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Non-technical skills

A critical evaluation of organisational learning for the UK Nuclear Industry from Aviation and Oil & Gas sectors

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Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil & Gas Sectors

Agha Ibiam

This thesis is submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy

December 2020

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RESEARCH DECLARATION

I declare that this thesis is wholly my work. Any use of the work of others were duly acknowledged both in-text citations and the reference list. I confirm that the thesis was carried out in compliance with the University's research ethics.

ABSTRACT

The development and application of Non-Technical Skills (NTS) in managing safety in high-tech industries is expected to yield possible results if properly harnessed. Accidents in high-risk organisations are often triggered by human errors, and have been destructive to life, equipment, organisations, and the environment at large. Therefore, urgent attention is needed to reduce the incidence of catastrophic events by guaranteeing that operators in these high-tech industries receive NTS training to deal with and counter risks associated with their tasks. Additionally, isomorphic lessons, organisational learning and risk characterisation are equally important when organisations become learning institutions by encouraging and promoting learning in a practical, methodical and synergistic manner. This involves the entire staff of the organisation in managing safety. As a result, this research revealed that the use of NTS, isomorphic lessons, organisational learning and risk characterisation in managing and improving safety performances are not common features in the nuclear industry. A comparative approach employing critical evaluation is drawn by comparing and cross-examining other industries such as aviation and oil and gas sectors; and if lessons learned in those sectors could be applied in the nuclear industry. Primary and secondary data comprised of 6 activities were used to critically investigate the three sectors, using 4 pillars which are NTS, isomorphic lessons, organisational learning and risk characterisation. The line of inquiries used are (1) 15 interviews; (2) online surveys on the four pillars and the three sector; another survey on impact of Covid-19 on the three sectors (3) review of six examples of accidents/incidents using cross-industry documents; (4) examination of documents from regulators from each sector; and (5) focus groups to test findings for validity. The population researched are safety experts from nuclear, aviation and the oil and gas sectors; while the sample size are nuclear (n=124, 54%); aviation (n=59, 25%) and oil and gas (n=49, 21%). Firstly, untapped opportunities exist for the nuclear industry to further advance and review their frontline training and awareness in NTS and boost the effectiveness of their internal learning capacities. Secondly, the research was designed to identify the value of cross industry benchmarking in safety training using a range of novel created outputs including industry toolkits, indices of industries publications, cross-industry accident analysis. There remains greater scope to share ideas, acknowledge common domain issues and implement better co-operation for shared benefits. Despite these findings this research affirms that good practice and a responsible attitude exists in all

industry practitioners engaged in this research, but the minimisation of human agents in systems can equally limit their potential to make positive contributions in emergency scenarios.

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LIST OF ABBREVIATIONS

ALARP - As Low As Reasonably Practicable

ASRS - Aviation Safety Reporting System

ATO - Approved Training Organisations

BOS - Bristol Online Survey

BOSIET - Basic Offshore Safety Induction and Emergency Training

BP - British Petroleum

CAA - Civil Aviation Authority

CRM - Crew Resource Management

CVRs - Cockpit Voice Recorders

EDF - Electricite de France

ENSREG - The European Nuclear Safety Regulators Group

EPA - United States Environmental Protection Agency

FAO - Food and Agriculture Organisation

FDRs - Flight Data Recorders

HASAWA - Health and Safety at Work Act 1974

HAZID - Hazard Identification

HAZOP - Hazard and operation

HFACS - Human Factors Analysis and Classification System

HFAM - Human Factors Analysis Methodology

HRT - High Reliability Theory

HSE - Health and Safety Environment

IAEA - International Atomic Energy Agency

INES - International Nuclear and Radiological Event Scale

INSAG - International Nuclear Safety Group

IOSH - Institution of Occupational Safety and Health

IS – Isomorphic Lessons

ISO - International Organization for Standardization

IWCF - International Well Control Forum

ILS - Instrument Landing System

KWT – Kruskal Wallis Test

LOPA - Layer of Protection Analysis

LTI - Lost Time Injury

NDM - Naturalistic Decision Making

NEA - Nuclear Energy Agency

NPP - Nuclear Power Plant

NRC - Nuclear Regulatory Commission

NTS - Non-Technical Skills

OGA - Oil and Gas Authority's

OL – Organisational Learning

ONR - Office for Nuclear Regulation

OPITO - Offshore Petroleum Industry Training Organisations

OSC - Oil Spill Commission

QRA - Quantitative Risk Assessment

RC – Risk Characterisation

RSSB - Rail Safety and Standard Board

SOAM - Systematic Occurrence Analysis Methodology

SOFIA - Sequentially Outlining and Follow-up Integrated Analysis

TEA - Training Education and Awareness

TEM - Threat Error Management

TEPCO - Tokyo Electric Power Company

TMI - Three Mile Island

ToR - Tolerability of risk

UK - United Kingdom

UKCS - UK Continental Shelf

US NAS - United States National Academy of Science

WHO - World Health Organisation

WNA - World Nuclear Association

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I am grateful to God for granting me the opportunity, knowledge, wisdom and unending provisions to successfully complete my PhD at a time there was virtually no hope of achieving such a feat.

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CHAPTER 1
INTRODUCTION

1 Background of Study

1.1 Accidents in High-Risk Industries (Nuclear)

The consequences of accidents in high-risk industries can be damaging to humans, organisations, equipment and the environment in general (**Perrow 1984**). Studies have shown that 80 per cent of accidents (**Turner 1994**) in industries are mostly caused by human errors (**Sheridan 2008; Reason 1990; Helmreich 2000**). The fact that human errors cannot always be eliminated, therefore means extra efforts should be made to reduce accidents by ensuring that staff receive adequate and appropriate Non-Technical Skills (NTS) training to deal with risks associated with their jobs (**Flin *et al*. 2008**); and if there is better understanding of risk, it will be possible to reduce or remove the observable dangers (**Perrow 1984: 3**).

Major accidents, such as the explosion of the Texas City refinery in 2005, the Macondo Well Blowout of Gulf of Mexico in 2010 (**OSC 2011**); the damage of the Piper Alpha oil rig platform of North Sea of 1988 in which 167 people died (**Cullen 1990**); and the Bhopal methyl isocyanate accident of 1984 are accidents that point to the need for process safety; and use of social and individual resource skills (NTS) which, added to technical skills lead to safe and well-organised work performance (**Kilskar *et al*. 2016; Christou *et al.* 2012; Flin *et al*. 2008**).

Other accidents worthy of note are the Space Shuttle Challenger of 1983, the overturn of the Herald of Free Enterprise in 1987, the King's Cross underground (tube) station fire of 1987, and the Tenerife airport disaster of March 1977. In contrast, the Hudson River landing of 2009 showed good use of NTS. Others are examples of failures in high-risk industries in lack of NTS has a contributing factor (**Flin *et al*. 2008; Reason 1990; kletz 2001**).

The Nuclear Power Plant (NPP) is not immune to accidents despite the great benefits people and society derive from it, ranging from energy supply and provision of nuclear medical isotopes. Nonetheless, accidents that stemmed from the industry equally have caused death and destruction of properties in high magnitude (**Shultz and Drell 2012**). The highest impact accident in the nuclear sector was the April 1986 Chernobyl accident in Ukraine (USSR), classified as one of the worst accidents in the history of nuclear power plants on the International Nuclear and Radiological Event Scale (INES) (**IAEA 2014**).

