world. As Delbridge and Kirkpatrick (1994) assert "in the social sciences we cannot hope to adequately explain the behaviour of social actors unless we at least try to understand their meanings" [114]. Besides, Saunders *et al*. (2007) state "participant observation is very high on ecological validity because it involves studying social phenomena in their natural context" which is important to estimate the boundaries of the enquiry [113].

The on-site observation was conducted in a small chemical plant in the Jeddah industrial area (a western province of Saudi Arabia). Since the research is concerned with safety and resilience, it was expected that participants will be reluctant to provide information about it. This issue was documented in many other studies where the blame culture is the norm (e.g. Shirali *et al*., 2012) [99]. Therefore, it was important to gain employees' trust to get an accurate assessment. This study used the 'participant as observer' technique by which the purpose of the visits was revealed to the participants. Because the goal of the visits was disclosed, employees were cooperative and helpful in providing valuable information on the safety of the organisation. The participant as observer technique was also necessary to pave the way to conduct informal interviews with the workers. The results from the observation stage will be discussed in detail in the results chapter.

3.3.2 Interviews

The use of interviews can assist in gathering relevant reliable primary data. Nevertheless, the practical implementation of this method should be consistent with the purpose of the research and research strategy. Interviews may vary due to the level of formality and structure. Saunders *et al*. (2007) suggest three types of interviews which are:

- Structured interview.
- Semi-structured interview.
- Unstructured or in-depth interview.

The aim of using the interview in this study is to explore the general topic of safety in Saudi Arabia. Therefore, unstructured interviews are used in this study to seek insight and gather data on the safety culture in the process industry. The interviews were conducted face to face and informally with no predetermined list of questions. The interviewee was given the opportunity to guide the conduct of the interview and talk freely about safety of the organisation, accident events, behaviours, and beliefs regarding safety. When the interviewee reveals something interesting, he was asked to elaborate on the issue. Informal interviews offer the interviewee a relaxed environment to provide information freely and provide the researcher the opportunity to direct the interview when necessary to gain in depth data. The unstructured interview also supports the breadth-first principle by not focusing on details but the normal state of the system as a whole. The main participants of the interviews were operators, their immediate supervisors, engineers, and a production manager.

3.3.3 Summary

In order to explore the safety climate in Saudi Arabian industrial complexes, three methods were used: reviewing the literature, on-site observation and in-depth interviews. Each of these methods were implemented carefully to gain the required knowledge and establish the scope of the problem. This exploration process provided the base for examining resilience through adequate procedures, which will be discussed next.

3.4 Research technique and procedures:

One of the aims of this project is to assess contributing factors of resilience engineering in the process industry. While resilience is the core concept here, this section will highlight its main attribute and measurement tools before going into details of the procedures. The resilience of a system relies greatly on its adaptive capacity. Adaptive organisations attempt to improve their performance by reacting to variations in their environment or disturbance to their production. The basic abilities of resilience engineering (monitor, anticipate, respond, and learn) capture the adaptive capacity of organisations and their ability to function at their normal-state level of production even after undesirable events (Hollnagel *et al*., 2011) [19]. The concept of resilience engineering attempts to sustain a balance among different organisational factors. Those factors might seem to contradict (such as: flexibility versus control). In order to survive, organisations must respond to arising new circumstances and change plans accordingly. At the same time, it is necessary to have appropriate governors over organisational processes with the aim of managing their activities.

The concept of resilience has been studied for a long time in disciplines such as biology, psychology, and ecology (Dinh *et al*., 2012) [115]. However, this concept is still relatively new to complex industrial organisations. Therefore, ways to measure, test, assess, and validate data are still under developed (Shirali *et al*., 2012) [99]. Thus far, assessing resilience is mainly accomplished through quantitative methods. Hollnagel *et al*. (2011) proposes a framework to assess potential resilience in a complex socio-technical environment [19]. The framework consists of identifying key aspects of a system, selecting assessment parameters and electing resilience factors that are relevant to the context.

In engineering systems, several studies have tried to use qualitative methods to measure the resilience of complex systems. These methods have their origins in the natural sciences. For instance, Mitchell *et al*. (2006) assert a qualitative approach borrowed from materials science to create a resilient system [116]. In their view, resilience of a system is expressed as the amount of energy stored before the instability state, whereas Slocum and Mendelssohn (2008) measured resilience through the recovery rate [117]. This could be done by modelling an experimental disturbance to a system and then assessing the recovery rate. The result of the experiments is then compared to known stress gradients. Carvalho *et al*. (2008) used micro-incident analysis to assess nuclear plant resilience [118]. This kind of applied research tends to emphasise the local environment and tests are very sensitive to small variations. Such approaches, however, maintain the sequential view of safety that understands system behaviour through comprehending its component parts. Hollnagel *et al*. (2006) criticised this approach and argued that societies and organisations exhibit an overwhelming degree of complexity [51]. Hence, most of these methodological efforts have focused on nominal resilience only. In the author's opinion, those attempts look terribly static and linear and cannot describe the dynamics of accidents.

This research proposes a resilience engineering framework to understand the ability of sociotechnical systems to respond to unexpected events. Within this scope, a quantitative approach is used to measure the potential resilience of industrial organisations. A questionnaire that targets employees and managers was developed to explore factors of interest to improve safety. Hollnagel (2011) proposed a generic questionnaire for each basic ability of resilience [19]. Table 3.3 gives an example of questions that could be tailored to a specific context. The survey uses qualitative responses that could be quantified at a later stage. Additional information on the questionnaire will be discussed in the next section. A factor analysis (FA), is then used to identify the most relevant factors to the petrochemical sector. The result of the analysis is then compared with findings from other studies from the industry (e.g. Shirali *et al*., 2013) [99]. The key factors are then used to build a specific construct that suits the process sector. More on FA and data preparation will be explained in section 3.5.

Table 3-3 Examples of detailed issues relating to the ability to monitor (Hollnagel, 2011)

Indicator list	How have the indicators been defined? (By analysis, by tradition, by industry

	consensus, by the regulator, by international standards, etc.)
Relevance	When was the list created? How often is it revised? On what basis is it revised? Who is responsible for maintaining the list?
Indicator type	How many of the indicators are of the 'leading' type and how many are of the 'lagging' type? Do indicators refer to single or aggregated measurements?
Validity	How is the validity of an indicator established (regardless of whether it is 'leading' or 'lagging')? Do indicators refer to an articulated process model, or just to 'common sense'?
Delay	For 'lagging' indicators, how long is the typical lag? Is it acceptable?
Measurement type	What is the nature of the 'measurements'? Qualitative or quantitative? (If quantitative, what kind of scaling is used?)
Measurement frequency	How often are the measurements made? (Continuously, regularly, every now and then?)
Analysis / interpretation	What is the delay between measurement and analysis /interpretation? How many of the measurements are directly meaningful and how many require analysis of some kind? How are the results communicated and used?
Stability	Are the measured effects transient or permanent?
Organisational support	Is there a regular inspection scheme or schedule? Is it properly resourced?

3.4.1 Measuring organisational resilience: survey design

Resilience is a family of related concepts that challenge internal and external forces. Those forces are dealt with through different organisational mechanisms. Organisational internal processes and functions exhibit the main concept of resilience, which allow for it to be adaptive. Therefore, measuring the potential of resilience could be attained using a qualitative approach. This research uses a questionnaire to assess the potential of resilience in the industrial sector in the Kingdom of Saudi Arabia. A pilot questioner was designed based on the Hollnagel *et al*. (2011) study for the UK rail infrastructure [19] (Appendix A). The questionnaire includes concepts that characterise resilient and non-resilient systems. The questionnaire has 4 sections representing the key aspects of resilience functions within organisational processes in addition to a section on key demographic information (age, gender, nationality, etc.). Twenty-two factors relating to the basic four abilities were examined. The 22 factors were selected based on two studies conducted in the UK and Islamic Republic of Iran (Wilson *et al*., 2009; Shirali *et al*., 2013) [99], [119]. In the Wilson *et al*. study, the authors found two factors that are less correlated than the other 20. These two factors were included in the study to validate the results and identify differences across industries. A comparison between the similar study of chemical plants in Iran (Shirali *et al*., 2013) and the process industry in the KSA could shed light on whether resilience constructs are consistent across industries and cultures [99]. In addition, if different industries have similar results this would validate the result of the original study.

The pilot study was conducted at a chemical plant in the Jeddah industrial complex. The aim of the pilot study is to acquire key relevant aspects of the systems operating in the process industries. This is the second step of the Hollnagel *et al*. (2011) suggested framework [19]. The results from the pilot study indicated some important changes that could be made. For instance, the phrasing of the questions needed more suitable language for the industry and the targeted audience. An important change to the scale used was necessary. Hollnagel *et al*. (2011) used a scale of 6 to measure the respondent's opinion. However, based on the pilot study, an additional “not applicable” was found to be important for some responders. Therefore, the questionnaire would use a scale of 7 (1: Strongly disagree, 2: Disagree, 3: Slightly disagree, 4: Slightly agree, Agree, Strongly Agree, 7: N/A). The pilot study also showed the sensitivity of conducting such studies in different languages. Translating the questionnaire “word-for-word” resulted in respondent confusion and a large variation in the results when compared to studies from different parts of the World. Therefore, when translating, it is important to account for the cultural factor in different locations. This issue was also a concern to Hollnagel and his colleagues. A copy of the translated questionnaire could be found in Appendix B.

The number of responses was based on an average of 7 people for each one of the 22 factors. Whereas a rule of thumb it should be between 5 to 10 respondents to each item. This average is widely used and an acceptable range for this survey. The same range was used in the study on the UK rail infrastructure and some other studies (e.g. Wilson *et al*., 2009). Thus, the acceptable number of responses needed is between 110 and 220. The target samples for the survey are floor shop worker, maintenance, engineers, and managers, all working at different levels in the related sectors. The survey was distributed in two forms: hard copies and an online survey. The target samples were approached either personally, or through online media. The respondents were given a brief introduction about the study and estimated time to fill in the questionnaire. The hard copies were collected personally; whereas, online responses were transferred to excel format and prepared for factor analysis.

3.4.2 Principle Component Analysis (PCA)

While methods of analysing raw data may differ depending on the subject at hand, this section describes the process of extracting meaningful information from the survey responses. This process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap and evaluate the data is called data analysis (Shamoo and Resnik, 2003) [120]. Data analysis is common practice to ensure data integrity and distinguish the phenomenon of interest from the noise (statistical fluctuations). Factor analysis (FA) is a statistical method used to describe correlated variables in terms of a potentially lower number of unobserved variables called factors. It is widely used to develop or evaluate tests or extrapolate measurements of a particular constructs or knowledge areas. There are two main uses of FA:

a) Exploratory: with the aim of gathering information about relationships among variables. This approach helps in developing a theory.
b) Confirmatory: to test a hypothesis by looking at a set of variables.

Therefore, FA was selected for this research in order to test resilience at a complex industrial level. In addition, it will help in identifying underlying trends between various safety factors.

FA includes many techniques to capture linear correlations from variables. It reduces the number of variables so we can study the variability within these correlations. Principle Component Analysis (PCA) is an advanced technique of FA. PCA transforms the original variables into a smaller set of components that have strong linear correlations. This technique allows the researcher to investigate the variance in all the variables, whereas, the Standard Factor Analysis (SFA) only allows the study of shared variance between variables. When using FA, it is important to keep in mind that relationships between components are not necessarily independent. PCA has three main steps:

1- Assessing the suitability of the data.

2- Component extraction.

3- Component rotation and interpolation.

1- Assessing the data

To conduct PCA, the data must be in a suitable form to use FA on them. This requires a sample size sufficient to carry out the analysis. There is great debate on what size is sufficient; however, a rule of thumb is used in this research where each item needs between 5 to 10 subject responses. Another factor to insure the suitability of the data is to test the strength of relationships between the variables. Only strong loading factors are chosen (whereby $r > 0.3$).

2- Component extraction

One of the challenges when using PCA is to select a sufficient number of components that best represent the interrelationships among the original variables. The difficulty lies in striking a balance between two conflicting needs. One is to find a simple solution, therefore the need to reduce the number of components chosen. The second is to explain the variance in the original data comprehensively. This means adding more components to get a detailed and complete picture. Balancing the efficiency and the depth of the analysis is not an easy task. Therefore, there are few ways that can be used to ensure the adequate level of analysis in choosing the number of components. This research uses Horn's (1965) Parallel Analysis (PA), which assesses the validity of the underlying factor structure through comparing the eigenvalues of the real data obtained with a random sample of the same size [121].

3- Component rotation and interpolation

After choosing the optimum number of components, we need to understand the correlation between the components. The components might be uncorrelated and in this case the items are more independent and easy to interpret. If the components are correlated it will be harder to interpret the results. Rotating the components does not change the solution but shows the loading of the correlations. Both correlated and uncorrelated are similar and the researcher should choose the easiest method to explain the phenomena.

All the data will be fed to SPSS to conduct the PCA. The 'Varimax rotation' method is used to minimise the number of the original variables. SPSS is a predictive analytics software package used for statistical analysis. The result of the data analysis will be discussed in the next chapter.

4 Chapter Four: Results and Analysis

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Summary:

In this chapter, we presented the main results of the factors affecting Resilience Engineering in the Kingdom of Saudi Arabia. In order to gather information about the process industry in the Saudi context, it was necessary to use on-site observation and unstructured interviews. The observation revealed superficial understanding of safety among employees. Safety measures are limited to fire extinguishers and safety banners. Safety manuals are outdated with no real authority to enforce rules. In addition, safety training only takes place after incidents occur with no specialised personal on safety or comprehensive safety management systems in place. The informal interview showed that concerns about safety are common among the staff; however, this did not have an effect on the daily practises. Employees still prefer to get the task done even if it means taking short-cuts. Some safety measures exist such as safety shoes and helmets; however, rules appear to be relaxed. Supervisors struggle to enforce such safety measures on employees because the majority of them think it will hinder getting the job done. Managers seem to understand the risks and their way of dealing with it is to conduct safety issues on the agenda after the occurrence of a mishap. The investigation into the accident points towards many factors regarding organisational, managerial, technological, and human issues. Those factors could be a concise way of viewing safety as a control problem and, therefore, more safety measures, and control over those factors (small agents) is recommended to fix it. The discussion of those results show the failure of the linear model and will be presented in the next chapter.

A survey was conducted incorporating 119 blue collar workers and managers at different positions in the process industry. The survey measures 22 items under five themes in resilience engineering framework. The data were analysed though exploratory Principle Components Analysis. The initial results showed seven main components that explains the variance within the data set. The further analysis indicated a four-factor solution with 10 highly interrelated items. The final four factors explain the majority (65.6%) of the variance within the data set.

The analysis of the data indicated an optimal three-factor solution to resilience in the KSA process industry. The extracted three factors are: efficient communication, information availability, and the ability to deal with external pressure. Those items correspond to the organisation's ability to be flexible under various working conditions and adjust to disruptions. Managers need to have control over working activities, and at the same time have efficient communication channels with workers. Communicating changes to work plans whenever problems arise is essential to the safety of the organisation. In addition, safety training and manuals should help the organisation to minimise mishap risk. Focusing on production and relying on outdated manuals can put organisations at risk of losing people and disrupting productivities. Employers should be given enough time to plan, reflect, and carry out their activities.

Regarding the similarities across industries, the findings are not conclusive. Further studies should account for all variants within the experiment. Although the final analysis shows that factors extracted have comparable loading factors, this was not reflected on the order of the constructs. The variability suggests that different industries have different contributing factors. This could also be the case for different organisations in the same sector. Perhaps these findings reflect the flexible nature of resilience where it attends to organisation specific needs.

Finally, we find that the energy sector in the KSA appears to be resilient. Further study should examine whether this resilience is systematic or casual. The observation seems to suggest the latter. Additional investigation is needed to clear up the maturity level of resilience of the organisations working in the KSA. The next chapter will discuss the findings in more detail, the limitations of the experiment and summarise the main conclusions.

4.1 Exploratory Results:

The methodology chapter explained a mixed approach strategy to answer the questions of this study. Qualitative techniques comprise most of the tools used especially for the exploratory part. The first section of this chapter will discuss the results of the exploratory part of the study, which includes on-site observation and informal interviews. Next, the case study will be presented, followed by illustrating how the data were collected and then analysed.

4.1.1 Observations:

Starting with the observation, the on-site observation was conducted through visits to a chemical plant in a specialised industrial area in the western province of Saudi Arabia.

The western province has a few refineries that are specialised in producing oil derivatives including various grades of fuel oil and gasoline. The contact was established after having an interview with a production manager working there. In the meeting, the purpose of the study was explained and a permission to access and observe was agreed on. The work force of the company was estimated to be around 200 employees. The plant uses a divisional structure where each department specialises in a predefined organisational management hierarchy. The organisational workplace was designed to support a positive work environment with workflow sequence in mind. The products move easily from one department to the next, and the work place is well lit and ventilated. On the safety management front, the plant had few personnel that were responsible for safety in the production line but they had no authority to enforce it on their fellow operators. The organisation had no safety management system in place nor was it part of a quality management system. Safety measures and indicators were not integrated in the product design or as a part of the product quality. The lack of safety on the conceptual level gave the impression that safety was defined in terms of occupational injuries and damage to the company's property. This view of safety is clearly outdated and adopts a passive approach to accident prevention. The existence of a passive sequential view of accidents insinuates that organisational accident investigations focus on hunting down broken components to improve safety.

Nevertheless, the plant has some safety measures in place such as safety banners and fire extinguishers at operators' disposal. Operators were not allowed to work if they had no safety shoes and gloves always; however, in some cases, operators were allowed to work without them. The lack of consistency in implementing safety rules indicates a trade-off between safety and production line performance. Safety manuals were found with some of the supervisors but were hard to find with operators. The manuals appear to have basic information about safety but most of it was outdated (1990's). There were no periodic meetings to discuss safety, with safety only being discussed once an event has occurred (either an accident or a near miss). The general organisational culture seemed to favour production over safety. The lack of safety culture was noticed also through the absence of safety rhetoric in the company's wall charts and posters. The wall charts were mainly informative about the plant's own products and partnerships. Regarding employee/ supervisor communication, informal communication appeared to be the main channel even with the existence of formal channels (emails, letters, etc.).

In general, the observation gave the impression that safety was not a priority to the organisation; however, there was some safety instruction in place. This study adopts the breath-first principle (see section 3.2.1) which advocates a holistic view to understand the normal functioning of the system. The breath-first principle emphasises general discovery of behaviour patterns and the meaning behind them. Within this scope, a participant observation method was used to gain general knowledge and understand the normal function of the organisation. The on-site observation was exercised at a chemical plant in Saudi Arabia to acquire insight into contextual factors relating to safety in the process industries. Regarding resilience, the observation pointed to a poor safety culture to support resilience. This provides a basis to go deeper into understanding the organisational function as a whole. However, exploring more areas related to safety will help in explaining some of the contradictions that were observed. The interviews will examine how safety is defined there and check the existence of resilience abilities within that system. Moreover, the interviews will shed light on the nature of trade-offs that operators, managers, and supervisors have to make normally.

4.1.2 Unstructured interviews:

The interview method was used to collect data concerning safety at a chemical plant working in Saudi Arabia. The unstructured interviews were selected to ensure a relaxed environment were personnel feel free to guide the interview. When an area of interest came up, the interviewees where asked to elaborate on the issue. The informal interviews with personnel helped in clarifying the picture. Operators talked freely about their concerns with the safety of the plant; however, no one had read safety manuals or seemed to believe that it would help in preventing accidents. The majority found those manuals useless in real life and some expressed the view that accidents are the 'will of God' and cannot be prevented. When asked about previous accidents, many of the operators tell you a story about it and many more a near-miss event. They acknowledged the manager's efforts after those events in promoting safety and conducting meetings; however, they found those meetings bureaucratic and just a form of control over their work. Moreover, the observation of operators did not reflect any safety mechanism except common sense. They view the instruction in manuals as rigged and a hindrance to getting the work done. That was reflected in their practices of short cuts where some of them are proud of developing new ways of reducing the time needed to get the work done. It was concerning that some workers have said that they did not have safety training. When they were asked to elaborate, they said they believed that 'it is a waste of time' and they can carry out the work fine without it. Some supervisors have expressed their frustrations about operators not following simple safety measures such as wearing safety shoes. However, supervisors seem to worry more about getting the work done so they turn a blind eye when rules are twisted. When asked about safety most of the interviewees think of fire safety and not many seem to realise the general concept of safety even with those who attended safety training. Since most of the safety practices are outdated, no one has heard of resilience engineering even on the managerial level. Managers do understand the importance of safety; however, they focus more on production efficiency. When asked about safety training and manuals, managers believe that the current programmes are adequate and do the job. Many of them have emphasised the learning obtained from previous accidents and the near miss events. When such events occur, they conduct special meetings to discuss and inform employees of the actions taken.