According to Fitzpatrick (2017), human faults and natural disaster contributed as major events that led to the Chernobyl and Fukushima accidents respectively. The two separate accidents occurred when the plants were no longer able to cool the reactors sufficiently (**Fitzpatrick 2017**). Miyagi (2005) noted that if the Soviet Union had paid all the compensation for the economic loss affected by other countries due to the accident, the Soviet economy would have collapsed. This indicates the seriousness and aftermath of any accident in a big-scale complex industry or system (**Miyagi 2005**); hence recurrent training of operators is important (**Perrow 1984**).

Another serious event was the Three Mile Island (TMI) nuclear power plant accident which occurred near Harrisburg, Pennsylvania, USA in 1979. The third major accident was at the Fukushima Daiichi nuclear power plant, triggered by the tsunami arising from the Tohoku earthquake in 2011. Backup generators or machines that should have kick-started the cooling pumps were seriously damaged (**Fitzpatrick 2017**). This is the second disaster to measure Level 7 on the INES (**Power Tech n.d; WNA 2017**).

Nuclear accidents of such magnitudes mentioned above have not occurred in UK power plants. The Windscale fire of 1957 is regarded as the worst nuclear accident in the UK ranked at severity level 5 on INES record (**Wakeford 2007**). Apart from numerous accidents that have occurred in nuclear power plants, there are other risks commonly linked to them. These risks are radiation release, reactor accidents, radioactive waste and other radiation related problems (**Cohen n.d; Fitzpatrick 2017**).

Therefore, there is an urgent need for this research to critically look at what UK nuclear power plants have put in place in terms of their knowledge of the use of NTS in training exercises, isomorphic lessons, organisational learning and risk characterisation to build a safety culture aimed at mitigating possible occurrences, since a disaster can occur without warning (**Toft and Reynolds 2006**).

Based on these disasters that have occurred in the nuclear industry, this research looked at other high–risk industries such as the aviation and the oil and gas sectors to draw lessons on how accidents were either successfully or unsuccessfully managed, with the aim of transferring such lessons to the UK nuclear sector as part of its recommendation. To achieve this, the research topic focused on: "Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil and Gas Sectors."

The research extensively incorporates models made by different authors on how risks progressively become disasters. The System Failure and Cultural Readjustment Model (SFCRM) developed by Toft and Reynolds (2006) is an example. The duo pointed out that the model has three different but connected areas. First is the incubation stage, regarded as the starting point before a disaster occurs. This is followed by the event that starts the disaster proper and the aftermath of salvaging the situation. The third stage is focused on the learning procedure which comprises investigation and inquiries and report production, after which is recommendations. The model noted that the most important aspect of the third stage is the feedback channel which helps to understand the incubation stage (**Toft and Reynolds 2006**).

1.2 Non- Technical Skills (NTS): The Roadmap

A substantial body of academic and professional research has identified the vital importance worldwide of NTS spanning cognitive, interpersonal, and personal resource skills as essential human factor traits for managing accidents, emergencies, and incidents effectively (**Flin *et al.* 2008**). However, additional research shows there is still room to markedly improve responder competences, interoperability (ability to use equipment), and to act on and implement persistent lessons identified from critical emergencies, incidents, and accidents in the United Kingdom (**Pollock 2013**).

Many scholars have raised concerns over the risks associated with nuclear industries and noted that there is urgent need to determine if the UK nuclear industry has maximised its human learning potential, taken on-board an organisational learning culture (for example isomorphic lessons), optimised the value of NTS in key segments of its workforce and committed to understand the importance of managing its own risk characterisation (**Stern and Fineberg 1996**).

This research looked at three accidents of high magnitude and another three incidents, one from each of the three sectors, and critically evaluated the probable causes relating to them. In doing so, the research employed four pillars, which are NTS, isomorphic lesson(s), organisational learning and risk characterisation to set standards for the nuclear sector.

Furthermore, the project looked at various achievements/failures made from the aviation and oil and gas sectors as two independent environments and controls on how they managed risks (**Wiener, Kanki, and Helmreich 1995; Hudson 2003**). Findings from the aviation and the oil and gas sectors were used as a framework for the UK nuclear sector. Thereafter, a toolkit was developed on how risk characterisation can be optimised and the use of NTS, organisational learning and isomorphic lessons to manage the UK nuclear sector.

Thus, the study provided the following outputs:

I. Framework: (People, Process, Technology, Infrastructure, Stakeholders, and Governance).
II. Toolkit: (Nuclear Toolkit – Learning and fine-tuning opportunities).
III. Benchmarking exercise: (Online surveys, review of regulatory data, interviews, accidents/incidents examples and focus groups were used).

The research adopted different approaches aimed at harnessing useful information which was critical to safety management in the nuclear industry. Firstly, high impact related journals, publications and studies were reviewed to get detailed information on approaches taken by the nuclear industry, aviation, and the oil and gas industries to manage risks. The research also incorporated seminal literatures and theoretical approaches connected with High Reliability Theory (HRT) (**Weick and Sutcliffe 2011**) and Normal Accident Theory (NAT) (**Perrow and Sagan 1998**) alongside human factors, safety systems, and error management to build and benchmark a comprehensive picture of the risk and hazard factors associated with the nuclear industry (**O'Connor and Flin 2003, Theophilus *et al*. 2017**).

1.3 Defining the Four Pillars used in this Research

1. Non-Technical Skills (NTS): This are cognitive and social skills which complement workers' technical skills (**Flin *et al*. 2008**); they are vehicles through which technical skills and knowledge can be applied (**Thomas 2018**).

2. Isomorphic lessons: This describes a responsive procedure, comprised of analysis of past understanding to shape a 'hazard model' of what is expected to happen in the foreseeable future (**Kirkwood 1999**).

3. Organisational learning: This refers broadly to an organisation's acquisition of understanding, know-how, techniques and practices of any kind and by any means (**Argyris and Schön 1978**)**.**

4. Risk characterisation: Is a step forward before decision making, which depends on an iterative, analytic-deliberative process (**US NAS 1996**).

1.4 Aviation and Oil & Gas as Key Sectors for Discussion

The research used an online survey to draw lessons from aviation and oil and gas into the nuclear sector, but deriving understanding from NTS, isomorphic lessons, organisational learning and risk characterisation. The two-key independent (control) sectors, which are aviation and oil and gas were utilised for the purpose of understanding applicable lessons for the nuclear sector. Efforts were made to look at how a series of notable accidents not involving technical faults led to wider consultations and investigations of further contributing factors (**O'Connor and Flin 2003; Reason 2016; NTSB 2010**).

Safety management in the aviation industry is a key issue which cannot be compromised whatsoever. A chief concern of the aviation industry is to improve global civil aviation safety which has led to the development of a strong process safety culture (**Scott and Wiegmann 2012; O'Connor and Flin 2003**). In aviation, human error in the cockpit can trigger multiple incidences, which could lead to fatal consequences (**Kilic and Ucler 2019**).

Since the 1970s, the aviation industry has identified the importance of human inaccuracies resulting to errors and has developed training programmes designed to reduce accidents and errors to increase the efficiency of flight crew. Therefore, Crew Resource Management (CRM) system covers different issues on knowledge, skills and approaches that include communications, situation awareness, problem solving, decision-making and teamwork and other disciplines (**Harris 2014**); and to manage safely **(Flin, O'Connor, and Mearns 2002; Wiener, Kanki, and Helmreich 1995**).

Likewise, the oil and gas sector, which is also a high-risk industry has recorded numerous disasters such as Piper Alpha (UK), Alexander Keiland (Norway) and Longford (Australia) (**Mearns and Yule 2009**). The Piper Alpha oil platform disaster was caused by lack of or poor communication (NTS) during shift handover. The disaster was also aggravated by leadership failure in the emergency response (**Cullen 1990**). The current study comprehensively looked at these chains of accidents in both sectors to see how they were effectively managed and if lessons could be learned from them to boost nuclear sector safety performance.

1.5 Scope of the Study

The study critically evaluated NTS for the UK nuclear industry from the aviation and the oil and gas sectors. It also examined organisational learning, isomorphic lessons and risk characterisation using an online survey to evaluate, benchmark and determine applicable transferable lessons from aviation and oil and gas sectors, to apply such findings to the UK nuclear industries for better safety management.

1.6 Research Gap

The challenge for this research was to examine if organisational learning is prevalent in the nuclear sector. So, the project was planned to close this knowledge gap with new research findings, as there was no composite research that is known to have existed regarding the cross-industry lessons between aviation, oil and gas and the nuclear industry.

Furthermore, there is no immediate evidence showing the compound effects of all the above areas of four pillars of focus being studied at the macro level within industries, let alone across industries. Then findings, which elicited on how risks were successfully managed in aviation and oil and gas were used as a real conceptual structure (framework) to support and produce a learning plan or toolkit to better manage and guide the UK nuclear industry.

1.6.1 Research Contributions

The research undertaken provided a platform for contributions spanning industry and academic applications. The principle contributions consisted of a toolkit comprising of the following deliverables: Lexicons; Benchmarking; Accident/Incidents examples, Training logs, List of publications and Archiving of incidents. The explanation is as follows:

(a) **Lexicons**: This is a comparison of terminology used in different sectors, which could mean the same thing in another sector. Therefore, this research suggested that there is need for the three sectors to adopt a common language or lexicon on NTS, despite having some similarities in meaning.

(b) **Benchmarking**: These are findings derived from the online survey on how each sector uses the four pillars to manage safety across the three sectors. Information was provided that meet the needs of managers and planners in an unpredictable environment. It also offered possible solutions gathered from best practices in either aviation or oil and gas. Benchmarking provide a means of improving competence through learning both within and outside organisations and between organisations.

(c) **Accident/Incidents examples:** This includes 3 accidents and 3 incidents examples. A3 is used to indicate that where there are lapses on NTS, isomorphic lessons, organisational learning and risks characterisation, accidents are bound to happen in such sectors. Therefore, this will be used by organisations to manage safety.

(d) **Training Logs**: Training/Reflection logs across the three sectors is expected to enrich workers understanding on the four pillars used in this research. However, this research did not develop a training log for the sectors as it may not be profitable to organisations on how its training logs should look like. However, after listening to participants view during the focus group discussion and recommendations they made, training logs produced by the three sectors should be shared within the three industry regulators for the purpose of safety management.

(e) **List of Publications**: This are different articles that are related to the three sectors on the four pillars. The list served as reference points to industries on different types of publications that supports industry learning which will invariably lead to managing safety.

(f) **Archiving of Incidents:** This again served as reference point to industries on the type of low incidents that has occurred in the sectors and contribute to isomorphic lessons or organisation learning. However, the stand of this research is that the three sectors should as a matter of facts archive incidents for future referencing should the need arise.

Another form of contribution from this research is that it has produced two journals which will further help industry learning (though awaiting publication). They are:

(a) Isomorphic Lessons & Organisational Learning: Prerequisite Tools for Managing Safety in High-Risk Industries (UK Nuclear Sector).

(b) Improving Nuclear Safety: Comparing the use of Non-Technical Skills and Organisational Learning in the Aviation and Oil & Gas sectors.

Additionally, the research has revealed that potential gaps exist in the use of the four mentioned areas or pillars to manage workplace safety for the nuclear sector. Furthermore, the nuclear sector has not fully familiarised itself at promoting all the elements of NTS in the workplace environment, therefore, there is need for the nuclear sector to train staff effectively to bridge those gaps, which will equip the workers earlier to manage safety.

Additionally, the recommendations made in this research has provided new insights and as part of the research contributions.

1.7 Research Aim

The aim of the research was to undertake a critical evaluation of the UK nuclear industry safety practices, focusing on the use of NTS from an online survey on non-technical skills, isomorphic lessons, organisational learning, and risk characterisations in aviation and oil and gas.

1.8 Research Objectives

This research has a broad range of objectives. They are:

(i) To critically evaluate and benchmark non-technical skills and their values in achieving workplace safety in the UK nuclear power industries.

(ii) To investigate the extent to which isomorphic lessons, organisational learning and risk characterisations derived from approaches used in safety-critical industries such as aviation and oil and gas informed and/or added value to the resilience practices undertaken in nuclear industry.

(iii) To design and create a holistic framework (with key processes, principles, terms, and toolkits) to support isomorphic lesson opportunities, optimise and benchmark NTS capabilities, risk characterisations, and organisation learning in the nuclear industry within the UK.

1.9 Research Questions

The research questions revolved around NTS, isomorphic lessons, organisational learning and risk characterisation. This was designed to draw out respondents' views and understanding on the four pillars used in this research.

Research Q1: To what extent does the nuclear sector use non-technical skills, isomorphic lessons, organisational learning and risk characterisation in training and managing safety in the UK?

Research Q2: To what extent could lessons learned from other organisations, such as aviation and oil and gas, help shape the UK's nuclear industry's safety?

1.10 Research Purpose

The overall purpose of this study is to create a framework with key processes, principles and toolkits to improve learning opportunities, appraise risk characterisations and increase NTS capabilities across nuclear industry stakeholders in the UK. This means that findings will be used as a framework for better training, development and evaluation, and to determine if isomorphic lessons can be applied from aviation and oil and gas into the UK nuclear industry to better manage the risk of critical nuclear incidents. More so, any lapses observed during the research were transformed using a framework of training development to train individuals, reshape their characters (behaviour), plan routine work and increase worker's technical skills aimed at achieving a safety environment. Figure 1 indicates the research context adopted for this research.

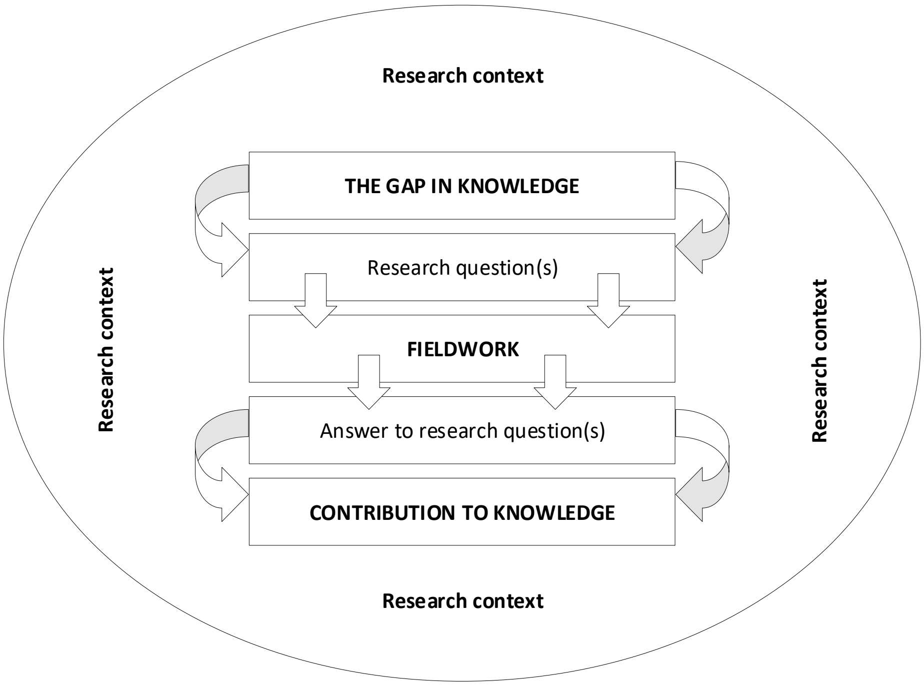


Figure 1: Research context

1.11 Limitations of the Study

The following sub-sections highlight the limitations of the study and the reason for focusing on NTS, isomorphic lessons, organisational learning, and risk characterisation.