4.2 Survey Results:

This thesis tries to find the most relevant factors affecting resilience in the process industry. In order to do that, a survey was published covering 22 factors under five themes of resilience engineering. The questionnaire was aimed at floor-shop workers and managers at different levels of industrial organisations. The sample size was chosen as 5 responses for each of the 22 items with a total of 119 participants. The data were collected as hard copies and in digital form. In order to analyse the data, SPSS was used to identify the association between factors relating to safety in the process industry. An overview of the data analysis process is shown in Figure 4.3. A principal component analysis (explanatory factor analysis) was used to identify the correlation between the 22 variables. This chapter presents the summary of the data collected, discusses the analysis process, and highlights the significant findings.

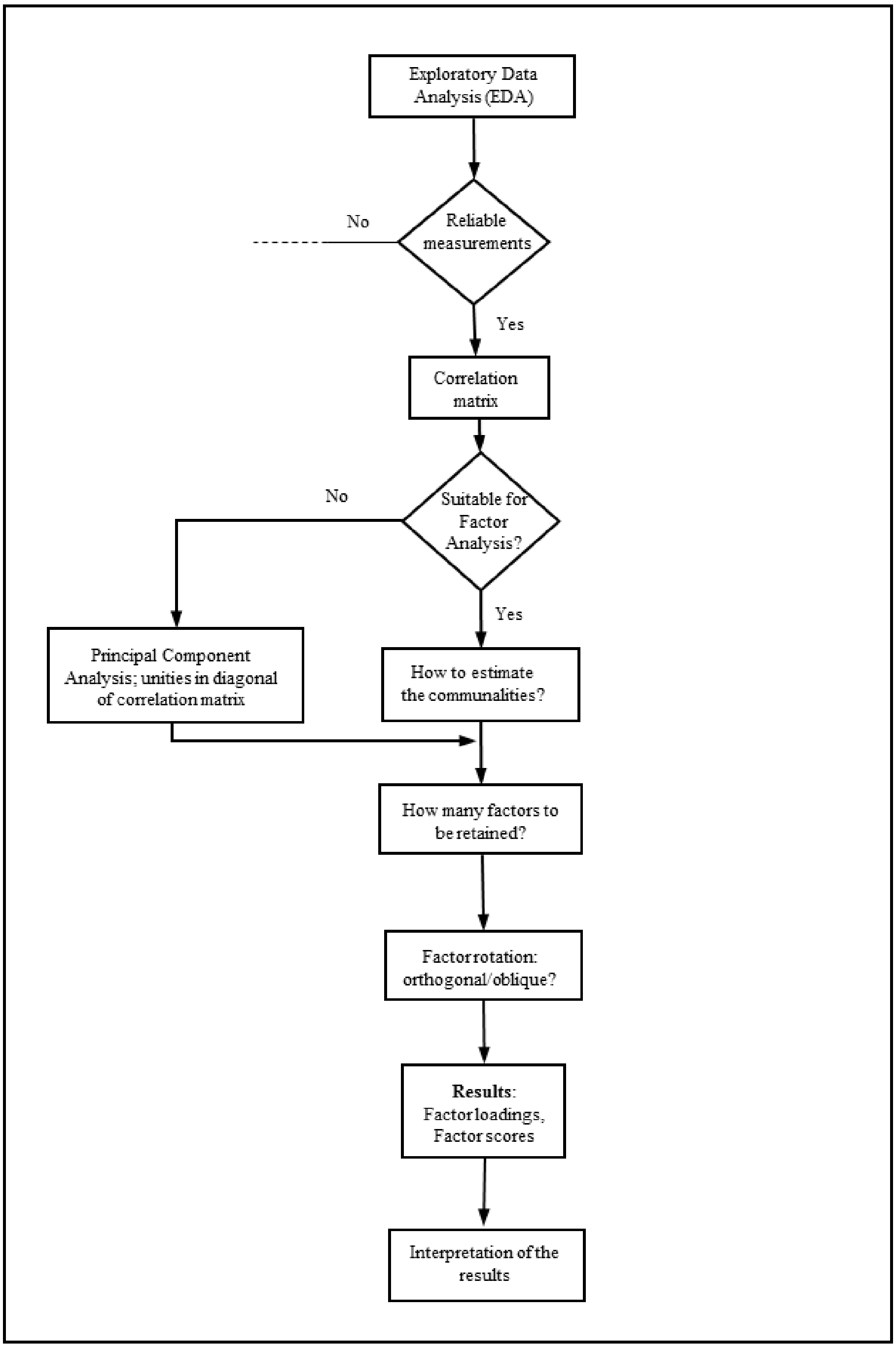

Figure 4-1 Overview of the steps in a factor analysis. Rietveld & Van Hout (1993).

4.2.1 Initial Analysis

4.2.1.1 Measures of appropriateness of Factor Analysis

The first stage in the analysis is to make sure that the data set is suitable for conducting PCA. This is done in two steps. First, we test the data using the Kaiser-Meyer-Olkin

(KMO) test of sampling adequacy and the Bartlett's ‘Test of Sphericity’. The value of the KMO measure of sampling adequacy for this set of variables is .638, which would be labelled as ‘mediocre’. The Bartlett's test is used to compare the observed correlation matrix to the identity matrix (null hypothesis). The test helps to check if there is a certain redundancy between the variables that can be summarised with a few number of factors. If the Sig. value for this test is less than our alpha level, we reject the null hypothesis. The Sig. value for this analysis leads us to reject the null hypothesis and conclude that there are correlations in the data set. In other words, the data set is appropriate for factor analysis. The results of the KMO and Bartlett's test is highlighted in Table 4.1. In addition, we examine the correlation among the items with loading r > 0.3. Having items that correlate with 0.3 or above ensures that PCA is suitable for our data.

Table 4-1 KMO and Bartlett's Test.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.638
Bartlett's Test of Sphericity	Approx. Chi-Square	727.215
	df	231
	Sig.	.000

4.2.1.2 Determine the number of factors to retain

After making sure that the data set is suitable to be analysed using PCA, the second stage is to select a sufficient number of factors to be extracted. This task is challenging since there are no fixed rules to follow. The researcher has to reach a balance between the number of components extracted and interpretability of those components. Choosing a large number of components will explain the variance in the data better; however, it will make the interpretation of those components problematic. On the other hand, choosing fewer components makes the analysis easier but might not explain the majority of the variance within the data set due to the loss of details by omitting further factors.

Although there is no standard way of selecting the ideal number of factors to be extracted, there are three main steps to decide on the number of components extracted which are as follows:

1- Using a Kaiser Criterion of eigenvalue > 1.00.
2- Looking for dramatic changes (Breaks) of the line graph from the Scree Plot.
3- Using Parallel Analysis to compare the eigenvalues of our data with randomly generated ones.

Using the Kaiser Criterion of eigenvalue greater than 1, Table R.2 displays the total variance explained by all the factors. The first column in the table shows seven components of the required eigenvalues. Those 7 components explain around 67% of the total variance in the data set (3rd column in Table 4.2). In other words, the majority of the variance is explained by those seven factors.

Table 4-2 Total variance explained for components with eigenvalue greater than one.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.247	23.849	23.849	5.247	23.849	23.849	3.988
2	2.281	10.370	34.219	2.281	10.370	34.219	1.998
3	1.994	9.063	43.282	1.994	9.063	43.282	2.538
4	1.629	7.407	50.689	1.629	7.407	50.689	2.401
5	1.320	6.000	56.689	1.320	6.000	56.689	2.219
6	1.211	5.504	62.193	1.211	5.504	62.193	1.514
7	1.046	4.753	66.945	1.046	4.753	66.945	2.572
8	.896	4.071	71.016				
9	.798	3.626	74.643				
10	.732	3.326	77.969				
11	.693	3.149	81.117				
12	.659	2.995	84.112				
13	.555	2.523	86.635				
14	.515	2.341	88.976				
15	.447	2.033	91.010				
16	.413	1.877	92.887				
17	.406	1.848	94.735				
18	.362	1.647	96.382				
19	.283	1.287	97.668				
20	.234	1.062	98.730				
21	.155	.703	99.433				
22	.125	.567	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The second step is using Scree Plot (Figure 4.4) to look for any breaks in the line graph. The Scree plot displays the eigenvalues associated with a component or factor (in this research we use both words interchangeably) in descending order versus the number of the component or factor. The plot is a visual tool to allow the researcher to check which components explain most of the variability in the data. Since we are using PCA as an exploration technique, there are no clear-cut rules to choose the ideal number of components. Therefore, the researcher should use his/her best judgement and then reiterate the analysis. Figure 4.2 shows one obvious break at the 2nd factor. This means that the first two components capture much more of the variance than the reaming components. Another less noticeable change is after the 5th factor. This makes a good case to extract the first two or the first five components in our analysis instead of seven.

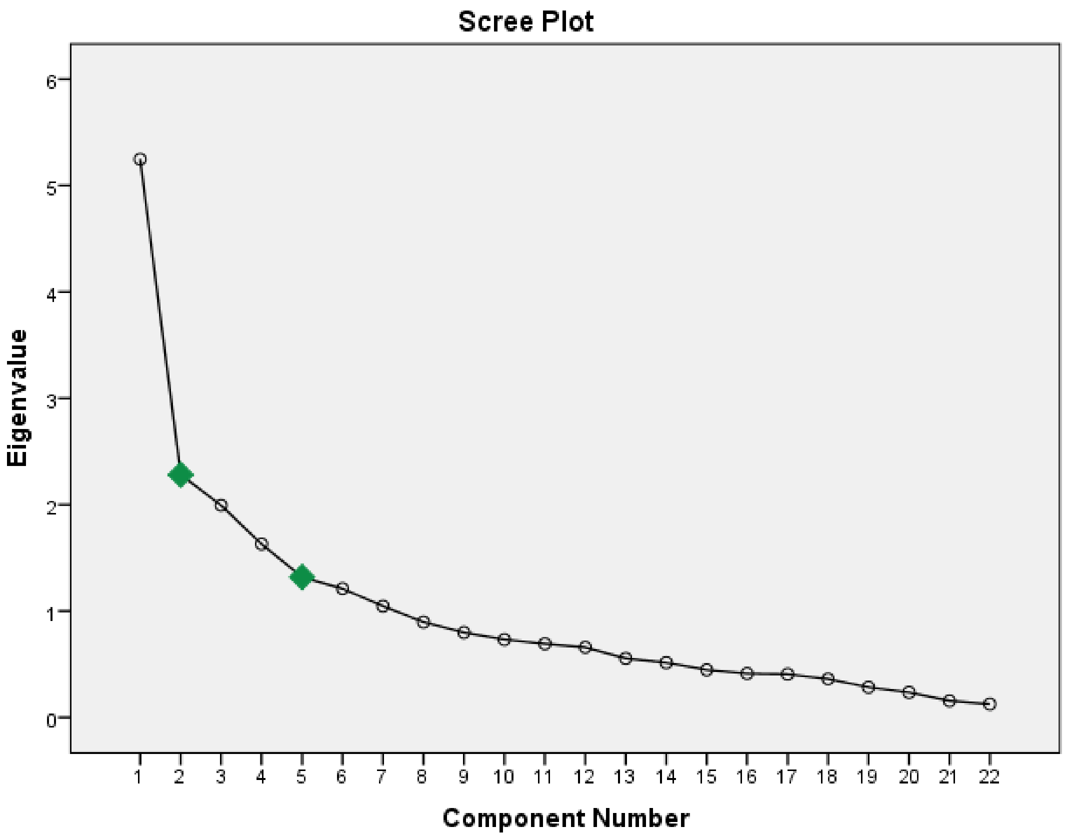

Figure 4-2 Scree plot of 22 factors.

The third step is to use a parallel analysis to compare the eigenvalues in our data to randomly generate eigenvalues of the same sample size. Parallel analysis is a method for determining the number of components to retain from PCA. Since SPSS does not have a built in parallel analysis function, we use Monte Carlo PCA software to conduct the analysis. Depending on the number of variables and responses, the Monte Carlo software generates an average eigenvalue (the number of iterations used is 100) from a random set of data of the same size as our data. By systematically comparing the eigenvalues in Table 4.2 with the corresponding randomly generated values (Table 4.3 using Monte Carlo PCA) we can assess components that can be retained. Factors with eigenvalues greater than the randomly generated ones indicate the significance of these factors. In our parallel analysis, we find that the first four components have eigenvalues greater than the random ones. This indicates that we could retain the first four components instead of seven shown by the total variance (Table 4.2).

Table 4-3 Monte Carlo PCA randomly generated eigenvalues.

Root	Means	Percentile
1	1.869047	2.019554
2	1.709267	1.819885
3	1.593962	1.689961
4	1.48495	1.574664
5	1.399385	1.468939
6	1.314733	1.373197
7	1.238954	1.299919
8	1.17093	1.219056
9	1.102134	1.1515
10	1.040196	1.095207
11	0.976506	1.023401
12	0.920375	0.969893
13	0.860774	0.91627
14	0.800942	0.860483
15	0.745529	0.800845
16	0.6954	0.744828

17	0.648046	0.691017
18	0.59233	0.641738
19	0.540567	0.593743
20	0.492331	0.549899
21	0.433975	0.488784
22	0.369665	0.429793

4.2.1.3 Criteria for selecting items

So far, to determine which components to retain, we used the Kaiser Criterion of eigenvalue > 1.00, then looked for breaks of the graph from the scree plot and finally used Parallel Analysis. The analysis showed seven factors that explain the majority of the variance in the data. However, the scree plot indicated that the first 2 components explain the variance more than the remaining factors. Lastly, the parallel analysis indicates that the first four factors are more significant than the rest. After a few iterations, we find that a three-component solution is adequate to explain the variance in our data set. There are legitimate reasons to include more components; however, the results of other solutions were not convincing or less efficient for various reasons. For instance, when we compare a three-component solution to other solutions we find that the total variance is explained better in the three factors solution. In this study, we are interested in reducing the number of factors contributing to resilience engineering in the process industry. This will give the industry a chance to focus their efforts on the most significant factors. Our cautious approach of limiting the analysis to only three factors does not mean totally disregarding the other factors in practice.

In order to improve the results, the third stage of the analysis looks at the interrelationships between the selected components and the rest of the items. The goal at this stage is to include items which contribute to a meaningful measure of an underlying factor and to remove items that weaken measurement of the underlying factors. In this research, we are using the following criteria:

- Communality of items with loading > 0.5.
- Factor loading with each item: primary interrelation above 0.5, preferably above 0.6.
- Item cross-loadings: by assessing how strongly each item loads on each other factor (a gap of at least ~.2 between primary and cross-loadings).
- Keeping items with meaningful and useful membership to a factor: by reading over the wording of each item and considering the extent to which the items appear to make a non-redundant contribution to the identified latent factor.
- Reliability: by checking the internal consistency of each factor using Cronbach's alpha and checking the "Alpha if item removed" option to determine whether removal of any additional items would improve reliability.

The communality Table 4.4 shows the interrelation between the 3 components and the rest of the items. By critically considering items with loading > 0.5, we can see that there are five items that satisfy the first criterion. After using the rest of the criteria, there were 10 items considered significant and retained for further analysis.

Table 4-4 Three components solution communalities.

Communalities

	Initial	Extraction
1	1.000	.460
2	1.000	.631
3	1.000	.449
4	1.000	.482
5	1.000	.246
6	1.000	.561
7	1.000	.601
8	1.000	.455
9	1.000	.374
10	1.000	.355
11	1.000	.403
12	1.000	.290
13	1.000	.597
14	1.000	.306
15	1.000	.342
16	1.000	.449
17	1.000	.353
18	1.000	.368
19	1.000	.451
20	1.000	.588
21	1.000	.498
22	1.000	.263

Extraction Method: Principal Component Analysis.

To sum up, the analysis shows that a four-component solution is the most appropriate for our data. Therefore, the next step is to force SPSS into using the data to create the four-component solutions. This was done by using the same method of dimension reduction and limiting the number of extracted factors to 3 instead of using the eigenvalue > 1.0. For further information please find the full tables attached in Appendix C. The results of the final analysis are shown in the next section.

4.2.2 Final Analysis: Four factors solution

This section shows the final results of the three-component solution. The results of the initial analysis point to a significant seven component solution. A further analysis was conducted to determine the appropriate number of components to keep. The analysis indicated that a three-factor solution is suitable for the data set. In addition, after assessing the communality table we excluded items that predetermine criteria. A summary of the final results are as follows.

Table 4.5 shows the results of KMO and the Bartlett's Test of Sphericity. The KMO has improved slightly from 0.638 to 0.689, whereas the cumulative total variance explained has decreased from 67% for the seven factors to 65.6% for the four factors. This might be viewed as a down side of the component reduction. However, when comparing the cumulative total variance explained for the three factors we find that it has increased by over 22%. The total variance explained is shown in Table 4.6. The correlation matrix (shown in Table 4.7) describes the statistical relationship between the three factors. Table 4.8 illustrates the proportion of each variable's variance that can be explained by the three components solution (i.e. the underlying latent continua).

Table 4-5 Three component solution KMO and Bartlett's tests.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.689
Bartlett's Test of Sphericity	Approx. Chi-Square	298.416
	df	45
	Sig.	.000

Table 4-6 Three component solution total variance explained.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.537	35.375	35.375	3.537	35.375	35.375	3.202	32.023	32.023
2	1.714	17.143	52.518	1.714	17.143	52.518	1.769	17.687	49.709
3	1.313	13.130	65.648	1.313	13.130	65.648	1.594	15.939	65.648
4	.739	7.387	73.035						
5	.655	6.552	79.587						
6	.636	6.364	85.951						
7	.465	4.650	90.601						
8	.414	4.138	94.739						
9	.295	2.950	97.689						
10	.231	2.311	100.000						

Extraction Method: Principal Component Analysis.

Table 4.7 The correlation matrix for four component solution.

Correlation Matrix

		1	2	3	4	6	7	8	13	20	21
Correlation	1	1.000	.566	.312	.138	.041	.063	.390	.169	.143	.260
	2	.566	1.000	.083	.165	-.011	-.017	.218	.110	.071	.081
	3	.312	.083	1.000	.466	-.012	.095	.165	-.064	.179	.006
	4	.138	.165	.466	1.000	.347	.412	.201	.188	.292	.023
	6	.041	-.011	-.012	.347	1.000	.514	.388	.381	.489	.529
	7	.063	-.017	.095	.412	.514	1.000	.398	.412	.520	.461
	8	.390	.218	.165	.201	.388	.398	1.000	.385	.348	.347
	13	.169	.110	-.064	.188	.381	.412	.385	1.000	.511	.420
	20	.143	.071	.179	.292	.489	.520	.348	.511	1.000	.517
	21	.260	.081	.006	.023	.529	.461	.347	.420	.517	1.000

Table 4-7 Communalities for four component solution.

Communalities

	Initial	Extraction
1	1.000	.806
2	1.000	.689
3	1.000	.733
4	1.000	.764
6	1.000	.629
7	1.000	.655
8	1.000	.504
13	1.000	.538
20	1.000	.614
21	1.000	.634

Extraction Method: Principal Component Analysis.

In addition, looking at the Component Correlation Matrix we assess the strength of the relationship between the four factors. Table 4.9 shows the results with the correlation matrix when using Oblimin rotation. The Oblimin rotation shows a significant interrelation between the 3 components. This means that using different rotation methods will produce a slightly different matrix. The output of the Varimax rotation is shown in Table 4.10.

Table 4-8 Component correlation matrix for the Direct Oblimin rotation.

Component Correlation Matrix

Component	1	2	3
1	1.000	.141	.164
2	.141	1.000	.094
3	.164	.094	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Table 4-9 Component correlation matrix for the Varimax rotation.

Component Transformation Matrix

Component	1	2	3
1	.905	.295	.306
2	-.407	.809	.425
3	-.122	-.509	.852

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Finally, in order to interpret the result, we need to identify items with strong interrelation with the four components. The component matrix (Table 4.11) shows the factor loading for each item on those 3 components. Items with strong interrelation are then linked to the general themes of resilience engineering. The final result is attached in Appendix D.

Table 4-10 Component matrix for four component solution.

Component Matrix[a]

	Component		
	1	2	3
1	.405	.728	-.335
2		.692	-.383
3		.550	.604
4	.499		.668
6	.714	-.338	
7	.737		
8	.665		
13	.664		
20	.760		
21	.693		-.321

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

4.3 Analysis:

This section discusses the interpretation of the results. The data were collected to assess the resilience constructs in the KSA and to identify the most relevant factors in the process industry in Saudi Arabia. The main questions under these two goals for the research are:

1. Is the Saudi Arabian process industry resilient? Under which category of ‘System-kind’?
2. What are the main contributing factors to resilience engineering in the Saudi Arabian energy industry?

To answer these questions, this research used a quantitative approach to assess and extract relevant factors to resilience engineering (RE) in the Saudi culture. Some of the results can be generalised to develop knowledge about the application of resilience engineering across cultures. The finding presented in this chapter evaluates the practicality of utilizing the RE framework in the KSA. The chapter will start by analysing the initial results, move on to the final solution analysis and finally give a broad conclusion to those findings.

4.3.1 Field work and pilot study

In order to design the questionnaire, field work took place at chemical plants on the western province in the KSA. The visits included informal interviews with operators and site managers. The main observation was that safety is not of concern to many employees. Only large corporations invest in developing safety systems. Most of the safety practices are outdated and support the leaner approach to safety. The observation from the visited sites indicated that many companies rely on risk assessment and accident analysis as their core concept of safety. The concept of resilience engineering was not clear to many professionals working in the process industry. Therefore, the survey had to have an introductory part explaining the concept to participants. Shop floor workers seem to have many concerns about safety at their work place; however, this was not shown in most of their daily practices. Similar observations were highlighted by Shirali *et al*. (2012) in a study that was carried in an Iranian chemical plant [99]. The state of the safety climate was also reflected from the pilot study where many have pointed out the absences of management commitment to safe practices and the lack of proper safety practice or training; thus, the survey had to have a “not applicable" option in the choices. The lack of management commitment was reflected in reality as the reluctance to introduce up-to-date safety systems. The absence of up-to-date safety manuals was not due to lack of financial resources as many employees have indicated. The majority of workers, during the informal interview, have criticised the safety manuals and the lack of spending on updating them. Shirali *et al*. (2012) pointed out many factors, including religious beliefs where people view accidents as an "act of God" and they cannot stop them. It is worth pointing out that religious beliefs are similar in both the Saudi Arabian and Iranian context.

The informal interviews and the pilot study have helped in getting feedback to improve the experimental design. The survey included an introductory part explaining concepts about safety and RE; in addition, a "not applicable" (N/A) was introduced to the answer options. The questionnaire can be viewed in Appendix B.

4.3.2 The survey

Initially, 320 surveys were sent out; 60 of them were in the form of hard copies and the rest were sent online. The response rate was 43% with a better response rate with the hard copies. Only 138 responses were retained, and 119 responses were considered to be legitimate for this research. Responses with incomplete information and clear outlier cases were excluded from the study. The survey assesses 22 factors under five RE constructs which are: adaptability & flexibility, awareness & preparedness, control, trade-offs, and time management (Appendix B). In the first part of the survey respondents were given a brief introduction to resilience engineering concepts, the aim of the study and some general information such as: age, gender, level of education, etc. In the second part the respondents were asked to give their agreement level (on scale from 1 to 6) with statements assessing factors contributing to RE constructs. The majority of responses were collected from the eastern province in the KSA, where most of the Oil and Gas companies are located, and a few of the chemical plants in the western province. The occupations of respondents are mainly engineers, such as: engineers, support engineers, chemical engineers, control engineers, and test operators. The study also covers managers at different levels of the organization surveyed under the chemical, energy, process, extraction and utility sectors. The respondents were mainly males; 60% of them were between 35 and 45 years old with an average of 6 years' experience in their organization. The age range is illustrated in Table 4.12. This study did not include females since the cultural factor does not support women to work in such sectors in the KSA.

Table 4-11 Age range for participants (n=119).

What is your age range?		
Answer Options	Response (%)	Response Count
18 to 24	31.10%	37
25 to 34	23.50%	28
35 to 44	21%	25
45 to 54	14.30%	17
55 to 64	7.60%	9
Prefer not to say	2.50%	3
Total	100	119

Although the field work and the pilot study indicated a poor safety climate, the general trends form a result indicating resilient behaviour for employees in the organizations surveyed in the KSA. However, although the results show some resilient responses, this is not enough evidence to judge the whole system as resilient. Carvalho *et al*. (2009) distinguish between front-end operators in an uncontrolled manner and the constructed organisational factors in a controlled manner [118]. The authors oppose calling a system with uncontrolled systematic manner resilient. This discussion leads us to the point that systems could be safe without being resilient (Hale and Tom, 2006) [122]. Shirali *et al*. (2012) assert that resilience should be systematic rather than causal [99]. From observation of industries in the KSA we seem to have causal resilience where managers are focusing on traditional risk assessment tools such as fault tree analysis. By causal resilience, we refer to the lack of developing a systematic proactive adoptive capacity.

4.3.3 Seven factors solution

The initial results indicated seven elements in the solutions. Those seven elements indicate a strong correlation between resilience engineering constructs and the ability of an organization to bounce back to a normal state of operations after disruptions. The seven factors explain 67% of the variance of our data set. The loading of those seven factors is presented in the communality Table 4.12. The table shows the loadings of each item with the general themes of resilience engineering. Priority wise the result suggested the following descending order: Time management, adaptability and flexibility, awareness and preparedness, control, and trade-offs. Table 4.13 shows the items with the most loading factors.

Table 4-12 Seven factor solution communality.

Communalities

	Initial	Extraction
1	1.000	.758
2	1.000	.742
3	1.000	.714
4	1.000	.754
5	1.000	.714
6	1.000	.692
7	1.000	.652
8	1.000	.525
9	1.000	.506
10	1.000	.523
11	1.000	.679
12	1.000	.637
13	1.000	.669
14	1.000	.687
15	1.000	.712
16	1.000	.748
17	1.000	.490
18	1.000	.548
19	1.000	.643
20	1.000	.671
21	1.000	.841
22	1.000	.825

Extraction Method: Principal Component Analysis.

Table 4-13 Corresponding constructs to the seven factor solution with loading factors.

Resilience Themes	**Items**	**Loading factors**
Time management	Time to reflect on planning.	0.84
	Management support (by giving enough time to plan).	0.83
Adaptability and flexibility	Management communicating new plans and information.	0.76
	Ability to adapt to unexpected situations.	0.75

	Ability to communicate efficiently.	0.74
	Risk assessment ability.	0.71
Awareness and preparedness	Readiness for future events.	0.74

Regarding time given to employees to reflect on planning, half of the participants seem to have enough time to plan. Moreover, 65% feel that managers give them enough time to reflect on their planning. Time management construct relates to an organisational buffering capacity, whereby the system must have the necessary time and resources to respond to an arising problem. When comparing the loading factor components with Ferreira *et al*. (2008), we find similarities regarding time management aspects [123]. Despite the fact that the Ferreira *et al*. (2008) study was conducted in a different country and industrial sector (on the UK railway network), the time management loading factors are very close. The time management aspect appears to have a strong correlation in both studies. Table 5.4 shows the comparison between Ferreira *et al*. (2008) and our results. As the table shows, time to reflect on planning and management support seem to have a similar loading factor in both the railway and energy sectors. However, the rest of items are not close. Table 4.14 demonstrates that there are broad variances in the results. Those differences could be product of many factors such as the industrial sector, organisational culture or sample size. The differences suggest that RE constructs may change with the industries using the same concept. So far, the results are not conclusive and we will have to move to the final analysis of our data.

Table 4-14 Comparing loading factors with Ferreira et al. (2008).

Loading factor for extracted seven items		
Items	Our data	Ferreira et al. (2008)
I have enough time to reflect on my planning.	0.84	0.84
I am encouraged to reflect on my planning.	0.83	0.53
I revise my planning whenever new information arises.	0.76	0.2
I can solve problems even when faced with unexpected situations.	0.75	0.04
I can communicate my decisions promptly to those that relay on them.	0.74	0.09
I can detect failures or errors in my planning before they create problems.	0.71	0.16
Because something has always gone well before, I feel confident that it will continue to go well in the future.	0.74	-0.1

4.3.4 Four factor solution

The further analysis of the data revealed an optimum solution of three factors. The four-factor solution explains 65.6% of the data variance. The optimization process highlights the importance of the following themes: adaptability and flexibility, control, awareness, and preparedness. Table 4.15 summarize the extracted three factors with the corresponding RE concepts.

Table 4-15 Corresponding constructs for the four factor solution with loading factors.

Resilience Themes	Items	Loading factors
Adaptability and flexibility	Efficient communication	0.63
Control	Information availability	0.6
	Control over work tasks	0.56
Awareness and preparedness	Ability to deal with external pressure	0.6

Adaptability and flexibility concepts correspond to the system ability to adjust to external changes and pressures. The concept of adaptability covers a wide range of factors such as ability to work under pressure, ability to communicate with others, and ability to respond to irregular disruptions. The importance of flexibility was emphasized in the previous work of Costella et al. (2009). Flexibility can help an organisation to respond to input fluctuations which allow the system to operate in various conditions. Table 4.16 show factors corresponding to the adaptability concept and how participants agree with it.

Table 4-16 Responses to the efficient communication item.

I can communicate my decisions promptly to those that relay on them		
	Responses	%
Strongly Agree	37	31.09
Agree	35	29.41
Slightly Agree	21	17.65

Slightly disagree	7	5.88
Disagree	10	8.4
Strongly disagree	6	5.04
N/A	3	2.52

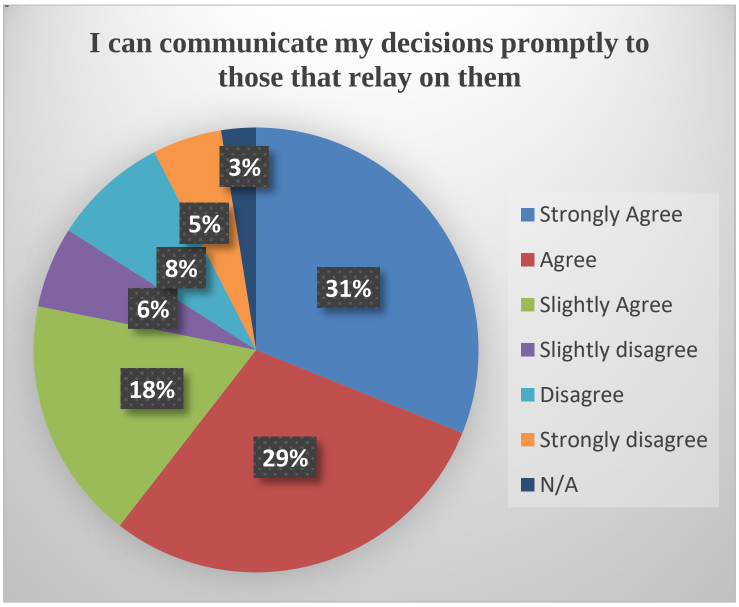

Figure 4-3 Responses to the efficient communication item.

Our data indicate that the energy sector in the KSA is adaptable and flexible. Over three-quarters (78%) of the respondents can communicate their plans efficiently with their colleagues. As Figure 4.5 shows, 31% trust their ability to communicate with others. In addition, during the observation stage, it was noted that employees seem to have good informal ways of communicating with each other. Informal communication allows workers to obtain information about planning or confirmation about the task in hand. Such communication contributes to resilience by offering a fast and reliable channel to change plans and discuss issues as they arise. This trust is reflected in the remaining factors related to the adaptability concept. Communication issues have been given particular attention in management studies. Informal communication was also highlighted by other studies in a different sector. Ferreira *et al*. (2008), for instance, studied resilience in the UK rail network, in which he emphasises the contribution of informal communication in the flow of information which is crucial to system resilience. The communication factor has the highest loadings in our data set. Another factor that had the highest agreement among respondents is the employees' ability to anticipate problems before they occur. The results show an overwhelming majority, with around 85% agreeing on their ability to detect planning failure (Figure 4.6). This is a sign of resilient behaviour which helps the organization to overcome mishaps. The responses to the ability to discover failures and errors were unexpected since the literature review (Chapter 2) revealed the opposite. Human error is accountable for 80% of accidents and 20% is due to technological failure. However, there are 23% who find difficulty in communicating their plans and 2.5% with no channels to communicate with others.

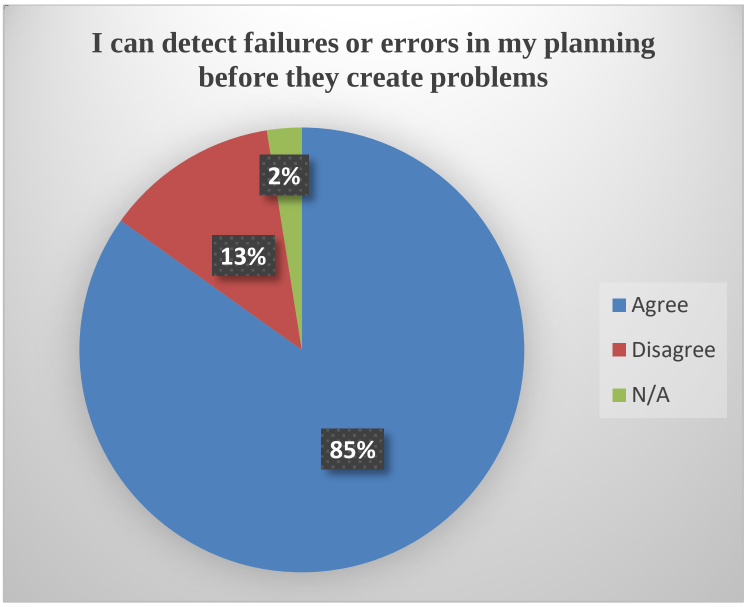

Figure 4-4 High consciousness to failures and errors.

The *control* concept refers to the system ability to control activities regardless of operational conditions. It assesses employers' ability to follow plans and anticipate problems. The energy sector in the KSA seems to have great control over activities. On a system level, controllability refers to the ability to reach a specific desired state in a certain time. Controllability is dealing with the desired output of dynamic systems. Employers seem to have enough information about their tasks. However, there seems to be some contradiction about what was reported and the observed reality during the questionnaire design stage. Although, the observation indicated lack of training or the existence of standard safety systems, the results showed around 68% of the respondents seem to believe they have all the information they need to carry out their tasks. In addition, 66% finish whatever plans they had. The contradiction could be explained by looking at the loading factor associated with the items under this concept. We find the information about the work and finishing the plans have the highest loading factor, whereas the rest of the factors have below 0.5 loading. The rest of the factors are more concerned with potential planning failure and dealing with unexpected situations. Therefore, employers could have exaggerated their confidence level. Figure 4.7 shows how confident employers feel about the control of their work activities. In general, the findings indicate that employers in the process industry are able to steer their job activities even under unexpected situations.

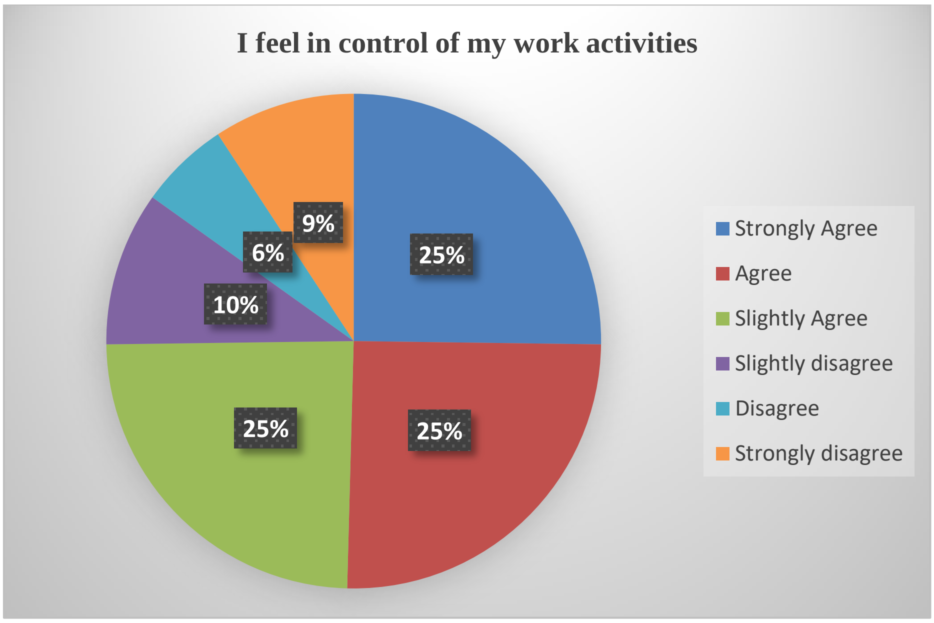

Figure 4-5 Responses to control over work tasks.

The third extracted concept relates to *awareness and preparedness*. The awareness and preparedness construct assess system ability to react to disruption to normal operation and the availability of appropriate information regarding performance standards. Items under this construct include the ability to adjust to external pressure, support of managers and feedback. The general outcome from our data set indicates that industrial sectors in the KSA are well prepared to face work pressures and changing plans accordingly. Within this construct, the ability to adjust according to external pressure has the highest loading factor with 0.59. Employers in the KSA seem to be highly prepared for unexpected external pressure. This was reflected in the data with 75% of responses agreed on their ability to adjust to pressure. On the other hand, 23% seem to have doubt about their organization's ability to deal with external pressure. This small fraction matches the findings from the observation stage. During the observation, employers seem to feel that their organizations are lacking preparedness to deal with external pressure. Many of them have expressed satisfaction with the information they were given to finish their tasks. This might be reflected in the question about their confidence in the future occurrence of accidents. This question had the lowest agreement level of the employees where 38.7% feel less confident about the occurrence of mishaps in the future. Figure 4.8 illustrates responses to how confidant employees are about future accidents.

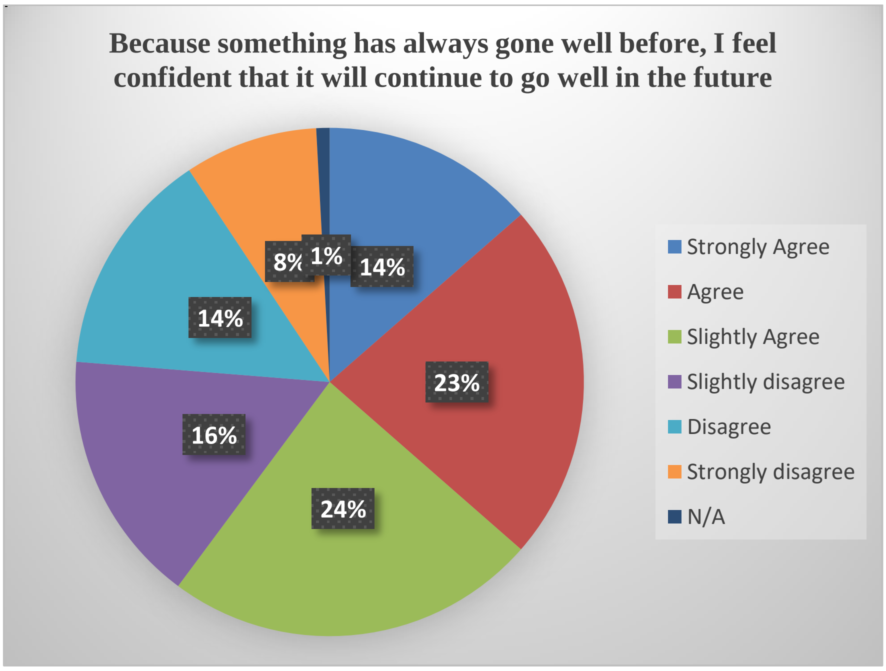

Figure 4-6 Responses to how confidant employees are about future accidents.

Those findings answer the first question in our research “What are the main contributing factors that help industrial systems to restore a normal state operation in the KSA?” The analysis revealed that efficient communication, information availability, ability to deal with external pressure and control over work tasks are the main contributing factors of RE in the KSA process industry. The main themes incorporating those extracted factors are:

- Adaptability and flexibility
- Control

- Awareness and preparedness

The factors extracted were emphasised in many other studies as the main contributing factors to resilient systems. This study confirms the importance of the extracted items in introducing resilient systems to current safety practices in chemical plants working in Saudi Arabia. Since this is the first research assessing RE in the KSA, those findings provide a starting point for further studies and applications in the Saudi context. In addition, it provides managers with an insight into the safety climate in the process industry.