1.12 Reason for Focusing on NTS, Isomorphic lessons, Organisational learning and Risk characterisation

As stated, the use of NTS to manage safety in high-risk industries has proven to be effective. For instance in the aviation industry, the use of NTS to train pilots and other crew members is made compulsory as this is aimed at reducing risks and accidents (**Harris 2014; Scott 2018**).

On isomorphic lessons, Toft and Reynolds (2006) stated that no specific accident ever happens twice, as each separate disaster is completely unique (**Toft and Reynolds 2006**). Therefore, isomorphic lesson is needed for organisations to avoid making similar mistakes that could lead to disaster.

Organisational learning, as explained by Maybey and Salaman (1995) is concerned with the expansion of new knowledge or understanding, that organisations have the potential to influence behaviour. It occurs within the wide institutional setting of inter-organisational relationships (**Mabey and Salaman 1995; Geppert 2000**). It also refers broadly to an organisation's acquisition of understanding, know-how, techniques and practices of any kind and by any means (**Argyris and Schön 1978**). How organisations respond to information to manage risk was equally important to this study.

On risk characterisation, despite the size or type of organisation, something that is of essence is that it must face both internal and external factors. Such impact makes it uncertain to contemplate if set objectives will be achieved (**ISO 31000:2009**). Therefore, managing risks successfully is vital for organisations to survive.

Put together, these are the reasons why this research decided to find meanings into those areas which could probably help foster solutions in high-risk industries.

1.13 Structure of the Thesis

The thesis is structured in a manner that will be reader friendly. As a result, each new argument or knowledge is introduced and written in a new chapter followed by a brief introduction. The thesis is divided into seven chapters, designed to run from introduction to recommendation as logically as possible.

The thesis is structured as follows: **chapter one** is an introduction of what the thesis is about including research gaps, aims, objectives, purpose and research questions, limitations and focusing on the four cardinal pillars.

Chapter two presents the literature review, where issues relating to human factors, the four key domains (pillars), three accident examples (case studies), three near misses and how the three key sectors have successfully managed the industries.

Chapter three presents the research methodology, focusing on online surveys, interviews and use of accident data as research designs and focus groups.

Chapter four shows all results analysis combined (online results, interviews, focus groups and accident data) carried out in this thesis. Chapter four also focused on discussion of result findings.

Chapter five focused on the conclusion of the entire thesis.

Chapter six is on research recommendations categorised according to the four pillars. There were some recommendations that also originated from general observations, toolkits and technology. These are all designed to strengthen the need for the UK nuclear sector to learn from other organisations to improve safety management.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

As noted in chapter one, this research is designed to investigate "Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from the Aviation and Oil and Gas Sectors." Chapter two reviewed relevant literature and scholarly articles, as disasters are said to be events that are created by people operating in a complex system (**Perrow 1984: 8**). Evidence suggests that where lessons are not learned, there is possibility of similar event reoccurring at that place (**Toft and Reynolds 2006**).

For instance, the use of CRM, an example of NTS adopted by the aviation sector (**DFSB 2018**) served as a reference point for the introduction of NTS in the nuclear sector. Therefore, attempts were made by this research to see if lessons could be learned from some of the high-risk industries and criss-cross lessons among them, focusing on NTS, isomorphic lesson, organisational learning and risk characterisation. Also, this research looked at how series of notable accidents not involving technical faults led to wider consultations and investigations of further contributing factors (**O'Connor and Flin 2003; Reason 2016**).

Chapter two discussed human factors as aetiology of numerous nuclear accidents both within and outside of the UK (**Fitzpatrick 2017; Reason 1990**); as it is known that 80 per cent of accidents are contributed by human error (**Turner 1994; Sovacool 2010**). System Failure and Cultural Readjustment Model (SFCRM) developed by Toft and Reynolds (1997) was equally highlighted. But theoretical approaches connected with High Reliability Theory (HRT) (**Weick and Sutcliffe 2011**) and Normal Accident Theory (NAT) (**Perrow and Sagan 1998**) was discussed alongside human factors, safety systems, and error management to build and benchmark a comprehensive picture of risk and hazard factors associated with the nuclear industry (**O'Connor and Flin 2003, Theophilus *et al*. 2017**).

2.2 Human Errors in Nuclear Power Plants (NPP)

Human error can occur at every step in the life of a nuclear facility (**NEI 2017**); as accidents typically happen when rules are not followed or broken. Within nuclear power plants, 80 per cent of substantial accidents or events can be credited to human error (**IAEA 2017**). However, it has been suggested in different quarters that the 1986 Chernobyl accident was the ultimate example of human ineffectiveness on different areas; and in TMI, human error also had an effect (**NEI 2017**). It is also noted that accident could occur due to the possible failure of a reactor of a nuclear power plant and a radiation accident could happen when discharging a radiation source to the river, all attributable to human factors (**Gordon 1996**).

According to Stanton (1996) human error or human factors are concerned with the relationships that exist between humans and technology with respect to achieving some targeted goals (**Stanton 1996**). However, Heinrich *et al*. (1980) stated that accidents are not expected to be credited to a single reason, or in most cases even to a single person (**Heinrich *et al*. 1980; cited in Shappell and Wiegmann 2000**). But Turner (1994) noted that if the 80 percent of human error is broken down, it informs that errors which relates to events comes from latent organisational weaknesses caused by humans in the past and which have been dormant in the system, while the remaining 20 percent are caused by individual workers operating equipment and other facilities (**Turner 1994**).

Turner (1994) noted that concentrating efforts on reducing human error will invariably reduce the chances of accidents. For instance, the Fukushima Daiichi accident caused by tsunami earthquake was not well managed by the workers and due to organisational weaknesses, which had increased the chances of human error. Nonetheless, human faults and natural disasters contributed as major events that led to the Chernobyl and Fukushima accidents respectively (**Turner 1994**).

The pie chart in Figure 2 indicates the role human performance, technical errors and natural disaster played in causing accidents in the nuclear industry from 1998-2018. (See secondary data analysis in section 4.7). It is evident in the chart that human factors contributed to 49% of the nuclear accidents during the period under review, while technical errors triggered 45% and natural factors caused 6% of the accidents. These figures imply that human factors (including non-technical skills) led to an average of 1 in 4 nuclear accidents between 1952 and 2010 (**Sovacool 2010**), then from 2011 to 2018 (**Laka n.d**). Sources of data used in this analysis was derived from Sovacool 2010 and Laka (accident database).