On the question of the similarities with other findings in different industries, there was no prior work in the KSA to compare with. Therefore, the results are compared to a study that was conducted in the rail network in the UK. When comparing the loading of the extracted three factors with Ferreira *et al*. (2008) we find no similarities (Table 4.17) [123]. The optimum solution, however, appears to have better results than the initial seven factors. The loading factors for the extracted four factors (under the three constructs) are not far off from Ferreira *et al*. (2008). Considering the differences between the studies, the findings suggest that RE constructs do vary according to the industry. Therefore, the answer to the second question is not conclusive. Further studies should be carried out across industries with control of all other variant factors (such as geographical location).

Table 4-17 Comparing loading factors with Ferreira et al. (2008).

Loading factor for extracted three items		
Items	Our data	Ferreira et al. (2008)
I can communicate my decisions promptly to those that relay on them.	0.63	0.32
I have all the information that I need to do my work.	0.6	0.83

I manage to finish whatever plans I started.	0.56	0.66
I can adjust my way of working according to external pressures.	0.6	0.18

5 Chapter Five: Discussions

Summary:

In conclusion, the resilience engineering framework offers a non-linear systematic approach for accident modelling. The framework has developed tools to overcome the complexity of sociotechnical systems and focus on the dynamics of the organisation. Practically, the essence of resilience engineering is to use the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state. This research tests the framework in the KSA process industry. The survey measuring resilience potential resulted in extracting three factors with most correlation with resilience abilities. Effective communication plays a major role in supporting sharing information within the system. This has led to the acquisition of a good ability to monitor systems' functions and coordinate appropriate responses to regular and irregular disturbances. The effective communication and information availability has also contributed to the ability to share knowledge and experiences regarding safety. On the other hand, lack of awareness and preparedness hinder the system's ability to anticipate developments further into the future. Knowing what to expect helps organisations to develop better strategies to deal with mishap risks. Our analysis shows that the Saudi Arabian process industry has resilience of the second type. Companies in KSA have a good ability to monitor and respond; however, learning ability needs to be strengthened by extending it to change policy design functions.

5.1 Introduction:

This chapter relates the findings with the general aims and research questions. The first section of the chapter will start by discussing the underlying theory of safety and accident modelling. The debate will focus on the dynamic and nonlinearity of accidents. Following the theoretical aspect, the research attempts to highlight the knowledge gap about safety climate in KSA and its influence on organisations. This research reviews the safety climate in KSA and the safety culture in the process industries in the light of results from observation and interviews. The relationship between Saudi national culture and its influence on organisational safe/unsafe behaviour will be assessed including some personal views on the matter. The second section focuses on assessing resilience engineering and the possibility of utilizing it in KSA. The discussion includes the interpretation of the results and analysis of the data collected. The assessment of resilience identifies the most relevant factors in the process industry in the Kingdom. This chapter will end with an assessment of the future outlook and suggestion for further work. It will highlight some of the challenges that researchers should be aware of and offer some ways to overcome them.

Is the Saudi Arabian process industry resilient? Under which category of 'System-kind'?

What are the main contributing factors to resilience engineering in the Saudi Arabian energy industry?

In order to answer these questions, this research uses a quantitative approach to assess and extract relevant factors to RE in the Saudi culture. Some of the results can be generalised to develop the knowledge about the application of resilience engineering across cultures. The finding presented in this chapter evaluates the practicality of utilizing the RE framework in KSA. The chapter will start by analysing the initial results, the final solution analysis, and final the broad conclusion from these findings.

5.2 Theoretical Dissection:

We start this discussion by expressing concern regarding the development of a comprehensive theoretical framework to view accident phenomena. Studying the development of accident models (See section 2.2) we can find two major turning points to this development. At the beginning, accidents were viewed as a linear process caused by physical elements. The first turning point was recognising the multi-linearity of accident phenomena. The second turning point was the acknowledgement of accidents' non-linearity. These two developments resulted in great confusion where fundamental questions about accidents and safety had to be reviewed. An indication of that confusion could be observed by vague definitions of safety and risks. In our view, this confusion is healthy and gives ground for new ideas to thrive and perhaps succeed. However, through examining accident prevention in an industrial context, we find there is a growing gap between theoretical and practical knowledge. The majority of industries appear to be satisfied with the conventional views therefore efforts to improve safety are limited. On the other hand, new frameworks are impractical either because they are complex or lack adequate tools to implement them in reality. On a deeper level, this impracticality emerges from attempts to address the multi-linearity of accident causes or the struggle to define socio-technical systems (boundaries, behaviours, etc.). This leads us to argue that accident phenomena lack adequate generalisation that simplifies our understanding of safety and risk.

Since the development of scientific management theory, performance was thought of purely in quantitative means. Scientific management developed efficient tools to measure the time needed to perform tasks and eliminate wasteful activities. However, further studies on performance indicated overwhelming evidence that imply wider social and environmental elements that govern human productivity at work. Up until that time, the need for systematic accident prevention was less justified, since industries were less complex where accidents occurrence was limited and consequences were less severe. The need for accident models grow with the increased number of injuries and fatalities that come with the development of complex industrial systems. This had led many to relate accident prevention with focusing on designing safer machines. Pursuing reliable technology with human safety in mind has helped in protecting operators from work related injuries to a certain degree. However, accident consequences in some industries presented significant challenges where single mishap events caused catastrophic loss of lives with broader impact on the environment. The modern approaches to accident prevention started with the pioneering study by Herbert Heinrich into injuries in industrial settings. Contrary to the general belief that physical and mechanical failures are the main cause of accidents, Heinrich's study discovered the role of human factors. Human error was found to be accountable for 88% of accident causes. Due to this fact, academics and professionals began to focus on the influence of human behaviour on safety performance. The shift towards social concepts, however, posed a new set of challenges including explaining the dynamics that influence social organizations and human behaviour.

The move towards understanding the psychology of human motivation and influences on social groups meant a change in the way that safety performance is measured. Since the industrial revolution, the reliance on machines to increase productivity has risen. Therefore, for a long time, managers related controlling efficiency to quantitative measures such as equipment specifications (e.g. life span, output/hour, and horsepower). Safer designs of production equipment were the best way to prevent operators' injuries. However, process industries and its managers seem to struggle to integrate the qualitative measures. Using such tools meant vague measures that depend on knowledge and interpretation of safety culture status and influences on it. Safety experts tried to overcome this challenge by introducing a solution at four different levels: legislative, executive, managerial, and operational. The first level proposed global standards for different industries to support implementation of universal practices that protect business and public interests. The International Organization for Standardization (ISO) is a prime example of such standards that provide practical guidelines to benchmarked organizational processes. The second relates to decision-making at the top level of organizations especially in hazardous industries. Administrators and shareholders were encouraged to declare commitment to employees' health and safety in organizational charters (e.g. goals, mission, etc.). This meant executive influence on risk taking behaviours by managers to reduce the number of accidents and injuries. On the managerial level, specialists integrated safety measures into the quality procedures for the products to make safety an inseparable part of the product itself. Such a role was delegated into existing departmental organization structures, such as quality management or assurance or ad hock projects. On the operational level, employees had to be certified to operate equipment and attend compulsory safety training courses to enhance safety awareness. The introduction of various mechanisms to motivate organizations to adopt safer behaviour had successes especially on the legislative and executive levels. However, implementing these measures in the industries has proven to be more challenging. In general, the introduction of legislative and executive commitment to safety was not reflected on managers' or operators' attitudes. In fact, most investigations into major accidents indicated systematic failure of the organizational safety culture.

Case studies on BP provide an illustration of the failure of traditional safety management systems. It indicates major weaknesses of the linear approach in general. The investigation of previous accidents appears to point at the same factors repeatedly. This was obvious when comparing the accident reports of the Macondo blowout in 2010 with the five-years-earlier explosion at Texas City. Investigators pointed at systematic failure of the safety management system, poor safety culture, and inadequate enforcement of procedures. All these factors are viewed as results of inadequate control of the system. Since many mishaps have happened to numerous other organizations across various industries that use the casual approach (e.g. Exxon Valdez oil spill (1989), Fukushima nuclear accidents (2011)), this points to the failure of the linear and multi-linear approaches. The fundamental inadequacy either by the way BP implemented the casual model or the linear approach itself reveals the need for new ways of thinking about accidents.

In the last few decades, the safety climate and culture was a subject of great interest to improve safety. Attempts to integrate these concepts were renewed by introducing a systematic view of organization. The systematic views acknowledged that industrial organizations are open systems in a dynamic state. Therefore, the performance of the organization must take into account the function of the system as a whole. Factors from the environment, as well as from within the organization, influence different functions in undiscovered ways. This view has had major impacts on the way safety is viewed. Not only does it challenge the scientific view of classical management, but also the linear cause-effect relationship that dominated accident prevention models for decades. This approach is relatively new in the safety arena, therefore tools to implement such an approach are still underdeveloped. In this thesis, we have discussed two examples of the systematic view: STAMP by Leveson, and RE by Hollnagel. The STAMP reflected the complexity and challenges of controlling socio-technical systems [7], [45]. Although the Leveson model seems to have great potential on the theoretical level; it has had little success in reality because it still lacks the quantitative tools and measures that the industries prefer to work with in reality. On the other hand, RE relies on existing abilities that organizations have (learning, anticipating, monitoring, and responding); which might be easier to implement in reality. This thesis chooses to investigate the RE concept in process industries to evaluate the practicality of using it as an alternative to the classical view of safety. Although we acknowledge that RE still uses qualitative measures and deals with qualitative concepts; it differs from other systematic models of accident by urging managers to use the existing abilities of the organization to improve safety and performance at the same time. This seems to offer a solution to the paradox of trading off production for safety, whilst at the same time encouraging the system to go back to normal operations after accidents.

Opposing the traditional view, resilience engineering offers some advantages to the view of safety in a socio-technical environment. The first advantage is tied in with the use of system theory by taking a holistic view of the system and all its interacting functions. This shifts the emphasis from hunting for individual components of the system to the dynamics of work processes. In order to evaluate the interactions of complex functions, the framework suggests the use of the breadth-before-depth principle to obtain a broad view of the organization as a whole. The overall view also provides a sense of the normal state of operation and the organizational culture expressed as common values among employees. The interactions between the various functions are then viewed at a deeper level of detail, where each function is explained by the elements it is possible to view (e.g. inputs and outputs). The framework introduces the Functional Resonance Analysis Method (FRAM) to reach an adequate level of analysis. With FRAM comes the second advantage of using RE, where it reduces the complexity of socio-technical system in favour of understanding interactions between functions. Lastly, the framework focuses on organizational ability to monitor variation in these processes, ability to react to disturbances, anticipate potential threats to its operation, and learning from previous failures and successes. These abilities exist naturally in most organizations; therefore it is easy to integrate RE into the organization. Assessment of these abilities, however relies on quantitative measures and managers' ability to interpret the data. This might be a challenge to adopt the framework by industries where they lack knowledge of the concept and prefer to use quantitative tools. In our view, this gap between the industry and social tools for measuring human performance present the main challenge in implementing the RE approach to organizational safety.

The gap between the industry and academic progress is even more observable in the Saudi Arabian context. In most western cultures (e.g. USA and UK) there is a well-established health and safety code of practice and organizations are require to follow it. On the other hand, industries in Saudi Arabia are still relatively new. Health and safety codes exists in local authorities (e.g. city councils), where most of these codes relate to the construction sector. The industrial sector in Saudi Arabia makes an interesting case to study because it is relatively recent in comparison with UK for instance. In addition, the Kingdom's industries started with the discovery of oil, where oil exploration companies from the US mainly brought with them, their own standards of safety. The difference in culture between the countries makes an interesting case to study the safety climate in KSA, since not many have examined it. Moreover, the lack of governmental legislation regarding national codes of health and safety suggest a unique safety climate in comparison with other cultures. Exploring safety culture in the Saudi process industry contributes to knowledge by furthering the understanding of influences on the safety climate and culture.

5.3 Saudi National Culture and Safety Climate:

The first aim of this thesis was to explore the safety climate in Saudi Arabian industrial complexes.

To explore this goal, we asked the following questions:

What are the general features of safety climate in Saudi Arabia?

What are the factors that influence organisational safety culture in the Kingdom?

In order to answer these questions, a survey of important articles, books and other sources was carried out. A summary of the main studies and research related topics were presented in chapter 2. Some evidence from the literature review indicated correlations between national culture and workforce attitudes toward safety and risk taking behaviour. In accordance with Hofstede's (1994) cultural dimensions framework, studies have shown an influence of individualism, masculinity, uncertainty avoidance, and power distance on workforce safe/unsafe behaviour [124]. Merritt and Helmreich (1996 & 1998), for instance, have argued that in cultures with high power distance (as is the case in KSA) organisations are expected to be highly hierarchical, which could result in a one-way flow of communication [125], [126]. Therefore, employees are expected to have passive behaviour and do not participate in creating a positive safety culture. The influence of national culture on the safety climate and performance were discussed broadly in chapter 2. To meet the first quest of this inquiry, the cultural diminution framework provides the following influences of Saudi national culture on organisational safety cultures, this is characterised as follows:

- High power distance: Saudi Arabia score 95 in this diminution; which indicates that organisation operations are highly hierarchical and roles are well defined. The decision-making in such cultures is centralised and workforce have little influence on the decision-making process. In KSA this could be observed through the presence of few labour unions (e.g. Saudi Council of Engineers, which was founded in 2002). The leadership style is expected to be autocratic, with top-down communication channels. In such a culture, we expect management commitment to safety to play an essential role in ensuring safe behaviour by the employees.
- Collectivism: on the individualism dimension the KSA score is 25. Hence, Saudi Arabia is a collectivist society, where relationships among group members are greatly valued. There is long-term commitment to family, extended family, and friends. These traits are manifested in the working environment by workforce loyalty to their organisations and group members have strong friendships. This has a positive influence on the safety climate and communication is less formal

as the flow of information is excellent. Employees are supportive to each other and avoid bringing shame to the group. In addition, employer/employee relationships are perceived in moral terms managers take decisions based on what is best for the group.

- Masculinity: the score of 60 in this dimension suggests a masculine society to some extent. In a masculine society, people value hard work to achieve their goals. There is a great emphasis in the Saudi society on equity, competition, and performance. Mangers are decisive, assertive, and encourage competition. Regarding safety, managers focus on production and achievements more than safety. Therefore, managers in masculine culture are risk-takers, which could compromise safety in the organisations. However, empirical studies are not sufficient to draw conclusive correlation between safety performance and this dimension.
- Uncertainty Avoidance: Saudi Arabia scores high (80) in this dimension, therefore, managers feel threatened by ambiguous situations. There are great tendencies to have more control and avoid uncertainty. In the Saudi culture, security is an important motivator to plan for failure in advance to avoid mishaps. However, workers tend to maintain the norms and following orders could hinder the organisational ability to adapt to a changing environment. The need to follow rigid codes of behaviours could result in great resistance to change and new ideas.
- Short term orientation: the score of 36 on the time orientation diminution point to short term oriented society. The normative nature of Saudi Arabian society makes people value traditions and be suspicious about new initiatives. There is great emphasis on achieving quick results. The effect of this diminution on

safety performance is not fully understood in the safety context since it was added lately to the framework and not much research was published about it.

- Indulgence: Saudi Arabia scores around 50, which does not point to a clear preference on this diminution. Therefore, we could assume that it has no effect on workforce behaviour towards safety.

Our aim is to understand the way these cultural dimensions affect safety culture and resilience in the industrial context. In other words, we are looking for supporting evidence from our experiment by testing the former hypothesis in the KSA process industry. For instance, we expect to find evidence that power distance resulted in centralised decision-making processes regarding safety, where operators have little influence on the decision. On the resilience level, this will be translated in rigid roles and practices that are unable to adapt to safety stresses. The field work and the survey were conducted with the former hypothesises in mind. We argue that the national culture dimensions influence safety climate in the country, which in turn affects industrial safety culture including organisational behaviour towards safety. The influence of national culture on organisations' safety has been supported by many studies (e.g. Haukelid, 2008) [59]. However, few studies were published on the relationship between national culture and resilience (e.g. Shirali et al., 2012) [99]. This research contributes to knowledge by understanding the way national culture influences both resilience and safety culture in industrial complexes. It looks into the way that power distance, collectivism, uncertainty avoidance, and masculinity affect organizational resilience potential and attitudes towards safety. Table 5.1 Summaries the findings of the influence of Saudi national culture on the safety climate in the process industry.

Table 5-1 Effect of Saudi National culture on the organisational safety culture in the process industry.

Cultural Dimensions	Index Score	Effect on organisational safety culture (Theorised)	Effect on organisational safety culture (Results)
Power distance	95	Negative: one-way communication and disengagement of employees.	Positive: High commitment by top management moderate this dimension.
Individualism	25	Positive: more cooperation among working group and thinking about others safety.	Positive: efficient communication and trust between group members creates healthy work environment.
Masculinity	60	Negative: risk-taking behaviour which favours production over safety.	Negative: Risk-taking behaviour and prioritising achievements over safety.
Uncertainty Avoidance	80	Negative: rigid system and resistance to change.	No effect: the results are not conclusive.
Long Term Orientation	36	Negative: less adaptation to changes in the environment.	The study did not include this dimension since it was added recently.
Indulgence	52	No effect: average score.	No effect: average score.

Regarding power distance, the field work revealed evidence supporting the negative effect of this dimension on safety climate. The on-site Observation suggested a centralised decision-making process. During the visits, no mechanisms were found for employees to express concerns about safety. Safety roles appeared to be communicated in a one way, top down, manner. These safety roles are usually communicated through outdated safety manuals and event-based safety meetings. Although, some safety training is required for operators; employees considered it as a ‘form of organisational bureaucracy’. All these observations suggest a centralised decision-making process and one way communication regarding safety. Regarding top management commitment to safety, the informal interviews indicate that operational manager’s take the safety of their employees seriously, which could have a positive impact on safety. However, there is a clear lack of awareness to updated safety views and practices. This was also supported by the lack of human resources that have effective authority to train or enforce safety practices. Therefore, the general findings suggest that power distance has a negative effect on safety culture in industrial organisations.

On the masculinity dimension, evidence was found to support the hypothesis of a negative effect on safety. This is mainly due to risk taking behaviours by employees. Short-cuts on the shop-floor were observed in terms of not wearing safety equipment all the time. Employees have admitted to carrying out their tasks even without following safety procedures. Risk-taking behaviour and prioritising achievements over safety seemed normal among operators. When asked about the use of short-cuts, many have expressed that it helps with getting the job done faster. In addition, some believe that following safety procedures will hinder the workflow and finishing the task on time. Operations managers also expressed understanding to easing safety roles under time pressure. Therefore, we conclude that there is evidence that masculinity have a negative influence on safety culture. However, we also suspect there are elements of a short-term orientation tide in with these observations, since no other conclusive evidence were found, support the focus on hard work values, equality, and/or high competition.

On the positive side, our field work also finds evidence that collectivism contributes positively to the safety culture in industrial organisations. The strong relationships among workers are easily observed on the production floors. Employees seemed at ease to ask for help from colleagues or when interacting with their supervisors. Informal communications seemed to save time and get information transmitted faster. Although these practices seem to counter safety practices, it has a major contributing role to safety in medium and small organisations. Supervisors and operation managers used the informal communication effectively regarding encouraging operators to follow safety practices (such as wearing helmets and safety shoes). In addition, the informality means that operators can report problems faster to their supervisor and get instructions on how to solve it. During the informal interviews, operators also have indicated strong relations among their working groups and support to co-workers. Therefore, the field work suggests a positive effect of collectivism on safety culture in KSA industries.

Regarding uncertainty avoidance, the field work suggests some contradictory evidence in interpreting this dimension. We hypothesised a negative effect of this dimension on safety; however, no observation supported this proposition. Although employees prefer to maintain norms and not challenge management orders, our observations suggest that they are willing to adapt to new situations. Operators seemed open to changing plans and executing new production orders. During the informal interviews, many have expressed their adeptness to work plans and change in work routines. Moreover, managers did not appear to be concerned about control over work processes. Production managers seemed to be flexible and prepared to rearrange load and processes if it results in better outcomes. Past incidents did not result in major changes of their current procedures and changing safety practices. This may suggest resistance to change; however, employees' attitude did not reflect such resistance. Therefore, we did not find reliable evidence from the field work supporting the negative impact on safety culture in the organisation.

To sum up, the findings of the field work suggest that power distance in Saudi Arabia is moderated by the management commitment to safety. In general, high power distance has a negative effect on the safety climate. This is due to the autocratic style of leadership and operators little influence on decisions regarding safety. Employees tend not to engage constructively in improving safety practices. The one-way communication discourages such engagement. Moreover, the data suggests that masculinity in the Saudi culture contributes negatively to the safety climate. Focusing on achievement and production could tip the production/safety balance in favour of achieving production goals. In addition, managers' tendencies in a masculine culture is to take risks, which could compromise safety standards. On the positive side, there was a great positive effect of collectivism to improve the safety climate for organisations working in the Kingdom. The tendencies to work in groups, thus providing social support to co-workers, can alleviate work stress and create a healthy working environment. In addition, communications among individuals and groups are efficient. Managers in KSA should make the most of this diminution by promoting safety and create a supportive culture towards safety. The consideration of the group, also, helps managers to avoid blaming individuals and creates trust between managers and operators. Still we need to understand how this feature of Saudi national culture could influence organisational safety and resilience.

5.3.1 Saudi National Culture and Resilience:

Following the discussion of national culture influences on the industrial safety climate this section extends the discussion to the RE framework. The discussion of this section will answer the question of:

Does Saudi national culture affect resilience engineering within industrial organizations?

Our survey was designed to measure the resilience potential in the KSA process industry. The survey evaluates the extent to which resilience abilities exist in the organisational processes in the normal operational state. The questionnaire asked working groups to give their opinions on organisational resilience abilities relating to: top management commitment to safety, the safety management system, safety information ambiguity, vigilance for future events, and rigidity of the system. Since there are relationships between cultural diminution and safety culture, we hypothesise that this influence extends to the organisational functions and abilities. Taking the features of the safety climate in the kingdom into account, we can hypothesis the following general relations between cultural dimensions and resilience:

1. Power distance: high power distance hinders adaptability and flexibility of organisations and therefore have a negative effect on the safety culture and RE.
2. Collectivism: better communications among groups and individuals helps in monitoring system functions and anticipating future threats; therefore, they have a positive impact on safety practices and RE.
3. Uncertainty avoidance: contradict flexibility however help organisations to learn from previous failure and successes.
4. Masculinity: KSA scores 60 for this dimension; this diminution could work both ways since risk taking behaviour could increase the flexibility; however, the emphasis on production could lead to minimising safety margins.

Regarding power distances, the data shows conflicting responses to the hypothesis. Although the responses point to the existence of a hierarchical structure and well defined roles for employees; employees believe that management look after them regarding safety decisions. Evidence of two-way communications between managers and operators were found. For instance, the majority of the responses indicated that managers encourage employees to participate in safety related decisions. Further analysis revealed positive responses that have affirmed top management commitment to safety. Moreover, the data shows that the organisation is willing to change plans to accommodate threats to employees' safety. Most respondents agreed that safety comes first and managers encourage them to stop operations if there is a risk of injury with no conditions. Although this contradiction to the hypothesis maybe explained by other dimensions (e.g. collectivism), the data shows no evidence of a negative correlation of high power distance on resilience. Our conclusion is that this diminution is closely related to higher managements' commitment to safety. If top management is devoted to the safety, then the enforcement of proper working standards becomes more effective.

On the collectivism dimension, all the data shows a positive impact of this factor on resilience. Collectivism seems to facilitate resilience abilities. The relationships among group members enhances good communication, which helps the group in responding to events quickly. The nature of the relationships also aids in conveying safety concerns to other members and managers informally. Collectivism also creates a healthy atmosphere for learning from others experiences and makes monitoring of organisational processes more efficient. The data supports the hypothesis of a positive impact from collectivism on resilience.

Considering uncertainty avoidance influences on resilience in the Saudi Arabian process industry, the data shows a negative impact. Regulations within organisations seem resistant to changes, which hinders flexibility. Employees are more comfortable working with existing procedures even if they have better ideas. Managers feel in control dealing with what they know instead of trying something new. The responses regarding this dimension also reveal a lack of proper knowledge of safety in these organisations. Learning from other experiences also appears to be limited and relies on employees' behaviour instead of changing the procedures. Most of the responses have acknowledged the existence of outdated safety manuals but still used it anyway. Perhaps resistance to change and rigidity of the system are the most obvious factors relating to this dimension. Our evidence supports the negative influence of high uncertainty avoidance on the resilience.

Regarding masculinity, the data shows supporting evidence to some extent. For instance, risk taking behaviour exists but could be used to increase performance or to stop operations in case of risk (as a safety-first measure). Competition exists, however there is more emphasis on the relationships among group members. Managers tend to be decisive but are willing to discuss safety plans with operators. Therefore, our data is not conclusive about the effect of this domain on resilience.

To summarise, both field work (on-site observations and interviews) and surveys revealed interesting facts about the influence of national culture on safety and resilience in the Saudi Arabian process industry. The highlight of the findings indicates the great positive influence of collectivism on safety culture and resilience. We can generalise this result to conclude that the individualism index has an inverse relation with resilience and safety culture in societies. Regarding other cultural diminution, our find

ings are not conclusive to conclude that there is a direct relationship with resilience abilities and organisational safety culture. We found evidence that high power distance could have a positive impact on organisational safety in the case when the top management are committed to safe operations. We need to test the case where there is high power distance and low management commitment to safety to generalise the positive relationship. However, this might be impractical research since most organisations show (at least in public) their commitment to safety. Similar inconclusive results were found about the influence of masculinity on resilience and safety culture. The inconclusiveness regarding the masculinity dimension is explained by the average score of KSA in this dimension. Regarding uncertainty avoidance, the survey does show that a high score on this index correlates with higher resistance to change, therefore it impacts negatively on resilience. The results from the field work, on the other hand, gave no clear evidence for such an effect. Therefore, we conclude that to some extent uncertainty avoidance effects resilience and safety negatively.

5.3.2 Resilience in Saudi Process industry:

The introduction of system theory to accident models is relatively recent (a decade old). Using system theory offered a solution to paradoxes that safety theorists have struggled with for decades. To be precise, the previous models failed to address the non-linearity of accidents, or integrate the social and the technical components of organisations. The systematic models of accidents offered a comprehensive view by which socio-technical systems are analysed and understood. Furthermore, a systematic view shifts the stress from systems' components to understand systems' dynamics. Systematic models of accidents emphasise the understanding of systems' processes and the interactions between their function and the environment. An example of systematic accident models is System-Theoretic Accident Model and Process' (STAMP) by Leveson [127]. However, critics of such frameworks point to the complexity of systematic approaches. In addition, many have questioned the usefulness of such frameworks because it does not fit with the current practice of safety data collection and analysis.

The Resilience Engineering framework has two main strengths. First, it can utilise organisations' existing ability (learning, responding, monitoring, and anticipating) in order to perform more safely. Secondly, it defines complex functions using minimal description (e.g. input and output) and focuses on understanding the function and its interactions. In a recent addition to the RE framework, organisation these characteristics can be divided into four system types. These system types differ in the extent to which they meet the definition of a resilient organisation. This research aims to contribute to the discussions on safety by assessing a resilience engineering framework in the Saudi Arabian process industry. Most previous studies have been conducted in western cultures, this research validates the framework for a non-western culture. In addition, an understanding of the way Saudi notional culture influences safety culture and resilience abilities is a novel contribution to knowledge. Our assessment of resilience in KSA can be divided into two sections. The first is concerned with assessing the resilience abilities of the process industry in the country. The second section will classify the types of system that exist in the KSA environment.

The survey used in this research measured the resilience option of four organisational abilities: learning, responding, monitoring, and anticipating. The analysis used the principle component analysis to identify the main contributing factors to these four abilities in KSA. Our analysis for the various factors related to these abilities were compacted into the following factors: adaptability, control, and awareness. The findings are summarised in table 5.2. The analysis discovered the following aspects of resilience abilities:

(1) Learning: the data shows that process companies in the Kingdom can learn from past experiences. However, this is done mainly through organisational channels of communication. Such a learning process is hard to observe at the governance level. The learning ability seems stronger at the operational level and gets weaker at the top level of the hierarchy. Therefore, small and medium size companies are more able to learn from incidents than large ones. The overall assessment of this ability is that it exists to some extent but it depends on the size of the organisation, flexibility, and organisational awareness.

(2) Responding: there are two types of responses in organisations: planned and unplanned. The survey shows that most planned responses are inadequate to deal with major accidents. The outdated safety procedures and lack of proper safety supervision provide the evidence for this failure. On the other hand, the data indicated high adaptability and awareness to safety by the employees. Operators have a good idea on threat sources and have experience in dealing with disturbances. The trade-off is mainly in favour of safety especially for operators and supervisory levels. The analysis shows a strong relationship between this ability and a good level of communications among group members. This could be explained by the collectivism aspect of culture that exists in the kingdom. Our conclusion supports the existence of a good response ability in the process industry.

(3) Monitoring: the data shows that the process industry has a good ability to monitor the function of the organisations. Well defined roles existed and defined control for organisational processes helps in this respect. The survey shows good

control over safety management systems exists and employees follow organisational guidelines. Therefore, we conclude that monitoring ability is good in the KSA process industry.

(4) Anticipation: this ability scores low in the data, where safety systems in the industry is not equipped to deal with a changing environment. The survey shows lack of trust amongst employees in their organisations to deal with pressure (internally and externally). Many also have indicated the absence of planning for future threats. This, in fact could be related to time-orientation diminution where the field study revealed a short-term planning orientation. Although, accidents are fundamentally unforeseeable, anticipating risks and threats to safety prepares the organisation better to deal with mishap consequences. Our conclusion is that anticipation is low in the Saudi Arabian energy sector.

Table 5-2 Potential of resilience engineering in the Saudi Arabian Process industry.

Resilience Abilities	Summary of the findings
Learning	Experiences are shared on the operators' level, but organisational system is resistant to change.
Responding	Planned responses are inadequate to deal major accidents, however there is good adaptability to disturbances (unplanned responses are good).
Monitoring	Good control over work processes and ability to monitor organisational

	functions.
Anticipation	Local ability to recognise deviations in the organisational functions and changes in the environment.

The Resilience Engineering framework relies on the integration of these four abilities to distinguish between the four types of systems. So far, we have found evidence that process industry has the ability to monitor, respond, and learn. In our view, anticipation is not well integrated into the system. The assessment is that the energy sector can react appropriately to mishap events. Industrial complexes use efficient communication to assess the current situation and prevent a serious situation from escalating. For the case of mishap risk, the company is able to intervene to minimize undesirable outcomes. The existence of good monitoring and responding abilities helps industries to survive accidents and get back to a normal operational state. However, these two abilities are used passively, where reactions are not well planned. Such an approach to safety will sooner or later lead to major accidents where the organisation may not be able to maintain its existence. The learning ability is used in the process industry to improve the way they monitor their systems and react to events. Experiences are shared between employees, and safety meetings emphasise evaluating mistakes and spread awareness about how to avoid them. Nevertheless, this knowledge is not used to build early intervention mechanisms. The weakness of the anticipating ability limits the decisions available to reactionary measures and procedures (a fire fighting approach). Risks can be dealt with through mitigation, transfer, avoidance, and acceptance. Without anticipation decisions are limited to either avoiding the risk or accepting them. Early intervention and forecasting changes allow the decision maker to mitigate the threats before they disrupt the operational mode. We note that organisations in the process sector are unaware of changes in the environment, which place the system at greater risk of mishaps.

Bearing in mind the former assessment, the Saudi Arabian process industry is of the second type. Figure 5.1 illustrates resilience types in the Saudi Arabian Process industry. Such a system can react appropriately when something happens, not least if it is something unexpected. Reactions to previous disturbances are used to learn how to improve the way to monitor and react. The data supports this conclusion, where we extracted the main three factors influencing resilience. Efficient communication and information availability contribute the most to resilience abilities within the system. These two factors contribute the most to organisational monitoring, learning, and responding abilities; whereas the lack of preparedness have a negative impact on resilience. This kind of resilience is casual and not sustained. Saudi Arabia seems to have causal resilience; where employees appear to have resilient traits with lack of systematic organizational control. In addition, learning from incidents and accidents has to be extended to make systematic changes to the safety system. In order to survive, organisations have to be able to be aware of changes and make plans to exploit, mitigate, or transfer them. Therefore, we recommend industries in KSA to be aware of deviations in the business environment and drifts of its own functions. Building a stronger anticipation ability in an essential skill to deal with stresses and manage them efficiently. Further recommendations will be presented in the conclusion chapter next where we will be discussing the system as a whole.

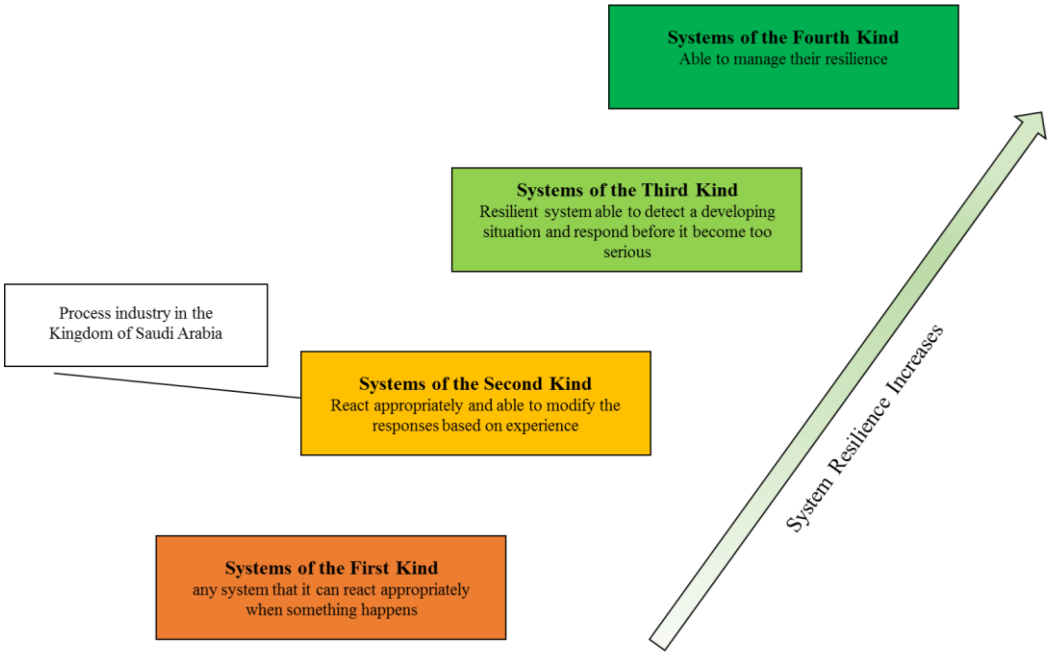

Figure 5-1 Resilience system type - showing position ofthe Saudi Arabian Process industry.

5.4 Comparison with other studies:

In this section, we will discuss the comparison with other studies on the influence of national culture on safety climate and resilience. First let us compare the cultural dimensions in KSA with other countries that will be discussed in this section. Chart 5.2 draws comparisons between cultural dimension indexes in KSA, Iran, US, UK, Japan, and China. Many studies have concluded the influence of national culture and organisational safety culture. Among these, Ralston *et. al.* (1997) have studied the impact of national culture on managerial work values [128]. The paper focuses on contrasting the underlying differences between Eastern and Western cultures especially regarding individualism index and openness-to-change. The authors argue that collectivist society could lead to poor performance. Therefore, countries that scores high on the individualism index, such as the US, will out preform countries with low scores such as Japan and China. Our findings from Saudi Arabia contradict this conclusion, where low individualism contributes the most to safety culture in the industry. However, this could be explained by looking at other findings of the paper [128]. Ralston et. al. looks into some sub-dimensional factors including security, which measures the motivational goal to maintain the safety, harmony, and stability of a society or relationship, and of self. The results from the security factor indicated that collectivist societies (China and Japan) scores significantly higher than individualistic culture (US). Our study actually supports these findings since we investigated the impact of Saudi national culture on organisational safety climate.

A more recent study that investigated the role of national culture in determining safety performance was conducted by Mearns & Yule (2009) [129]. The paper compares power distance, individualism, and masculinity in the oil and gas industries for different countries including the UK. The authors concluded that masculinity and power distance is a significant predictor of risk taking behaviour. The study also emphasized the role of top management commitment in influencing the adoption of safer behaviours. Evidence from our study supports the significance of power distance as a predictor of safety performance. However limited evidence in our data supports the role of masculinity. This could be explained by the higher masculinity score of the UK when compared with KSA. The difference in the power distance indexes could also explain the observation on the subject of management commitment. Mearns & Yule noted that workers in the UK (score 35 in power distance index) perceived management commitment to be low; whereas in our study we note that worker perceived high management commitment associated with high power distance in KSA (score 95). This might support the Mearns & Yule view that management commitment is more important than the power distance index.

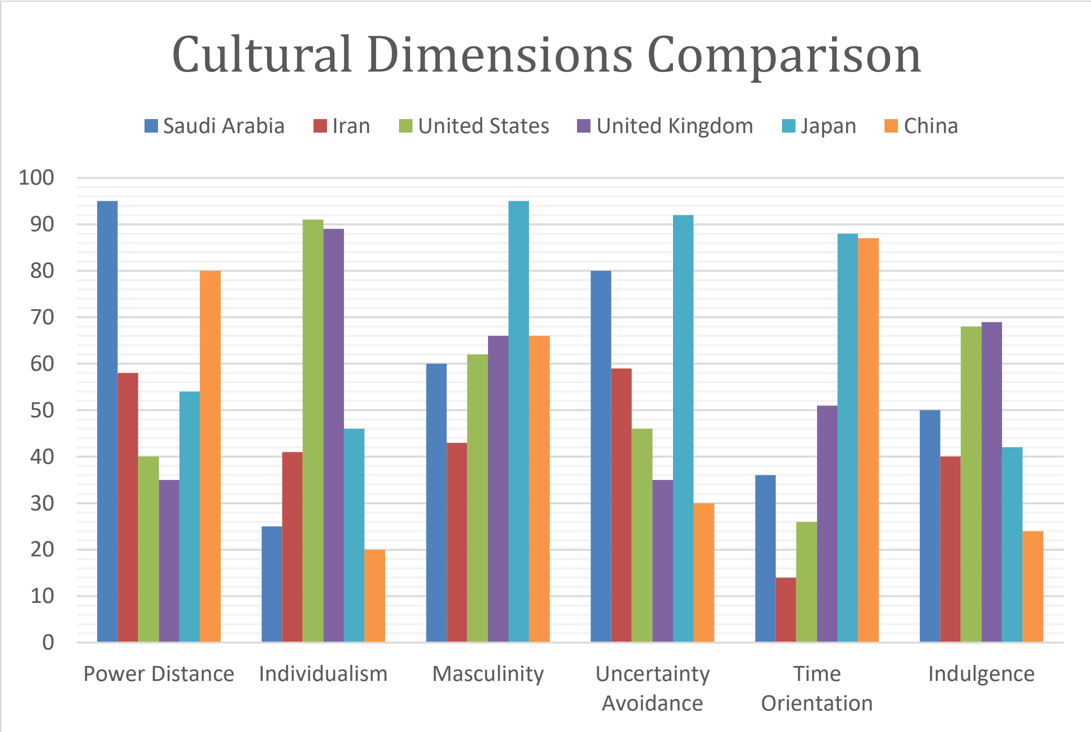

Figure 5-2 Cultural dimensions comparison between Saudi Arabia, Iran, US, UK, Japan, and China (The Hofsted Center, 2016).

On the topic of resilience abilities in different cultures, fewer studies have been conducted in different industries. Here we point to Jeffcott *et al* (2006), where flexibility, learning, and commitment were investigated in the UK railway companies [130]. The study noted the role of centralisation of decision making in contradicting the creation of rigid processes within organisations. In the UK railway example the study points to the effect of centralised management in discouraging frontline operators in participating efficiently in safe culture. In our study (in KSA) we found that centralised decision-making does not necessarily lead to less flexibility. We find that management commitment to safety plays a major role in creating a flexible safety culture. Therefore, when looking at Jeffcott *et al.* (2006) assessment of top management commitment to safety, senior managers in the UK were more committed to production than safety. This supports the conclusion of the existence of a correlation between top management commitment to safety and the creation of a good safety culture and resilience. The difference between them could be explained by different scores of national cultural indexes between the two countries. In our study the management commitment to safety was linked to high power distance, average masculinity, and low individualism; where the UK has a low power distance and high masculinity and individualism. In KSA, the collectivism has contributed the most to the top management commitment to safety; therefore, managers in the UK could be less committed as a result of high individualism. Jeffcott *el al.* (2006) have highlighted employees' feeling of lack of engagement and support by their line managers. "line managers were distracted by concerns for their own personal accountability, more so than had been the case under BR" [130]. In addition, the authors have noted "poor communication and trust in the subordinate-supervisor relationship". Contrary to common belief, this evidence indicates the positive role of collectivism in creating a resilient system.