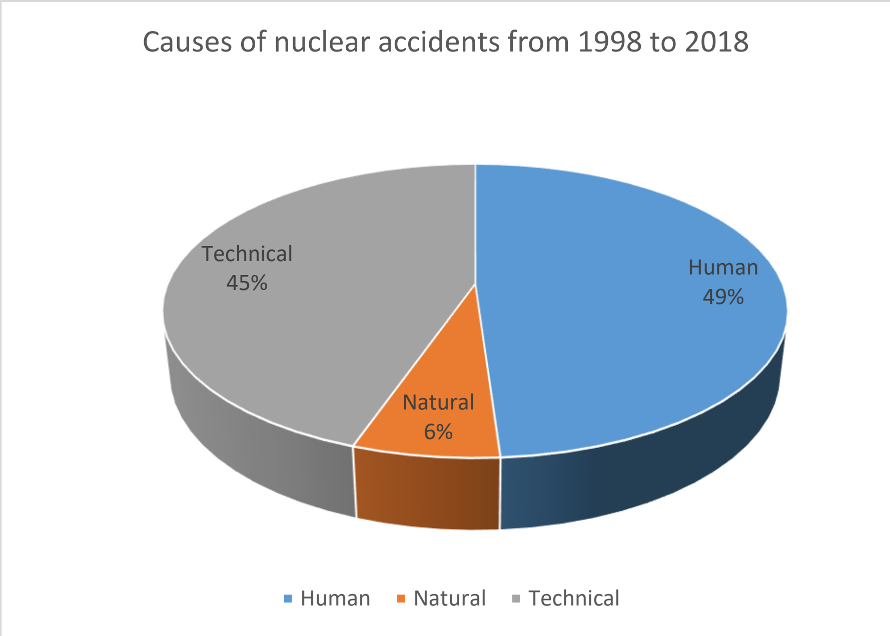


Figure 2: Classification of nuclear accidents from 1998-2018

The Nuclear Regulatory Commission (NRC) review of past events relating to fuel damaged in the reactor revealed that human factors were common in 21 of 26 reactors, which represents 81 percent of accidents. The report indicates that the risk is about how staff are trained, the level of professionalism they have, their performance at work and the way staff are managed (**US DoE 2009**). The statement supports Flin *et al*. (2003) thinking on the use of NTS in staff training, as skills acquired help to complement workers technical skills.

However, the consequences of human mistakes could lead to negative outcomes and could be expensive. Accidents endangers organisation's capability to keep/protect the workforce, physical facilities, the public, and the environment from danger. Human mistakes also have negative effect on the economy (**Flin *et al.* 2008**). According to IAEA (2017), Fukushima accident demonstrated how natural disaster such as earthquake and flood combined and led to a continued power failure and the complete damage of the heat sink, though complicated by human failure (**IAEA 2017**).

Although, the US DoE (2009) stated that there is nothing wrong with any system, but experience shows that the inability of organisational processes and cultural standards are rather involved in most accidents. As a result, a mixture of different factors sometimes goes beyond the control of the workforce. So, the organisational context of human activities is an important consideration. Accident free entail a combined view of human act from those who are interested in achieving success; which involves how well staff, supervisory team, and management operates as a team and the extent of arrangements of processes and principles in the attainment of the organisation's economic and safety objectives (**US DoE 2009**).

Kletz (2001) said most accidents are largely due to error caused by people, which could be managers or supervisors who take decisions on what to do; or the individuals, either operators or maintenance workers that carry out the job which does not lead towards active methods of preventing accidents (**Kletz 2001**). More so, even telling people to take precautions will also not avoid errors. What is important is knowing the reason why error occurred and act decisively to remove opportunities that will cause accidents (**Kletz 2001; Reason 2000**).

In the aviation industry which is a complex and safety critical environment, still human error is suggested to be the major cause of almost 80 per cent of accidents *(***Skybrary 2010***)*. Inappropriate maintenance adds up to a significant amount of aviation accidents and incidents. This happens due to a small proportion of maintenance works that are executed wrongly due to human error (**ATSB 2008**).

NEI (1988) noted that the nuclear industry has a complex industrial system and a lot of tasks are achieved by machines (**NEI 1988**). The statement corroborates Charles Perrow's view of tight coupling, where people tries hard to work safely but unexpected interaction of two or more failures causes a cascade of failures (**Perrow 1984**). However, man is still involved to a large extent in their design, testing, maintenance and operation. Because the performance of the person operating within a complex mechanical/automatic system largely depends on the individual competences, limitations and behaviours as well as on the quality of instructions and training the individual received is important; hence NTS being relevant in staff training (**NEI 1988; Flin *et al*. 2003; Kletz 2001; Reason 2000**).

Sheridan (1992) argues differently. He stated that causes of error can be credited to flaws in design, procedures, operators training, machine maintenance, and or management at the “blunt end”. Though most applications focus at the “sharp end” (such as pilot, surgeon, soldier, driver, or other machine operators). Mostly, causes of accident are untimely interventions by operators and not providing enough feedback when something goes wrong. Sometimes, someone with an improper understanding of how a system works, will likely make more mistakes trying to use them (**Sheridan 1992**).

Based on literature, it is proven that human error causes accidents due to ineffective application of NTS. Though the occurrence of accidents is somehow on the decline, however, it remains to be a leading influence which is almost 80 to 85 per cent of causes of accidents in high-risk industries (**Baker and McCafferty 2005**). It is equally believed that failures of situation awareness (NTS) and situation assessment overwhelmingly prevail as a causal factor in most of the accidents ascribed to human error. Finally, human fatigue and task omission which are related to failures of situation awareness and human errors as causes of accidents (**Baker and McCafferty 2005**). Therefore, prompting this research is to investigate (using an online survey) if workers in the nuclear sector have received training on NTS and other pillars discussed in this research to operate safely.

With the development of technology which has increased system reliability during the past years, human reliability has not changed over the same period (**Ziedelis, Noel, and Institute for Energy (European Commission) 2011**). Consequently, human error is still considered the most significant causes of accidents in safety-critical systems. As a result, there is need to develop methods and techniques that can suitably identify causes of equipment failures and human errors, in order to formulate effective counter-measures to reduce their future repetition (**Ziedelis, Noel, and Institute for Energy (European Commission) 2011**).

2.2.1 Reason’s “Swiss Cheese” Argument on Model of Human Error

Reason (1990) explained three stages of human failure in aviation. The first includes the condition of the aircrew as it affects performance. This is referred to as preconditions for unsafe acts, which involves conditions such as mental fatigue, poor communication and coordination practices, often referred to as CRM. If fatigued aircrew fail to communicate and coordinate effectively, their actions or activities with others in the cockpit and even on the external activities to the aircraft (air traffic control, maintenance), poor decisions are made and errors often result (**Shappell and Wiegmann 2000**).

However, the accident model recognised as the "Swiss Cheese model" developed by Reason (1990) is regarded as the most significant piece of work in the field of human factors. This model has been extensively used to explain the dynamic causes of accidents, which explains how complex systems can be affected due to combination of simultaneous factors emanating from alignment of the holes on the Swiss cheese slices in Figure *3*.

Many Human Reliability Analyses later developed were to some extent based on Reason's model. Some of them are the Human Factors Analysis Methodology (HFAM) **(Pennycook and Embrey 1993**); the Sequentially Outlining and Follow-up Integrated Analysis (SOFIA) (**Blajev 2002**); the Human Factors Analysis and Classification System (HFACS) (**Shappell *et al*. 2007**), which is widely used to explore military and commercial aviation accidents, and then the Systematic Occurrence Analysis Methodology (SOAM) (**Licu *et al*. 2007,** quoted in **Moura 2017**). See Appendices on causation chains in accident. Figure 3 explains accident trajectory on both active and latent causes.