On the topic of learning ability, the UK railway companies seem to have an advantage over the KSA process industry. The UK companies have mechanisms to ensure systematic efficient learning (e.g. anemones reporting system); whereas in KSA, safety concerns are discussed in random meetings and mainly after mishap events. The learning ability is somewhat hindered by the process industry in KSA; however, this could be understood since the history of industrial development in the country is relatively new, when compared with the UK. Moving a culture closer to KSA, Shirali *et al.* (2012) have studied the challenges in building resilience engineering in the Iranian chemical plant [131]. The study supports several findings from our data. First, the general conclusion that safety management strategies (in Iran as in KSA) are based on a static and linear approach. The second similarity is regarding the lack of anticipation ability in both countries. Other points of agreement include the use of outdated safety procedures and manuals, and the role of religion. The main difference between our study and Shirali *et al.* (2012) seems to be the management attitude when it comes to sacrificing safety for production. Shirali *et al.* (2012) noted that managers of chemical plant always favour production over safety. “Production is always a winner because some of the plant managers believe that safety is a big barrier against progress for production goals” [131]. In our study, we have evidence supporting the commitment by managers to the concept of ‘safety always comes first’. However, in Shirali *et al.* (2012) managers seem to neglect that concept in reality under the influence of required production goals. In general, both studies (in KSA and Iran) agree on the existence of resilience abilities in both countries with expiation of the foresight and anticipation ability.

Since there are many similarities between the Saudi safety culture and neighbouring countries, how do our findings compere to other studies in the Kingdom? Most of the studies on safety culture in KSA focuses on the construction industry. Al Haadir and Panuwatwanich have the critical success factors for safety program implementation among construction companies in Saudi Arabia [10]. The study conclusions suggested seven critical factors that can account for 80% of the successful implementation of safety programs including management support, clear and reasonable objectives, teamwork, and effective enforcement. Some of these factors could relate to our awareness and preparedness (such as clear objectives) or control (such as effective enforcement). The long list of the study factors (15 factors) include communication, which is emphasised in this study. Al Haadir and Panuwatwanich also agree on the relatively low assessment of overall safety in KSA. In a different study, Jannadi and

Bu-Khamsin (2002) have investigated safety factors considered by industrial contractors in KSA [9]. These factors include: management involvement, personal protective equipment, emergency/disaster planning & preparation as the most important main factors influencing the industrial construction contractor safety performance. Our study has also emphasised the role of management commitment (involvement) and the importance of building the anticipation ability in order to prepare and plan for future events. Our results seem to have a lot in common with other studies from KSA, however our findings cannot be generalised to other sectors in the Kingdom. I believe that different sectors have enough differences that they should be manifested in different safety culture.

6 Chapter Six: Conclusions

Summary:

The safety climate in KSA is characterised by high power distance and uncertainty avoidance, above the average masculinity, and low individualism. The collectivism is the most influential dimension to safety culture in the process industry there. The other dimensions have a negative impact on safety culture. In the kingdom, top management commitment to safety moderates the power distance effect, where high commitment can contribute positively to the safety culture. Regarding resilience, the process industry is of the second type of the resilient system. The industry has good monitoring and responding abilities; however, the learning ability needs improvement. It is also necessary to build the ability to anticipate risks and plan for the long term. The main contributing factors to resilience are effective communication, information availability, control over work tasks, and dealing with external pressure. In KSA, there are good communication channels and control over workflow; however, information about safety is unsuitable to deal with disasters. Companies working in the process industry are unaware of changes in the environment and unable to foresee drifting of its own functions. Evidence was found to link national culture to the potential of resilience. Effective communications and collectivism plays a constructive role in building resilience. Therefore, the general conclusions could be summarised into the following points:

- **Influence of distinctive patterns of the collective value systems in different countries on organisational safety culture.**
- **National culture influences individual behaviour towards safety.**
- **Collectivism has a positive effect on safety culture and safety performance.**

- **Management commitment has influence on safety culture and system resilience.**

- **Effective communication, information availability, control over work tasks, and dealing with external pressure are the main contributing factors to resilience in the KSA process industry.**

- **Process industry in the KSA is characterised with resilience of the second type where there is good ability to respond and monitor but low ability to learn or anticipate.**

6.1 Introduction:

This research started by presenting the development of safety approaches. In the early stages, industrial processes were simple and people used common sense to avoid accidents. The early attempts to build safety mechanisms relied on investigating the causes of accidents and then taking preventive actions against its reoccurrence. The domino model (by Heinrich, 1931) is a prime example for this approach [3]. Such an approach emphasizes robust control over previous causes of mishaps to ensure a safer future. As the industrial revolution emerged, industrial systems grew to become more sophisticated. New industries with heavy machinery to improve production efficiency led to an increased number of accidents. The simple linear approach to safety has proven to be impractical in such contexts. Business interests in increasing productivity led to the development of management science including safety management. The paradigm of safety had to shift from being passive to become proactive. With this shift, researchers started to redefine safety and continue to develop new tools to help organisations to minimise the risks of mishaps. Many tools were devolved to accommodate the evolution of industrial systems. Companies started to identify risks beforehand and devote resources to mitigate them. Safety started to become part of the organisational management system and the quality of the products.

Studies have identified three levels of safety which are: personal, process (engineering), and organisational. The majority of companies were fixated on tackling the personal (individual human error) while scientists have emphasised the contribution of process and social aspects of organisations. Building on that, many studies were conducted to understand the nature of accidents in complex systems. During that time, researchers were puzzled by the inevitability of accidents in sociotechnical systems. Complex systems appear to have non-linear nature that links micro elements with macro changes; which cannot be understood by using a linear approach. Complexity beyond a certain level cannot be explained or controlled by upward causation. Qualitative causality can help in understanding the outcomes of an accident; however, fail to disclose correlations and interactions of a system as a whole. It was clear that complex industrial systems count on the interactions between technical, human, social, organisational, and environmental components. Recent efforts have resulted in introducing new ways of thinking about safety. However, these attempts still lack maturity on a comprehensive theoretical basis.

The BP Gulf of Mexico event is an illustration of the failure of traditional safety management systems. It also indicated major weaknesses of the linear approach in general. Investigations of previous accidents appear to point at the same factors over and over again. This was obvious when comparing accident reports of the Macondo blowout in 2010 with the five-years-earlier explosion at Texas City. Investigators pointed at systematic failures of the safety management system, poor judgment, inadequate enforcement of procedures, and inadequate adjustment. All these factors are results of inadequate control of the system. Since many mishaps have happened to numerous other organizations across various industries that uses the casual approach (e.g. Exxon Valdez oil spill (1989) or Fukushima nuclear accidents (2011)), this points to the failure of the linear approach. The fundamental inadequacy of the way these companies implemented the casual model or the casual approach itself reveals the need for new ways of thinking about accidents.

In conclusion, we still believe that not all accidents are preventable; however, accident models help us in preventing them to a large extent. The decreasing numbers of fatal disasters is evidence of the usefulness of safety science. Accident models provide the following advantages:

- Understanding accident phenomena more profoundly.
- Avoiding preventable accidents to a large extent.
- Equip us better to deal with risks, stresses, and undesirable outcomes.

6.2 Resilience Engineering:

Over the last decade, accident modelling starts to find theoretical grounds using system theory. The systematic approach to accident modelling is a promising method with which to view the phenomena. The strengths of this approach being derived from shifting the focus towards the system as a whole. Understanding the organisation as an open system with dynamic interactions is a more appropriate approach in describing sociotechnical environments. Industrial facilities in a modern world are very complex and cannot be defined in terms of their component parts only. The systematic approach goes beyond the linear approach to accommodate the non-linear, non-static nature of accident causation. It broadens the horizon to include processes, interactions within an organisation, and exchanges with the environment. Although some have criticised this approach for being too complex; a proper level of analysis is required to overcome the growing complexity of industrial systems. Another criticism to the systematic approach relates to the practicality of these models. The tools used in most industrial sectors to control and measure safety were developed based on the Heinrich sequential model of accidents. Multi-linear tools have proven to be suitable to some extent in specific situations. The capacity of these tools, however, to describe and accommodate the complexity of real life is very limited. We recognise that systematic tools and frameworks are still underdeveloped. However, new frameworks started to emerge in order to address the complexity and practicality of systematic accident modelling.

One of the promising frameworks that has been developed recently is Resilience engineering (RE). This framework shifts the focus from the individual level to the process engineering aspect of safety. Resilience engineering views organizations as non-linear dynamic systems. Accidents are viewed as emergent properties of a system; hence, it is difficult to foresee it. This approach redefines safety as accidents that did not occur and acknowledge the fact that different parties may have a different view of risks. The essence of resilience is to use the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress. Therefore, breaking the pattern of thinking of safety as an unchanging state and paying more attention to how factors interact within a complex system is central to RE. The core concept of resilience is to adapt to changes and incorporate the ability to recover from mishaps quickly to a normal state of operation. This helps in creating a safer working environment, at the same time keeping production rate at acceptable levels. In order to be resilient, a system or an organisation must have the following four qualities:

- The ability to respond to regular and irregular threats in a robust, yet flexible manner.
- The ability to monitor what is going on, including its own performance.
- The ability to anticipate risks (threats events) and opportunities.
- The ability to learn from experience.

The Resilience engineering framework introduces a different set of principles and instruments to accident modelling. The breadth-first principle, for instance, provides an understanding of the everyday functioning of a system. It helps in developing a balanced level of analysis that captures the essence of the system and all its functions. The Functional Resonance Analysis Method (FRAM) is a risk assessment tool offering a simple representation of complex organisational functions. It helps in assessing the variability of multiple functions of the system that combine and interact in unexpected ways. In addition, Resilience Assessment Grid (RAG) is a practical tool to be used by managers to check resilient performance at the organisational level. It provides visual representation of the four basic abilities potentials. Tools under this framework continue to evolve to attend to various industrial sector requirements.

The broad-spectrum of resilience engineering is one of the main strength aspects of this framework; however, it continues to evolve as a standalone concept separate from safety. Although it was originated to deal with safety, resilience concepts appear to have more to do with organisational performance in general. Risks can have positive or negative outcomes; therefore, threats and opportunities are viewed as two sides of a coin. The benefits of assessing hazards are easily extended to evaluate opportunities. Keeping the system in a dynamic equilibrium improves performance in general including the safety of the system. From a safety point of view, resilience engineering is a promising framework because it:

- Takes a holistic view of the system.
- Deals with the nonlinear dynamics of accidents.
- Deals with various aspects of organisations (e.g. social, technical, and processes).
- Increases organisational safety performance and resumes the normal state of operations after disturbances.
- Monitors safety and observes deviation of organisational functions.

For these reasons, we find resilience concepts are of great benefit to the safety of the process industry and the energy sector. The safety of industrial complexes in KSA is of particular interest, since the history of the industries there are less than a decade old. Companies appear to commit to safety passed on a desire to avoid risk of accidents without governmental guidelines regarding health and safety. This makes KSA an interesting case to test and validate the resilience engineering framework. The findings of this study will provide a starting point for future work across industry and give insight into safety climate and industrial safety in the kingdom. Safety professionals and managers could make use of this study to better understand safety culture in the kingdom and use its organisational features to improve performance.

6.3 Safety in the Kingdom of Saudi Arabia:

The development of safety practices in KSA industries makes it an interesting case to assess safety. The energy sector is the backbone of the Saudi economy. The Kingdom possesses a quarter of the world's proven oil reserves, and is the world's largest producer and exporter of oil. The country's estimated oil reserves are more than 260 billion barrels. Most are located in the Eastern Province, including the largest onshore field in Ghawar and the largest offshore field at Safaniya in the Arabian Gulf. Saudi refineries produce around 8 million barrels of oil per day, and there are plans to increase production to around 12 million barrels per day. Saudi Arabia is also developing its additional energy resources – natural gas that once were flared off from oil wells, it is now collected and used, and the Kingdom has become a producer of refined oil products and petrochemicals such as kerosene, diesel oil, and gasoline. Since the 50's, many industries started to thrive in support of the oil and gas industry. We focus in this study on these supporting industries including refineries, petrochemicals, manufacturing, and the like. On the contrary to the oil industry, the supporting industries were developed and manged by the private sector. Due to the absence of national industries (until recently), coherent legislation governing safe practices are still unavailable. Governmental companies were started by international organisations with an established safety culture and standards. After nationalising these companies, they built on these practices their policies regarding health and safety codes of practise. Among these policies is choosing contractors with a significant commitment to safety standards. The development of supporting industries in KSA is quite different from other sectors in the country (e.g. construction). Therefore, the assessment of safety in the process industry makes a curious case to study.

Previous studies on the application of RE includes nuclear power plant and electricity distribution, aviation and the chemical industry. Regarding major hazard process industries, a few studies were conducted on the oil and gas industry, refining plant, and offshore helicopter transportation system. This study is focused on assessing the potential of RE in the energy sector in a different cultural context. It moderates RE framework to establish system based indicators specific to the process industry. It provides an understanding of resilience by analysing the dynamics by which cultural factors influence organisational safety. These main factors will be extracted and could be used by professionals to improve safety. In addition, this is the first study on RE in Saudi Arabia; therefore, it adds to the body of knowledge on resilience engineering and safety in Saudi Arabia. The main question in this paper is: what are the main contributing factors to safety (and resilience) in the process industry in KSA? We choose to conduct the study in KSA because it is the largest producer and exporter of oil around the world. In addition, since the majority of the studies on resilience has been conducted in a Western culture, testing RE concepts in different culture could provide insights into cross cultural application of the framework. In general, this research can support the efforts of adopting RE concepts in the Middle East and help in reducing occupational injuries in the process industries.

In order to assess the safety climate in the process industry in Saudi Arabia, this study uses qualitative methods for different purposes. In the first part of the study, qualitative methods were used to gain background knowledge and investigate some aspects of the problem. Literature review, informal interview, and on-site observation were essential to design the experiment. All former methods were used as an exploratory and explanatory means. The literature review revealed a gap of knowledge regarding the safety climate in the kingdom. Previous studies on KSA organisational safety focused on construction, manufacturing, and industrial contractors; none of which discussed accident models. These studies were mainly conducted using a linear view of safety where accident causes were identified. Furthermore, the dynamic by which cultural diminution influences safety practices were not explored before. Therefore, the first part of this study explored the safety climate in KSA and analysed the national culture influence on organisational safety.

The analysis revealed interesting relationships between cultural dimensions and organisational safety. According to Hofstede's cultural dimension model, Saudi Arabia scores high on power distance, uncertainty avoidance, and collectivism dimensions. The country also scores average regarding indulgence and masculinity dimensions. Since Hofstede's model, many cross-cultural studies have supported the influence of national culture on safety. Our analysis supports the findings of Haukelid (2008) of the existence of associations between national culture and safety [59]. The field work revealed an inverse relationship between organisational safety culture, scores of power distance, and masculinity dimensions. The effect of power distance appears to be moderated by top management commitment to achieve high standards of safety. In general, the higher the power distance the harder it is for employees to engage constructively in improving safety. Masculinity also encourages risk taking behaviour where safety standards could be compromised in favour of achieving task goals. On the positive side, there is positive correlation between organisational safety culture and the collectivism score. The social support and good communication between group members creates a healthy working environment. Employees feel comfortable discussing workplace risks with managers and have co-workers support when faced with difficulty. Regarding uncertainty avoidance, the field work did not support the hypotheses of correlation between this dimension and the safety culture in the organisation. Although a high uncertainty avoidance score can result in rigidity of the system, our findings regarding safety aspects indicated flexibility of employees (managers and operators) to alleviate mishap risks. Overall, our findings sustain the existence of correlation between the Saudi national culture and safety culture in the process industry. Based on these findings, we predict the existence of correlation between national culture and resilience at organisations. Therefore, the second part of the study was designed to measure the potential of resilience in the Saudi process industry and extract the main contributing factors in this context. Resilience abilities and the main contributing factors are then analysed taking account of the effects of national culture. **The general conclusions about the influence of national culture on organisational safety culture can be summarised as follows:**

- **Evidence supporting the influence of distinctive patterns of the collective value systems in different countries on organisational safety culture.**
- **National Culture influences individual behaviour towards safety.**
- **Collectivism, contrary to the common believe, has positive effect on safety culture and safety performance.**
- **Management commitment to safety has greater influence than expected on safety culture and system resilience.**

6.4 Potential of resilience in the process industry:

In order to assess the potential of resilience a quantitative method in the form of a survey was used. The questionnaire targeted employees and managers working in petrochemical, energy, process, extraction, and utility sectors. The survey was developed based on Hollnagel et al. (2011) to explore 22 factors of interest to improve safety [19]. The study uses a scale of 6 to measure participant attitude towards resilience factors within their companies. The majority of responses were collected online, and hard copies were distributed and collected personally. Factor analysis (FA), was used as an exploratory and confirmatory quantitative tool. The Principle Component Analysis (PCA) technique helped in identifying core factors contributing to safety and in explaining the underlying trends between the 22 factors of resilience. The result of the analysis was then compared with findings from other studies from the industry.

Initially, 320 surveys were sent out targeting chemical plant, energy companies, and organisations working in the extraction of oil and gas. Respondents were mainly males working as managers, engineers, and front-end operators. A total of 119 responses were considered to be legitimate for this study. The KMO measure indicated a mediocre adequacy for sample size and null hypothesis proved the existence of correlation among the variables (factors). The initial results established the seven-factors solution that explains 67% of the total variance within the data set. The seven contribution factors are:

- Time to reflect on planning.
- Management support.
- Communicating new information and changes to plans.
- Ability to adapt to unexpected situations.
- Ability to communicate efficiently.
- Risk assessment ability.
- Readiness for future events.

Further analyses were conducted to determine appropriate number of components to extract. The further study showed an optimum four components solution that explains 65.6% of the total variance within the data set. The optimization process underlines the importance of the following contributing factors:

- Efficient communication.

- Information availability.
- Control over work tasks.
- Ability to deal with external pressure.

The highlight from the data collected could be summarised as follows: Over three-quarters (78%) of the responders can communicate their plans efficiently with their colleges. Communication contributes to resilience by offering a fast and reliable channel to change plans and discuss issues as they arise. Another factor that had the highest agreement among respondents (but low loading weight) is employees' ability to anticipate problems before they occur. The results show an overwhelming majority, of around 85%, agree on their ability to detect planning failure. Subsequently, the information availability is a crucial aspect of resilience. Our data shows that around 68% of the respondents appear to believe they have all the information they need to carry out their tasks. Regarding control and time to finish work tasks, 66% are managing to finish whatever plans they started. On the down side, employers in KSA seem to be less prepared for unexpected external pressure. This was reflected in the data with 75% of responses having doubts about their organization's ability to deal with external pressure. One last significant finding is regarding employees' level of confidence in the future occurrence of mishaps, 38.7% feel that it could happen soon.

These four factors have had the most correlation from the data collected. Efficient communication has the most loading factors; which is in agreement with our field work. During the observation and interviewing, this aspect was observable in the form of informal communication between employees and a sense of group identity. This factor relates directly to the organisational ability to monitor and respond. In addition, it improves the learning ability through sharing knowledge and experiences. We find this factor highly correlated with the low index of individualism in the country. This is further support of our hypothesis of the influence of national culture on organisational resilience. Another factor that supports the evidence for national culture influence on resilience is control over tasks. From a cultural point of view this factor relates to power distance and uncertainty avoidance. Theoretically, we hypothesised that control over work must be stronger since in high uncertainty avoidance societies the culture is to maintain a high degree of control to avoid ambiguity. The data reflects this point, where respondents prefer to have more information about task goals and risk sources. This leads us to the information availability factor where our data contradicts the finding from the observation stage. Safety instructions were outdated and many managers know little about safety regulations. Employees' knowledge of work place threats could have been through safety training; however, we found that training courses were not of the required standards. The Information availability factor relates to the ability to learn and anticipate. The findings point to a lack of long term planning or awareness of changes in the environment. The low quality of information available revealed a lower anticipating ability in the process industries.

Although the results indicated resilient behaviour among participants, the informal interview and the on-site observation revealed an unawareness of the resilience concept or new approaches to safety. Most of the safety practices are outdated and support the linear tactics to safety. Likewise, safety management systems and manuals seemed to be out of use. During the informal interview, many employees criticised the safety manuals and the lack of investment in new technologies. Employees appear to have concerns about their safety in the workplace; however, it was not reflected into their practices. Short-cuts are common; and informal communication seemed to be the preferred channel to interact and cooperate. Change in plans and work related issues are communicated informally (besides the formal channels). When the study was piloted, there was a need to add a “not applicable” option to some of the resilience/safety factors. In addition, the pilot study reflected the sensitivity to translating questions into the native language (Arabic) of the respondents. The informal interviews and the pilot study helped in acquiring background knowledge, overall safety claimant, and feedback to improve the experimental design.

The general conclusion of this study indicates the existence of resilience behaviour in the Saudi Arabian energy sector. The resilience of the system is of the second type; where the system is able to monitor, respond, and learn to a certain extent. The process industry in the Kingdom needs to improve its ability to learn by creating mechanisms to integrate knowledge from past experiences to modify codes of practice on a systematic level and modify long term plans accordingly. By doing so, resilience of the third type could be achieved. In addition, there is a substantial need to engineer the anticipation ability into process companies. The linear approach to safety that disregards deviations in its own functions and interactions with changing environments is not sufficient to manage safety properly. This ability could be engineered through acquiring awareness of changes and plan in advance to exploit opportunities or mitigate threats. On the question of “What are the main contributing factors that help industrial systems to restore normal state operation in KSA?” The analysis revealed that efficient communication, information availability, ability to deal with external pressure, and control over work tasks as the main contributing factors of RE in the KSA process industry.

6.5 Contribution to knowledge:

This research contributes to knowledge by understanding the way national culture affects both resilience and safety culture in industrial complexes. It furthers the knowledge about safety climate and organisational safety in the KSA. In addition, it links national culture dimensions to the potential of resilience in organisations; which means that resilience varies across-cultures. The four main factors influencing resilience abilities were identified and could be used by professionals in the energy sector to engineer resilient systems. The systematic approach to model an accident is relatively new but it has great potential for improving safety in the industry.

The study concludes that national culture is an essential part of resilience of industrial systems and safety in general. The findings of this research support the Haukelid (2008) view that organisational cultures outdo classic safety control tools. Strong culture directs the attention to basic shared values and common goals; which could mature into an innate regulation mechanism. Only organisations that genuinely believe that its employees are the greatest resource can develop such capacity. This was reflected in our study by a strong correlation between top management commitment to safety and resilience in the process industry. However, sometimes commitment to safety contradicts businesses core values of delivering the maximum profit to its shareholders. The paradox of trading off safety for profits appears to be at the centre of discussion once again. In addition, many have argued that culture creation is a bottom up process; therefore, only members within the organisation can create it. Top management can influence this culture but not manage it. Furthermore, many reports indicated a mistrust between industries and labour unions, which widens the gap and urges for greater efforts to develop a safe culture. Resilience engineering is a useful tool to complement existing safety systems within organisations. It shifts the attention towards process engineering safety instead of individual human error.

Reason (1998) stated "accident models can only be judged by the extent to which their application enhances system safety". The linear approach still pushes for more complex systems by incorporating additional defence lines and factors into the organisational safety structure. This has made these models difficult to comprehend and work with. However, it was the only way to go; therefore, these models (on the theory level) and regulation (on legislation level) has become, in a way, a barrier to getting the job done. The employee finds them redundant therefore they tend to find a better way to carry out the tasks. The management sees them as event reports and more paper work to get done. The supervisors look at them as standard checklists that need to be followed literally. On the other hand, resilience engineering offers a new way of thinking about accidents, however it still lacks a coherent theoretical basis. The concept focuses more on the process level safety; which is a shift from the individual level safety that is commonly implemented within the industry. In addition, the constructs of resilience are still vague, therefore measuring its potential is open to debate. On the plus side, resilience concepts rely heavily on system ability to adapt, but adaptability exists in different systems with different variations and up to a certain limit. Those limits are called safety margins. Safety margins seem to have a great impact on the system's ability to adapt to its environment. After ten years of developing the main framework, no conclusive evidence was found to support the framework ability to prevent mishap. Future work should study long term gains of engineering resilience into companies. Such study will provide conclusive evidence regarding the gains of using a resilience engineering framework.

This work adds to the knowledge on safety management in Saudi Arabia and resilience engineering literature in general. On a theoretical level, the resilience engineering concept could be defined as the margins of safety. The larger the margin the easier for an organisation to adapt and resume a normal state of operation after an accident. The main findings of this study modify the current framework of resilience engineering to a specific industry. Efficient communication, information availability, ability to deal with external pressure, and control over work tasks are the most relevant factors in the Saudi context. There are limited publications on the Saudi context, this work gives an insight into that culture and allows for further studies to be conducted. This is the first research assessing RE in KSA, the findings provide a starting point for further studies and applications in the Saudi context. In addition, it provides managers with an insight into the safety climate in the process industry.

6.6 Future work:

The findings indicated an influence of power distance on safety culture, however this dimension seems to be moderated by management commitment to safety. In fact, when comparing this result with other studies, we find greater evidence supporting the role of management commitment to safety in organisational safety and resilience. Therefore, future work should investigate how management commitment to safety (as separate concept/factor) influences resilience and safety culture. In addition, among the interesting findings of this study was the impact of collectivism on both system resilience and safety culture. Our findings implied the role of collectivism on improving communication and relationships between group members, as well as between line managers and operators. Other studies have hypothesised the negative impact of collectivism on safety culture due to high conformity, which leads to groupthink. However, we argue that collectivism could lead to higher participation of front line operators in decision making regarding safety. Therefore, further studies should explore the influence of individualism on risk-taking decisions in different cultures to understand the dynamics between individualism and safety. Furthermore, the comparison between the process industry and construction industry has revealed some differences regarding factors influencing safety performance and organisational culture. For this reason, more studies need to be conducted across-industries to understand how these factors change in various sectors. This will also help to obtain coherent understanding of the safety climate in the KSA.

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Appendices

Appendix A: Questionnaire Resilience in the planning of rail engineering work (Ferreira, Pedro N.P., 2011).

Questionnaire for the assessment of planning decision making processes and problem solving

This questionnaire looks at how people make decisions related to planning and the areas that affect them.

Thank you for your cooperation!

Route		Territory / Area	
Title		Years of planning experience	

Section 1: Generic assessment						
Mark how much you disagree or agree with the following statements	1 - Strongly disagree	2 - Disagree	3 - Slightly disagree	4 - Slightly agree	5 - Agree	6 - Strongly agree
I receive feedback on the outcome of my planning						
I have a clear picture of how my planning contributes to the building of an integrated national delivery plan						
I manage to finish whatever plans I start						
I have all the information I need to do my work						
I have the information necessary to deal with unexpected situations						
I have the information needed to detect potential planning failures						
I have enough time to do my planning thoroughly						
I have enough time to reflect on my planning						
I am encouraged to reflect on my planning						
I revise my planning whenever new information arises						
I take into account a balance between safety and efficiency in my planning decisions						
I can adjust my way of working according to external pressures						
I can solve problems even when pressured to deliver fast results						
I can solve problems even when faced with unexpected situations						
I feel in control of my work activities						
I assess the potential safety impacts for each of my planning decisions						
I can identify when my planning decisions are pushing the boundaries of safe performance						

I can detect failures or errors in my planning before they create problems						
I have the support of my manager to make decisions						
My management does not blame me for any poor outcome of my planning						
Because something has always gone well before, I feel confident that it will continue to go well in the future						
I can communicate my decisions promptly to those that rely on them						
Section 2: Assessment of specific issues previously identified as impacting on planning						
Mark how you feel the following factors influence your performance as a planner	1 - Not at all	2 - Very little	3 - Little	4 - Some	5 - Much	6 - Totally
The organisational division of planning units (NDS, NAU, II, IM…)						
The range of inputs (formats, type of information and timings) to the planning process						
Difficulties in obtaining accurate information						
Working with incomplete or inaccurate information						
Planning experience						
Geographical knowledge of the railways						
Having trustworthy work contacts within the planning organisation						
Informal flow of information by means of phone calls, e-mails						
Informal face-to-face discussion of issues						
Understanding the impact of planning decisions on delivery						

Appendix B: Resilience Engineering Survey (Translated to Arabic)

استبيان عن مرونة الشركة

عن الاستبيان:

هذا الاستبيان هو جزء من بحث علمي يهدف الى تحسين مستوى السلامة والامان في المؤسسات الصناعية. يتناول الاستبيان مستوى مرونة المؤسسة الادارية (Resilience Engineering) من منظور العاملين فيها. لمرونة المؤسسة دور هام في تهيئتها للتعامل مع الحوادث. ينقسم هذا الاستبيان الى ستة اجزاء، كل جزء يقيس اداء المؤسسة في احد نواحي المرنة الادارية. الرجاء تعبئة الاستبيان بأقرب رأي يمثل وجهة نظرك.

يستغرق اكمال هذا الاستبيان حوالي 10 دقائق.

معلومات شخصية:

المسمى الوظيفي *: ....

الفئة العمرية *: ○ 18-24 ○ 25-34 ○ 35-44 ○ 45-54 ○ 55 او أكثر

الاسم (اختياري): ....

الجنسية (اختياري): ....

عدد سنوات الخبرة (اختياري): ....

الدرجة العلمية: ....

الاستبيان:

التزام الإدارة:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
1. مديري يقدر مجهودي في العمل	○	○	○	○	○
2. احصل على التقدير من مديري امام زملائي في العمل	○	○	○	○	○
3. في رأيي، التقدير العلني يزيد من مكانة الموظف بين زملائه	○	○	○	○	○
4. الانتاجية تحتل الاولوية في نظر الادارة	○	○	○	○	○
5. في حال وجود خطر محتمل، استطيع التوقف عن العمل واحث زملائي على التوقف عن العمل	○	○	○	○	○
6. في حال وقوع حادث ما، الادارة تبحث عن الاشخاص المسؤولين عن الحاث لا عن اسباب الحادث	○	○	○	○	○
7. الادارة توفر وسائل سلامة كافية وتحاول تحسينها بشكل مستمر	○	○	○	○	○
8. مديري مدرك لنواحي الخطر التي قد تؤدي لتوقف الانتاج	○	○	○	○	○

9. مديري مهتم بتوجيهي للقيام بعملي بشكل سليم وامن	○	○	○	○	○

ادارة السلامة:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
10. اذا كان لدي (او احد زملائي) مخاوف تتعلق بالسلامة، استطيع مناقشتها بصراحة مع مديري	○	○	○	○	○
11. الادارة توفر وسائل للإبلاغ عن المشاكل المتعلقة بالسلامة	○	○	○	○	○
12. مديري يتقبل الاخبار السيئة بدون عصبية	○	○	○	○	○
13. الإدارة تشجع على ابتكار وسائل للتحسين مستوى السلامة	○	○	○	○	○
14. الادارة تستمع للموظفين وتشركهم في اتخاذ القرارات	○	○	○	○	○
15. عند وجود خطر محتمل، ينبغي التوقف عن العمل	○	○	○	○	○
16. في مسائل السلامة، الادارة تشرك الجميع الموظفين بدون تميز	○	○	○	○	○
17. الموظفين من مختلف الاقسام والمستويات يحظرون اجتماعات عن السلامة	○	○	○	○	○
18. روح الفريق والتعاون متوفر في القسم الذي اعمل به	○	○	○	○	○
19. السلامة جزء من تقييم ادائي	○	○	○	○	○
20. المعاملات الورقية تساعد في تحسين الاداء الخاص بالسلامة	○	○	○	○	○

المعرفة:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
21. ادرك العواقب المترتبة على فشلي في اتمام مهامي	○	○	○	○	○
22. عند وجود خلل ما في احد الاجهزة، يجب ان اتحدث مع المسؤولين عنه في الشركة	○	○	○	○	○
23. عند وجود خلل ما في احد الاجهزة، يجب تحليل اسباب الخلل ومناقشتها مع الاخرين في الشركة	○	○	○	○	○
24. في رأيي، مناقشة الاخطاء والمخاطر مع زملائي مهم	○	○	○	○	○
25. في حال حدوث مشكلة ما، يتم اتخاذ اجراءات لتلافي حدوث المشكلة في المستقبل	○	○	○	○	○
26. بشكل عام، اسباب الحوادث لا تعتمد على تاريخ الحوادث في الشركة	○	○	○	○	○
27. اعتقد ان زملائي يجتهدون في التعلم من اخطاءهم	○	○	○	○	○
28. لدى الشركة دورات (برامج) تدريبية تحث على الاعتماد على الذات في التعلم	○	○	○	○	○
29. يوجد لدى الشركة دورات (برامج) تدربيه مجدولة ومعلومة للمهتمين	○	○	○	○	○
30. عند التحاقي بالعل، تم تدريبي للقيام بهامي بشكل صحيح وامن	○	○	○	○	○
31. من خلال خبرتي، استطعت التعرف على طرق جديدة لتلافي حدوث الاخطاء في مكان عملي	○	○	○	○	○
32. كتيب التعليمات والارشادات قديم وغير ملائم للقيام بالأعمال بشكل سليم	○	○	○	○	○
33. استخدام كتيب التعليمات والارشادات غير ملزم في شركتي	○	○	○	○	○

34. تعليمات الامان تحدث بشكل دوري	○	○	○	○	○
35. الشركة لديها شخص مسؤول عن السلامة كجزء من وظيفته	○	○	○	○	○

الغموض:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
36. الادارة تتوقع مني القيام بأكثر من مهمه بنفس الوقت	○	○	○	○	○
37. المهام التي اقوم بها لها اكثر قد تتعارض في اهدافها	○	○	○	○	○
38. علي انجاز بعض المهام بدون شرح كافي عن كيفية القيام بها	○	○	○	○	○
39. السلامة مقدمة على الانتاج	○	○	○	○	○
40. لدي وقت كافي للقيام بمهامي	○	○	○	○	○
41. القيام بمهامي بشكل امن قد يزيد من تكلفة الانتاج	○	○	○	○	○
42. الموظفين في الشركة يحصلون على تدريب كافي عن السلامة	○	○	○	○	○
43. المس تأثير تدريبات السلامة على تصرفات زملائي	○	○	○	○	○
45. اعلم الطرق جيدة وامنه للقيا بمهامي	○	○	○	○	○
46. في حالات الطوارئ، يسهل اتباع ارشادات السلامة	○	○	○	○	○

47. انا على اطلاع جيد بما بمصادر الاخطار في مكان عملي	○	○	○	○	○

الاستعداد:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
48. ارشادات السلامة و تعليمات الادارة مناسبة ويمكن استخدامها في المستقبل	○	○	○	○	○
49. عقد اجتماعات و ورش عمل عن السلامة هو حل مناسب للاستعداد و تلافي الحوادث في المستقبل	○	○	○	○	○
50. افضل مناقشة مخاوفي المتعلقة بالسلامة مع زملائي والادارة	○	○	○	○	○
51. من المهم ان تحفز الادارة الموظفين على البحث عن مكامن الاخطار في المستقبل	○	○	○	○	○
52. من المهم وضع ميزانية محددة لتحسين مستوى السلامة و التعامل مع المشاكل المتوقعة ضمن هذا الاطار	○	○	○	○	○
53. دئما هناك احداث غير متوقعة تحدث في مكان عملي	○	○	○	○	○
54. وقوع حادث في مكان عملي متوقع بشكل كبير	○	○	○	○	○
55. الادارة تتعامل مع موضوع السلامة بجدية	○	○	○	○	○
56. الشركة تحتاج خطة شاملة للتعامل مع الحوادث المتوقعة في المستقبل	○	○	○	○	○

المرونة:	موافق بشدة	موافق	محايد	غير موافق	غير موافق بشدة
57. لدى الشركة موارد كافية للتعامل مع الاحداث غير المتوقعة بشكل فعَال	○	○	○	○	○

58. انا افضل التضحية بالإنتاج في سبيل القيام بمهامي بطريقة امنة	○	○	○	○	○
59. في حالات الطوارئ، يجب اخذ موافقة الادارة قبل القيام بعمل يضر بإنتاج الشركة	○	○	○	○	○
60. يوجد في الشركة ارشادات للتعامل مع تغير خطط الانتاج المفاجئة	○	○	○	○	○
61. لدي الشركة القدرة على التعامل مع الضغوطات (الداخلية والخارجية) بنجاح	○	○	○	○	○
62. بعد وقوع حادث ما (لا سمح الله)، لدى الشركة القدرة على العودة للاستقرار بشكل سريع	○	○	○	○	○

شكرا على مشاركتك في هذا الاستفتاء.

Appendix C: Seven Factors Solution Results

```
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Q19 Q20 Q21 Q22
  /MISSING PAIRWISE
  /ANALYSIS Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18
Q19 Q20 Q21 Q22
  /PRINT INITIAL CORRELATION KMO EXTRACTION ROTATION
  /FORMAT BLANK(.30)
  /PLOT EIGEN
  /CRITERIA FACTORS(7) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /METHOD=CORRELATION.
```

Factor Analysis

Notes

Output Created		06-APR-2016 17:43:22
Comments		
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	Split File	<none>
	N of Rows in Working Data File	122
Missing Value Handling	Definition of Missing	MISSING=EXCLUDE: User-defined missing values are treated as missing.
	Cases Used	PAIRWISE: Correlation coefficients for each pair of variables are based on all the cases with valid data for that pair. The factor analysis is based on these correlations.
Syntax		FACTOR /VARIABLES Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 /MISSING PAIRWISE /ANALYSIS Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 /PRINT INITIAL CORRELATION KMO EXTRACTION ROTATION /FORMAT BLANK(.30) /PLOT EIGEN /CRITERIA FACTORS(7) ITERATE(25) /EXTRACTION PC /CRITERIA ITERATE(25) /ROTATION VARIMAX /METHOD=CORRELATION.
Resources	Processor Time	00:00:00.94
	Elapsed Time	00:00:01.20
	Maximum Memory Required	58024 (56.664K) bytes

Correlation Matrix

		1	2	3	4	5	6
Correlation	1	1.000	.566	.312	.138	.180	.041
	2	.566	1.000	.083	.165	.337	-.011
	3	.312	.083	1.000	.466	.033	-.012
	4	.138	.165	.466	1.000	.019	.347
	5	.180	.337	.033	.019	1.000	.035
	6	.041	-.011	-.012	.347	.035	1.000
	7	.063	-.017	.095	.412	.029	.514
	8	.390	.218	.165	.201	.239	.388
	9	.013	.181	-.116	-.058	.137	-.046
	10	.138	-.070	.115	.004	-.053	.298
	11	.210	.073	-.110	.122	.211	.378
	12	.313	.211	.053	.229	.368	.234
	13	.169	.110	-.064	.188	.040	.381
	14	.166	.410	.058	.313	.100	.155
	15	.138	.089	.031	-.035	-.091	.032
	16	.278	.377	.146	.093	.155	.095
	17	.265	.206	.120	.172	.126	.214
	18	.132	.152	.350	.396	.050	.149
	19	.190	.125	-.104	.061	-.034	.180
	20	.143	.071	.179	.292	-.099	.489
	21	.260	.081	.006	.023	.032	.529
	22	.237	.262	.001	.018	.252	.355

Correlation Matrix

		7	8	9	10	11	12
Correlation	1	.063	.390	.013	.138	.210	.313
	2	-.017	.218	.181	-.070	.073	.211
	3	.095	.165	-.116	.115	-.110	.053
	4	.412	.201	-.058	.004	.122	.229
	5	.029	.239	.137	-.053	.211	.368
	6	.514	.388	-.046	.298	.378	.234
	7	1.000	.398	.027	.295	.379	.335
	8	.398	1.000	.128	.230	.324	.380
	9	.027	.128	1.000	.076	.216	.104
	10	.295	.230	.076	1.000	.333	.102
	11	.379	.324	.216	.333	1.000	.234
	12	.335	.380	.104	.102	.234	1.000
	13	.412	.385	.229	.336	.424	.365
	14	.171	.167	.221	.050	.210	.062
	15	.074	.029	.204	.212	.240	-.004
	16	.069	.140	.077	.100	.217	.124
	17	.310	.288	.106	.257	.278	.250
	18	.228	.270	-.042	.079	.190	.107
	19	.308	.138	.338	.228	.267	.026
	20	.520	.348	.125	.362	.226	.268
	21	.461	.347	-.068	.392	.171	.341
	22	.135	.384	.191	.096	.083	.131