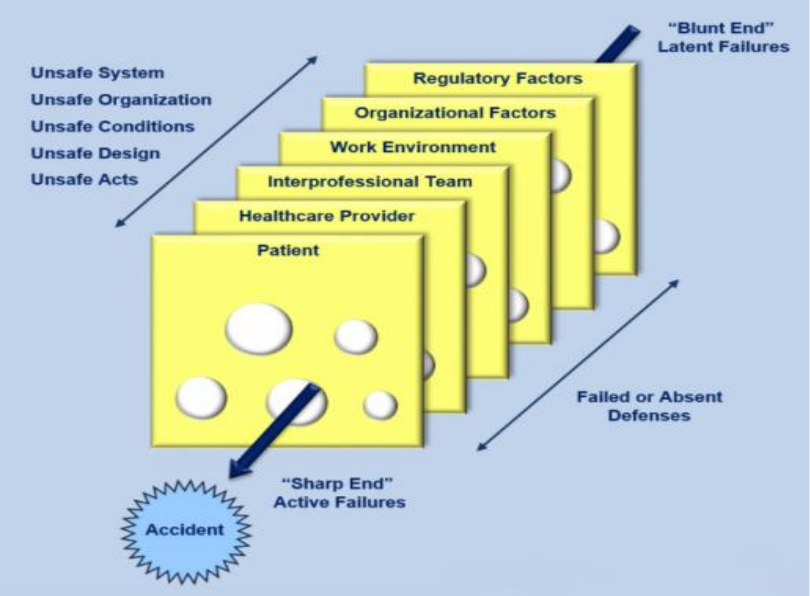


Figure 3: Accident trajectory indicating active and latent failures (Reason 1997)

2.2.2 Remedies for Human Error

Sheridan (2008) said the normal remedies to reduce human mistakes are system design, to make equipment simple and easy to use by operators. Another solution is staff training, active warnings/notices that forestall a system that will possibly lead to accident and restricting operators' exposure to opportunities for mistake. (**Sheridan 2008**).

In their view, NEI (1988) noted that other ways to stop human mistakes are by distinctive and constant tagging of equipment, documents, control panels and exhibiting information regarding the condition of the plant so that the operator can simply comprehend without making a faulty analysis; and designing systems to give unmistakable answers to enable operators understand incorrect actions. Systems should be constructed to reduce the need for human intervention (automation), overcome failures due to human attributes or at least lessen their penalties (**NEI 1988**).

Kletz (2001) noted that TMI reveals that complex plants cannot be operated by writing chains of instruction that should be followed to the letter. Problems which were not envisaged will also cause the likelihood of instruments manifesting conflicting results. Therefore, Kletz (2001) suggests that operators should need:

I. Understand what goes or is happening to the plant.
II. Have diagnostics skills.
III. Be given diagnostic aids as support.

Kletz (2001) views equally represents what Flin *et al*. (2008) noted on 'Safety at the sharp end' that NTS is a prerequisite skill that complements technical skills to managing safely in high-risk industries (**Kletz 2001; Thomas 2018**).

2.3 Safety Culture

According to safety experts, the notion of safety culture arose in the aftermath of Chernobyl tragedy (**Pidgeon 1991**); as safety culture represents a new way of conceptualising processes of risk handling and management in organisational and other contexts (**Pidgeon 1991**). However, Booth (1995), cited in (**Misnan and Mohammed 2007**) noted that the word safety culture was made known to the nuclear safety debate by the International Nuclear Safety Group (INSAG) of the IAEA in their analysis of the Chernobyl tragedy (**Misnan and Mohammed 2007**).

Both IAEA (1986) quoted in (Misnan and Mohammed 2007) and HSE (1994) defined safety culture of an organisation as: "The product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of an organisation's health and safety management." (**HSE 1994; Misnan and Mohammed 2007**). Generally, safety culture can be termed as a set of beliefs, norms, attitudes and social technical practices that are concerned with reducing the exposure of individuals within and beyond an organisation to conditions that are considered unsafe or harmful (**Misnan and Mohammed 2007**).

Glendon and McKenna (1995) noted that effective safety management is a combination of functional management control, monitoring, executive and communication sub-systems; and human which involves leadership, political and safety culture sub-systems that are paramount to safety culture (**Glendon and McKenna 1995**). Equally, the notion of safety culture arose from earlier ideas of organisational climate, organisational culture and safety climate, as safety culture comprises set of principles which define what an organisation is in its health and safety (**Misnan and Mohammed 2007**).

Safety culture affords a global categorisation of some of the common behavioural conditions to accidents in high-risk socio-technical systems (**Pidgeon 1991**), which could prove to be a heuristic tool to aid risk management strategies to supplement current risk assessment practice (**Pidgeon 1991**). Turner *et al.* (1989) noted that safety culture is a set of beliefs, norms, attitudes, roles and social and technical practices that are concerned with reducing the exposure of employees, managers, customers and members of the public to conditions considered dangerous or injurious. (**Turner *et al*. 1989**).

Culture is conceptualised as mainly an ideational system of meanings, while safety culture is regarded as one concerned with the norms, beliefs, roles, and practices for handling hazards and risk (**Pidgeon 1991**). Elements of good safety culture are classified under three headings, namely: norms and rules for dealing with risk; safety attitudes; and reflexivity on safety practice (**Pidgeon 1991**).

Put differently, safety culture means doing the right thing even when no one is watching. However, there are two kinds of safety. One is occupational safety which directly focuses on keeping people safe; while the second one is process safety, as it refers to the procedures for minimising risk more generally (**OSC 2011: 218**).

For instance, at British Petroleum (BP), despite the improvement in injury and spill rates, the company had caused several disastrous workplace incidents which suggest that its approach to managing safety was more focused on individual worker occupational safety than on process safety (**OSC 2011**). The numerous accidents that occurred in BP and subsequent analyses point out that the company did not have reliable risk-management processes and was unable to meet its avowed commitment to safety (**OSC 2011: 218**). As evidence has shown, for organisation to maintain a high safety culture, NTS is expected to be put in place as that has the capability of sharpening workers non-technical skills (**Flin *et al.* 2008**).

2.3.1 Safety in Nuclear Power Plants

Nuclear safety is concerned with the achievement of proper operating conditions and the mitigation of accident consequences, which leads to protection of workers, the public and the entire environment from undue radiation dangers (**ENSREG n.d**). Related to the definition by ENSREG (n.d), is that made by WNA (2019): nuclear safety is defined as all aspects of protection of humans and the environment from the harmful effects of ionizing radiation existing or produced during operation **(WNA 2019**). The organisation further noted that nuclear safety focuses on unplanned conditions or events leading to radiological releases from authorised activities. This relates mostly to core problems or hazards (**WNA 2019**).

According to Meneley (2012), nuclear safety is explained as provisions which are targeted at limiting as far as is reasonably possible in normal operation as well as in the case of an accident the release of radioactivity to the environment and maintaining such releases low enough to prevent risk to workers, public or the environment (**Meneley 2012**).

2.3.2 Defence in-depth in Nuclear Safety

The notion of defence in depth which is about the protection of both the public and workers is essential to the safety of nuclear power plant (**INSAG 1996**). To attain optimal safety, nuclear plants function using a 'defence in-depth' approach, multiple safety systems supplementing the natural features of the reactor core (**WNA 2019**). INSAG (1996) noted that nuclear safety does not depend on one line of defence but is attained using a variety of complementary means. These factors commence with the design and construction of a nuclear facility which needs choosing a good design and appropriate site, use of high-quality construction materials and testing before commencing operation (**INSAG 1996**). INSAG 1996 noted that:

> *"All safety activities, whether organisational, behavioural or equipment related are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected without causing harm to individuals or the public at large. This idea of multiple levels of protection is the central feature of defence in-depth..."*

According to WNA (2019), key aspects of the defence in-depth approach are: high-quality design and construction, equipment that prevents operational disorders or human failures and errors emerging into problems, broad monitoring and steady testing to discover equipment or operator failures, redundant and diverse systems to control damage to the fuel and avoid significant radioactive releases, provision to confine the effects of severe fuel damage to the plant itself (**WNA 2019**).

These can be summed up as: prevention, monitoring and action. They are geared towards mitigating any consequences of failures. The safety provisions comprise a series of physical barriers between the radioactive reactor core and the environment; providing of multiple safety systems, each with backup and planned to accommodate human error. Safety systems in nuclear stations account for about one quarter of the capital cost of such reactors (**WNA 2019**).

2.3.3 Key objectives of defence in-depth

ENSREG (n.d) stated that there are three key objectives of defence in-depth in nuclear power plant.

These are:

(i) To **compensate** for probable human and component failures;
(ii) To **maintain** the efficiency of the barriers by preventing damage to the plant and even the barriers too;
(iii) To **protect** the public, including workers in the industry, and the environment from harm should the barriers fail (**ENSREG n.d; INSAG 1996**).

Overall, the entire strategy for defence in-depth is to prevent accidents. Nevertheless, if prevention fails, the strategy restricts the consequence as much as possible and averts further escalation to more serious conditions. It is intended to ensure a low chance of failures in the systems used, combined with reduction in design should one system fail. Other independent diverse lines of defence safeguard an accident from occurring (**ENSREG n.d**).

2.3.4 Five levels of defence in-depth

Table 1: Levels of defence in-depth in nuclear power plant (INSREG 1996)

Levels of defence in depth	Objective	Essential means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Defence in depth is usually organised in five levels. In case one level fails, it will be compensated for, or modified by subsequent levels (**ENSREG n.d**).

2.4 Four Pillars of Discussion in this Research

2.4.1 Introduction

This section fully discusses the four pillars of this research thesis which are: non-technical skills, isomorphic lessons, organisational learning and risk characterisation as useful values to managing safely. These pillars are germane to understanding the relevance of the research used to extrapolate lessons from aviation and oil and gas into the nuclear sector for safe and efficient task performance. Also, isomorphic lesson was used as a yardstick to measure if organisation understands its usefulness in terms of learning from similar occurrences.

2.5. Risk

The International Organisation for Standardization (ISO 31000: 2009) defines risk as the “effect of uncertainty on objectives” as its effect could be either positive or negative; a total deviation from what is expected. This definition recognises that human beings operate in an uncertain world. Whenever there is need to achieve any set objective, there are chances that things could go wrong or not according to plan (**ISO 31000: 2009**).

ISO 31000 further explained that uncertainty is a condition which involves a lack of information that leads to insufficient understanding. Unexpected events happen when there is inadequate or incomplete knowledge of an event, consequences or outcomes, or its likelihood (**ISO 31000: 2009**). On the other hand, risk is the outcome of unplanned event on set objectives that could be completely different from what is planned, as what is already planned and its outcome cannot be predicted because it has not happened (**Hillson 2007**).

Risk is classified as unlikelihood which should raise concern when it has the tendency of affecting set plans (**Hillson 2007**). Conversely, Stanton and Webster (2014) states that what is considered as risk by some people could mean different things to other people (**Stanton and Webster 2014**). Bouder *et al*. (2007) believe that risk means a mixture of two mechanisms or things, which could be possibility of a likely result or the severity of actions or consequences caused by human error, normal actions or occurrences or could be the combination of both. The authors stated that the consequences that occurred due to risk could either be positive or negative, but subject to the values individuals share (**Bouder, Slavin, and Lofstedt 2007**).

Different authors such as Ewald (1991:199), quoted in Foucault *et al.* (1991), noted that risk from concept was believed not to have been caused by human beings nor their actions. It was presumed to be a natural event like flood or other forms of natural disasters rather than human factors. It is expected that people should do nothing than to estimate the possibility of such disaster occurring and plan how to take actions to reduce their influence (**Ewald 1991**). Ewald (1991) further remarked that the idea that risk was not a handwork of nature was disregarded and human beings have to be included because of their actions in society (**Foucault *et al*. 199**1).

Giddens (1990) noted that with the passage of time, theory of risk symbolises a new way of viewing the world and its disordered display of events, its exigencies and fears (**Giddens 2013**); the unexpected consequences could be as a result of human act instead of the hidden values of natural or extreme purposes of the deity (**Devine-Wright 2005, Firestone and Kempton 2007**).

However, this research takes the view made by Rodgers (2006), quoted in Stanton and Webster (2014). They suggest that without risk there will be no innovation, new knowledge and nothing like brave adventure. What risk does according to them is to help people seek for new ideas, as the utmost risk is taking no risk (**Stanton and Webster 2014**).

Kaplan and Garrick (1981) said whatever people do in life, both business, and decision taken are all but risk and its expectant reward. So, risk is relative to the person observing it. It is also a subjective thing, and again depends on who is looking (**Kaplan and Garrick 1981**). Countering the above assertion, Beck (1998) stated that risk is also an organised way of controlling hazards and uncertainties prompted by industrialisation (**Beck 1998**). As a result, this research will examine if organisations such as the nuclear sector characterise risk effectively in the workplace using an online survey.

Risks have both positive and negative sides, however, depending on what is being perceived as risk. Lupton (1999) stated that strong constructionist believes nothing is risk, that what is known as risk is a creation of socially, historically, and politically contingent on people's perception and constructed in their minds. Risks do not mean certainties waiting to happen, but the gatherings of ideas, decisions and views around material occurrences, giving those events forms and shapes (**Lupton 1999**).

This research holds the view that risk is meant to be tolerated. The view is supported by HSE (1992) that risk tolerability does not necessarily mean that risk is acceptable. Instead, it denotes the preparedness to live and cope with a risk to attain some benefits with the assurance that it will be suitably controlled or managed (**HSE 1992**).

Risk is a concept sometimes used to assist management decision about hazards which cannot act on the world itself. Technically, the word 'risk' is ordinarily considered to involve two components. First, a numerical probability that a hazard will eventuate. While the second is a numerical approximation of the consequences which might occur if risk is not managed. If the two numbers are multiplied, the product then becomes numerical risk value which is associated with specific hazard identified (**Toft and Reynolds 2006**). Therefore, this research examined how the three organisations characterised risk with the hope of managing safety. See risk matrix on Table 3.

2.5.1 What is Risk Characterisation?

Regardless of the size or type of organisation, it must face both internal and external factors; such effect determines if set objectives will be achieved. Basically, the effect of achieving set objectives in any organisation, that is, effect of uncertainty on objectives is risk (**ISO 31000: 2009**). Risk can be quite complex and controversial to cope with as significant resources are devoted to developing and applying methods of risk analysis and risk characterisation to make well informed and more dependable decisions about threats to the environment, health and welfare of staff. Yet these methods sometimes fail to meet expectations to improve decision making (**Stern and Fineberg 1996**).

Stern and Fineberg (1996) noted that risk characterisation may fail for some reasons. It could show the scientific and technical information or evidence that could lead to making a rash decision. It could provide scientific and technical evidence in a manner that is not valuable for those that take decisions, as risk characterisation should be geared towards a decision-driven activity aimed at informing choices and targeted at problem solving (**Stern and Fineberg 1996: 1**).