Correlation Matrix

		13	14	15	16	17	18
Correlation	1	.169	.166	.138	.278	.265	.132
	2	.110	.410	.089	.377	.206	.152
	3	-.064	.058	.031	.146	.120	.350
	4	.188	.313	-.035	.093	.172	.396
	5	.040	.100	-.091	.155	.126	.050
	6	.381	.155	.032	.095	.214	.149
	7	.412	.171	.074	.069	.310	.228
	8	.385	.167	.029	.140	.288	.270
	9	.229	.221	.204	.077	.106	-.042
	10	.336	.050	.212	.100	.257	.079
	11	.424	.210	.240	.217	.278	.190
	12	.365	.062	-.004	.124	.250	.107
	13	1.000	.165	.223	.032	.461	.125
	14	.165	1.000	.017	.312	.232	.187
	15	.223	.017	1.000	.435	.173	-.026
	16	.032	.312	.435	1.000	.271	.247
	17	.461	.232	.173	.271	1.000	.113
	18	.125	.187	-.026	.247	.113	1.000
	19	.396	.278	.330	.102	.334	.042
	20	.511	.215	.092	.038	.333	.288
	21	.420	.048	.034	-.019	.251	.079
	22	.133	.243	.147	.334	.080	.201

Correlation Matrix

		19	20	21	22
Correlation	1	.190	.143	.260	.237
	2	.125	.071	.081	.262
	3	-.104	.179	.006	.001
	4	.061	.292	.023	.018
	5	-.034	-.099	.032	.252
	6	.180	.489	.529	.355
	7	.308	.520	.461	.135
	8	.138	.348	.347	.384
	9	.338	.125	-.068	.191
	10	.228	.362	.392	.096
	11	.267	.226	.171	.083
	12	.026	.268	.341	.131
	13	.396	.511	.420	.133
	14	.278	.215	.048	.243
	15	.330	.092	.034	.147
	16	.102	.038	-.019	.334
	17	.334	.333	.251	.080
	18	.042	.288	.079	.201
	19	1.000	.193	.041	.057
	20	.193	1.000	.517	.201
	21	.041	.517	1.000	.475
	22	.057	.201	.475	1.000

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.638
Bartlett's Test of Sphericity	Approx. Chi-Square	727.215
	df	231
	Sig.	.000

Communalities

	Initial	Extraction
1	1.000	.758
2	1.000	.742
3	1.000	.714
4	1.000	.754
5	1.000	.714
6	1.000	.692
7	1.000	.652
8	1.000	.525
9	1.000	.506
10	1.000	.523
11	1.000	.679
12	1.000	.637
13	1.000	.669
14	1.000	.687
15	1.000	.712
16	1.000	.748

17	1.000	.490
18	1.000	.548
19	1.000	.643
20	1.000	.671
21	1.000	.841
22	1.000	.825

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	5.247	23.849	23.849	5.247	23.849
2	2.281	10.370	34.219	2.281	10.370
3	1.994	9.063	43.282	1.994	9.063
4	1.629	7.407	50.689	1.629	7.407
5	1.320	6.000	56.689	1.320	6.000
6	1.211	5.504	62.193	1.211	5.504
7	1.046	4.753	66.945	1.046	4.753
8	.896	4.071	71.016		
9	.798	3.626	74.643		
10	.732	3.326	77.969		
11	.693	3.149	81.117		
12	.659	2.995	84.112		
13	.555	2.523	86.635		

14	.515	2.341	88.976		
15	.447	2.033	91.010		
16	.413	1.877	92.887		
17	.406	1.848	94.735		
18	.362	1.647	96.382		
19	.283	1.287	97.668		
20	.234	1.062	98.730		
21	.155	.703	99.433		
22	.125	.567	100.000		

Total Variance Explained

Component	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings		
	Cumulative %	Total	% of Variance	Cumulative %
1	23.849	3.861	17.548	17.548
2	34.219	2.138	9.719	27.267
3	43.282	1.908	8.675	35.942
4	50.689	1.824	8.292	44.234
5	56.689	1.763	8.014	52.248
6	62.193	1.680	7.638	59.886
7	66.945	1.553	7.059	66.945
8				
9				
10				
11				

12					
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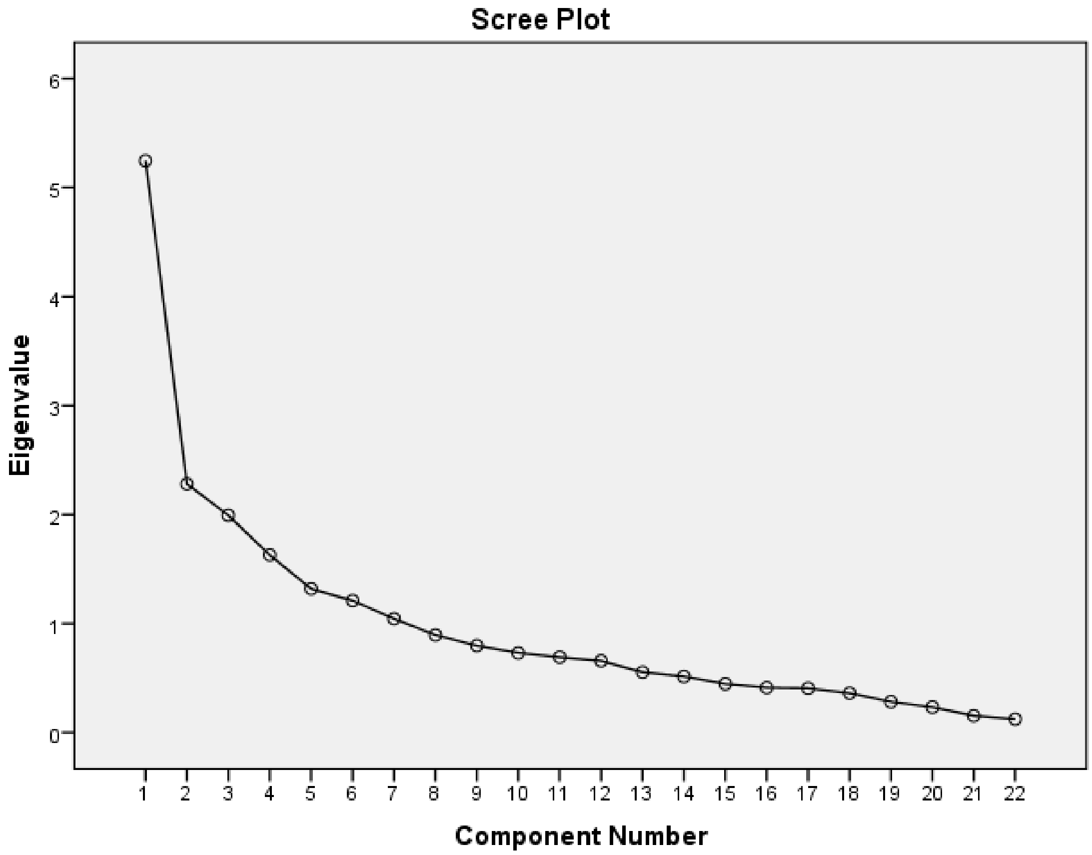
16					
17					
18					
19					
20					
21					
22					

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
1	.473	.479				-.417	
2	.370	.703					-.306
3			-.596	.384			
4	.423		-.547	.419			
5		.437		-.501	-.307		.343
6	.624	-.393				.315	
7	.661	-.381					
8	.657						

9			.533				
10	.465	-.330			.327		
11	.561						.489
12	.517			-.385		-.323	
13	.675						
14	.418	.359				.451	
15			.504	.335	.436		
16	.366	.546			.371		.328
17	.572					-.309	
18	.386		-.440	.301			
19	.420		.524	.344			
20	.666	-.355					
21	.597	-.362		-.418	.337		
22	.461			-.389	.396	.502	

Extraction Method: Principal Component Analysis.[a]

a. 7 components extracted.

Rotated Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
1				.813			
2			.363	.664			
3		.633	-.312	.418			
4		.817					
5					.801		
6	.675						.339
7	.691	.332					
8	.474				.403		
9			.668				
10	.588					.394	
11	.375				.488	.422	
12	.369				.644		
13	.694		.342				
14		.385	.649				.300
15						.807	
16						.674	.346
17	.428			.346			
18		.695					
19	.309		.654				
20	.744						
21	.763						.407

22							.852

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 10 iterations.

Component Transformation Matrix

Component	1	2	3	4	5	6	7
1	.741	.317	.289	.274	.306	.234	.210
2	-.638	.209	.239	.563	.276	.204	.242
3	-.005	-.666	.573	-.122	-.020	.454	-.081
4	-.079	.559	.263	-.093	-.538	.363	-.426
5	.081	-.154	-.509	.202	-.444	.530	.438
6	-.108	.201	.346	-.501	-.195	-.158	.717
7	-.142	.188	-.289	-.542	.552	.510	-.050

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Appendix D: Four Factors Solution Results

```
FACTOR
  /VARIABLES Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22
  /MISSING PAIRWISE
  /ANALYSIS Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22
  /PRINT INITIAL CORRELATION KMO EXTRACTION ROTATION
  /FORMAT BLANK(.30)
  /PLOT EIGEN
  /CRITERIA FACTORS(4) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /METHOD=CORRELATION.
```

Factor Analysis

Notes

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Missing Value Handling	Definition of Missing	MISSING=EXCLUDE: User-defined missing values are treated as missing.
	Cases Used	PAIRWISE: Correlation coefficients for each pair of variables are based on all the cases with valid data for that pair. The factor analysis is based on these correlations.
Syntax		FACTOR /VARIABLES Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 /MISSING PAIRWISE /ANALYSIS Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 /PRINT INITIAL CORRELATION KMO EXTRACTION ROTATION /FORMAT BLANK(.30) /PLOT EIGEN /CRITERIA FACTORS(4) ITERATE(25) /EXTRACTION PC /CRITERIA ITERATE(25) /ROTATION VARIMAX /METHOD=CORRELATION.
Resources	Processor Time	00:00:00.20
	Elapsed Time	00:00:00.19
	Maximum Memory Required	58024 (56.664K) bytes

Correlation Matrix

		1	2	3	4	5	6
Correlation	1	1.000	.566	.312	.138	.180	.041
	2	.566	1.000	.083	.165	.337	-.011
	3	.312	.083	1.000	.466	.033	-.012
	4	.138	.165	.466	1.000	.019	.347
	5	.180	.337	.033	.019	1.000	.035
	6	.041	-.011	-.012	.347	.035	1.000
	7	.063	-.017	.095	.412	.029	.514
	8	.390	.218	.165	.201	.239	.388
	9	.013	.181	-.116	-.058	.137	-.046
	10	.138	-.070	.115	.004	-.053	.298
	11	.210	.073	-.110	.122	.211	.378
	12	.313	.211	.053	.229	.368	.234
	13	.169	.110	-.064	.188	.040	.381
	14	.166	.410	.058	.313	.100	.155
	15	.138	.089	.031	-.035	-.091	.032
	16	.278	.377	.146	.093	.155	.095
	17	.265	.206	.120	.172	.126	.214
	18	.132	.152	.350	.396	.050	.149
	19	.190	.125	-.104	.061	-.034	.180
	20	.143	.071	.179	.292	-.099	.489
	21	.260	.081	.006	.023	.032	.529
	22	.237	.262	.001	.018	.252	.355

Correlation Matrix

		7	8	9	10	11	12
Correlation	1	.063	.390	.013	.138	.210	.313
	2	-.017	.218	.181	-.070	.073	.211
	3	.095	.165	-.116	.115	-.110	.053
	4	.412	.201	-.058	.004	.122	.229
	5	.029	.239	.137	-.053	.211	.368
	6	.514	.388	-.046	.298	.378	.234
	7	1.000	.398	.027	.295	.379	.335
	8	.398	1.000	.128	.230	.324	.380
	9	.027	.128	1.000	.076	.216	.104
	10	.295	.230	.076	1.000	.333	.102
	11	.379	.324	.216	.333	1.000	.234
	12	.335	.380	.104	.102	.234	1.000
	13	.412	.385	.229	.336	.424	.365
	14	.171	.167	.221	.050	.210	.062
	15	.074	.029	.204	.212	.240	-.004
	16	.069	.140	.077	.100	.217	.124
	17	.310	.288	.106	.257	.278	.250
	18	.228	.270	-.042	.079	.190	.107
	19	.308	.138	.338	.228	.267	.026
	20	.520	.348	.125	.362	.226	.268
	21	.461	.347	-.068	.392	.171	.341
	22	.135	.384	.191	.096	.083	.131

Correlation Matrix

		13	14	15	16	17	18
Correlation	1	.169	.166	.138	.278	.265	.132
	2	.110	.410	.089	.377	.206	.152
	3	-.064	.058	.031	.146	.120	.350
	4	.188	.313	-.035	.093	.172	.396
	5	.040	.100	-.091	.155	.126	.050
	6	.381	.155	.032	.095	.214	.149
	7	.412	.171	.074	.069	.310	.228
	8	.385	.167	.029	.140	.288	.270
	9	.229	.221	.204	.077	.106	-.042
	10	.336	.050	.212	.100	.257	.079
	11	.424	.210	.240	.217	.278	.190
	12	.365	.062	-.004	.124	.250	.107
	13	1.000	.165	.223	.032	.461	.125
	14	.165	1.000	.017	.312	.232	.187
	15	.223	.017	1.000	.435	.173	-.026
	16	.032	.312	.435	1.000	.271	.247
	17	.461	.232	.173	.271	1.000	.113
	18	.125	.187	-.026	.247	.113	1.000
	19	.396	.278	.330	.102	.334	.042
	20	.511	.215	.092	.038	.333	.288
	21	.420	.048	.034	-.019	.251	.079

22	.133	.243	.147	.334	.080	.201

Correlation Matrix

		19	20	21	22
Correlation	1	.190	.143	.260	.237
	2	.125	.071	.081	.262
	3	-.104	.179	.006	.001
	4	.061	.292	.023	.018
	5	-.034	-.099	.032	.252
	6	.180	.489	.529	.355
	7	.308	.520	.461	.135
	8	.138	.348	.347	.384
	9	.338	.125	-.068	.191
	10	.228	.362	.392	.096
	11	.267	.226	.171	.083
	12	.026	.268	.341	.131
	13	.396	.511	.420	.133
	14	.278	.215	.048	.243
	15	.330	.092	.034	.147
	16	.102	.038	-.019	.334
	17	.334	.333	.251	.080
	18	.042	.288	.079	.201
	19	1.000	.193	.041	.057
	20	.193	1.000	.517	.201
	21	.041	.517	1.000	.475

22	.057	.201	.475	1.000

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.638
Bartlett's Test of Sphericity	Approx. Chi-Square	727.215
	df	231
	Sig.	.000

Communalities

	Initial	Extraction
1	1.000	.475
2	1.000	.646
3	1.000	.597
4	1.000	.658
5	1.000	.497
6	1.000	.574
7	1.000	.611
8	1.000	.519
9	1.000	.374
10	1.000	.365
11	1.000	.404
12	1.000	.438
13	1.000	.597
14	1.000	.363
15	1.000	.454

16	1.000	.488
17	1.000	.376
18	1.000	.459
19	1.000	.569
20	1.000	.601
21	1.000	.672
22	1.000	.414

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	5.247	23.849	23.849	5.247	23.849
2	2.281	10.370	34.219	2.281	10.370
3	1.994	9.063	43.282	1.994	9.063
4	1.629	7.407	50.689	1.629	7.407
5	1.320	6.000	56.689		
6	1.211	5.504	62.193		
7	1.046	4.753	66.945		
8	.896	4.071	71.016		
9	.798	3.626	74.643		
10	.732	3.326	77.969		
11	.693	3.149	81.117		
12	.659	2.995	84.112		
13	.555	2.523	86.635		

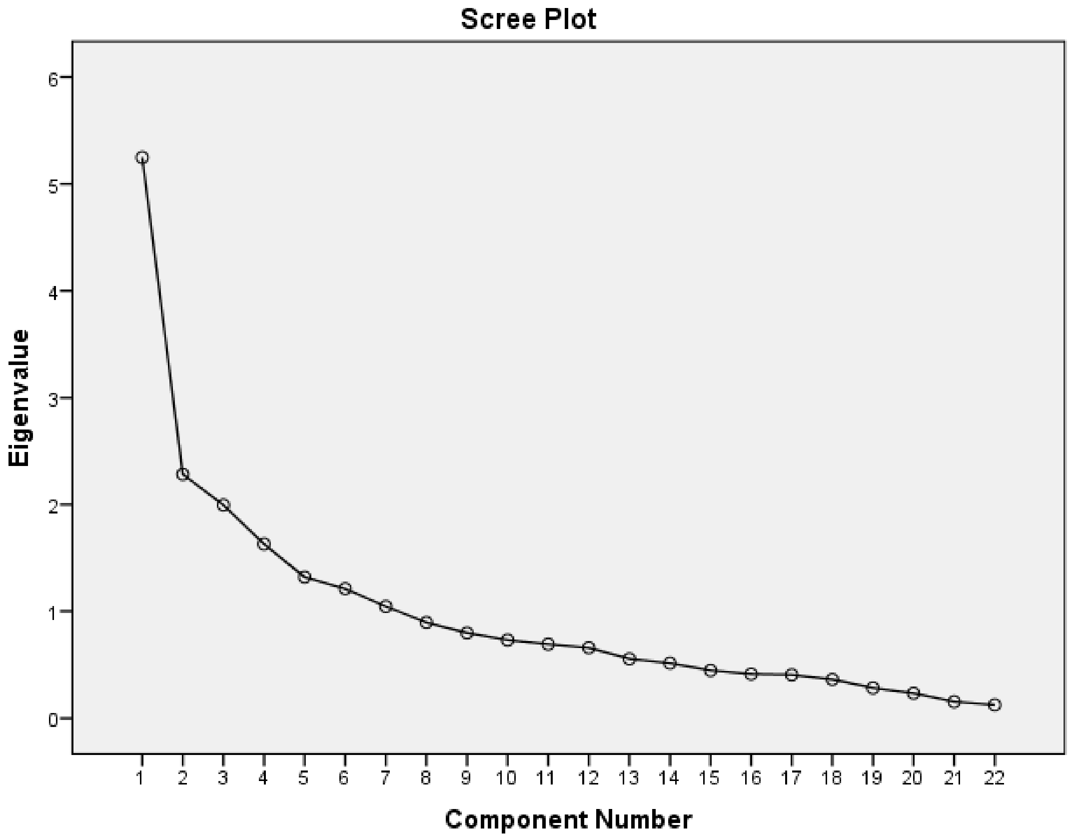
14	.515	2.341	88.976		
15	.447	2.033	91.010		
16	.413	1.877	92.887		
17	.406	1.848	94.735		
18	.362	1.647	96.382		
19	.283	1.287	97.668		
20	.234	1.062	98.730		
21	.155	.703	99.433		
22	.125	.567	100.000		

Total Variance Explained

Component	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings		
	Cumulative %	Total	% of Variance	Cumulative %
1	23.849	3.949	17.951	17.951
2	34.219	2.586	11.752	29.704
3	43.282	2.419	10.996	40.699
4	50.689	2.198	9.990	50.689
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				

15				
16				
17				
18				
19				
20				
21				
22				

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component			
	1	2	3	4
1	.473	.479		
2	.370	.703		
3			-.596	.384
4	.423		-.547	.419
5		.437		-.501
6	.624	-.393		
7	.661	-.381		
8	.657			
9			.533	
10	.465	-.330		
11	.561			
12	.517			-.385
13	.675			
14	.418	.359		
15			.504	.335
16	.366	.546		
17	.572			
18	.386		-.440	.301
19	.420		.524	.344
20	.666	-.355		
21	.597	-.362		-.418
22	.461			-.389

Extraction Method: Principal Component Analysis.[a]

a. 4 components extracted.

Rotated Component Matrix[a]

	Component			
	1	2	3	4
1		.600		
2		.699		
3				.764
4				.774
5		.697		
6	.745			
7	.732			
8	.513	.478		
9			.543	
10	.537			
11	.447		.425	
12	.419	.506		
13	.672		.372	
14			.420	.335
15			.672	
16		.390	.490	
17	.374		.420	
18				.646
19			.707	
20	.717			

21	.751			
22		.581		

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 9 iterations.

Component Transformation Matrix

Component	1	2	3	4
1	.754	.429	.389	.311
2	-.636	.665	.282	.271
3	-.048	-.076	.725	-.683
4	-.158	-.606	.494	.603

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.