The activities of any given organisation involve risk management, which is identified, analysed, and then evaluated to ascertain if the risk should also be modified by risk assessors with the hope of satisfying risk criteria (**ISO 31000:2009**). Risk characterisation is a prelude to taking decisions which are dependent on an interactive, analytic and deliberative processes (**EPA 2000**). Risk characterisation is a qualitative and/or quantitative approximate which includes attending to uncertainties of the possibility of occurrence and severity of known or potential adverse health effects in a given population or environment based on threat (hazard) identification, hazard characterisation and exposure assessment **(FAO and WHO 2009; Williams and Paustenbach 2002**).

Duffus (2001) noted that risk characterisation is the incorporation of evidence, reasoning, and conclusions aggregated in hazard identification, dose-response assessment, and exposure assessment and the estimation of the probability (**Duffus 2001**); a mixture and summary of information about a hazard which addresses the needs and interests of managers and of interested and affected parties. Risk characterisation is a step forward before decision making, which depends on an iterative, analytic-deliberative process (**US NAS 1996**).

2.5.2 Tolerability of Risk in Nuclear Power Plants (ToR)

HSE expects that the highest risk that could be regarded as acceptable from any high-risk industry or plant in the UK should be one death a year in 10,000 members of the public. This, according to HSE is 10 times smaller than the limiting risk for workers. It is expected that organisation must do what they practically can to confirm that the actual risks exposed to workers and members of its public from most plants are much lower (**DM and P 1996; HSE 1992**).

The health and safety watchdog (HSE) hope that maximum risk that should be acceptable to the public of any accident in 100 and 1,000 deaths in the UK nuclear plant should not exceed at least one in 100,000 per year. This is not to say that the nuclear industries have done enough to meet these goals of tolerability; still, they are mandated by law to continually reduce the risks as low as reasonably practicable. The Nuclear Installation Inspectorate (NII) has the power to decide if the industry have done well by considering what is technically possible, what it would cost and what safety gains the organisation will derive (**HSE 1992**). Figure 4 shows tolerability of risk in any given high-risk sector in the UK.

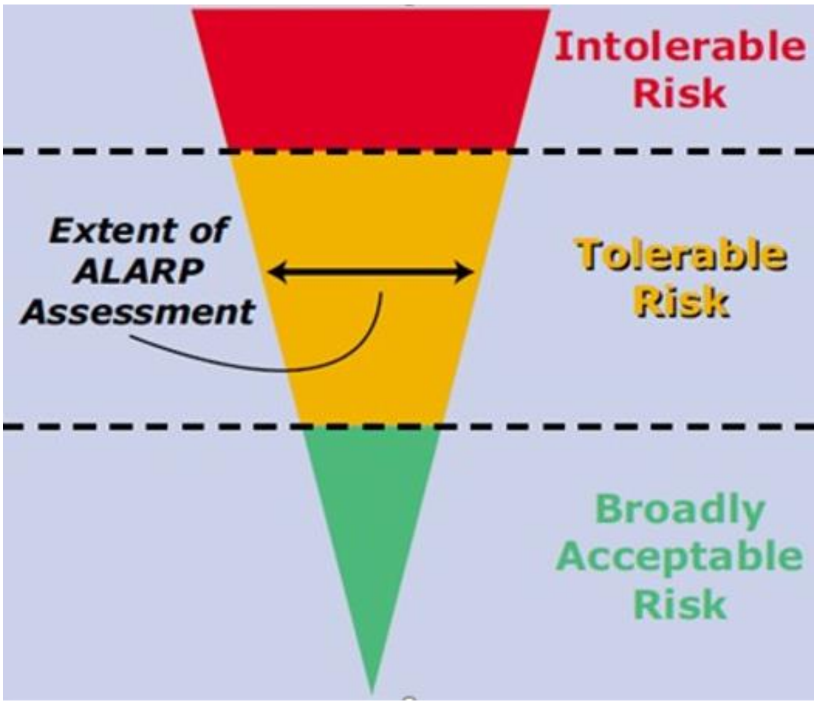


Figure 4: Tolerability of risk, as low as reasonably practicable-ALARP (HSE 1992)

Table 2 is the different categories of risk.

Table 2: Tolerability of risk

Unacceptable	If the risk is unacceptable, the operation or activity should stop immediately or not take place. Major mitigation will be necessary to reduce the severity if the risk actually occurs or reduce the likelihood of the risk occurring. Normally it is the likelihood of the occurrence that can be reduced rather than the severity.
Review	If the risk falls into the review category, the severity or likelihood of occurrence is of concern; measures to mitigate the risk to as low as reasonably practicable (ALARP) should be sought. Where the risk is still in the review category after this action has been taken it may be that the cost of actions required to reduce the risk further are too prohibitive. The risk may be accepted, provided that the risk is understood and has the endorsement of the Accountable Manager.
Acceptable	If the risk is acceptable the consequence is so unlikely or not severe enough to be of concern; the risk is acceptable. However, consideration should still be given to reducing the risk further.

Risk characterisation is important to the nuclear industry in managing safely as it creates a total conclusion about risk that is complete, informing, and useful to taking decisions. This view was supported by EPA (2000) as they noted that it helps a risk assessor undertake critical decisions (**EPA 2000**). It is also of importance because it helps to give useful information involving possible hazard situation which terms to address the need and interests to take decision. Risk is a prelude to taking decisions which is reliant on a cooperating, analytic and calculated process (**Stern and Finberg 1996; EPA 2000**).

Sabin *et al*. (2012), quoting Mitroussi (2003) states that when organisational survival is at stake, the people or staff should be willing to surrender old values or standard, practices and take up new methods. Therefore, an organisation should be willing to change its safety culture practices if there is a suitably strong and pressing internal or external risk or threat (**Sabin *et al*. 2012**).

Risk Calculation Matrix

Table 3: Using 5x5 Risk Matrix System

0 – 5 = Low Risk 6 – 10 = Moderate Risk 11 – 15 = High Risk 16 – 25 = extremely high unacceptable risk		Severity of the potential injury/damage				
		Insignificant damage to Property, Equipment or Minor Injury 1	Non-Reportable Injury, minor loss of Process or slight damage to Property 2	Reportable Injury moderate loss of Process or limited damage to Property 3	Major Injury, Single Fatality critical loss of Process/damage to Property 4	Multiple Fatalities Catastrophic Loss of Business 5
Likelihood of the hazard happening	Almost Certain 5	5	10	15	20	25
	Will probably occur 4	4	8	12	16	20
	Possible occur 3	3	6	9	12	15
	Remote possibility 2	2	4	6	8	10
	Extremely Unlikely 1	1	2	3	4	5

This research attempts to find out how risk is characterised in the nuclear industry, aimed at managing the sector safely. For instance, the Fukushima Daiichi accident is rated at 25 x 5 (almost certain at severity of potential injury/damage at 25 and extremely unlikely at 5 that is, the likelihood of the hazard happening) according to experts, either with or without hindsight of the accident.

2.6 Non-Technical Skills (NTS)

2.6.1 Introduction

Non-Technical Skills (NTS) is another pillar used in this research. NTS are means by which technical skills and knowledge can be applied (**Thomas 2018**). Therefore, effort was made to critically analyse the usefulness of NTS and what lessons the nuclear industry should learn from other high reliability organisations such as aviation and oil and gas that have used similar strategies such as Crew Resource Management (CRM) in aviation to manage safely.

2.6.2 Crew Resource Management

Regulators in aviation industry made it compulsory that CRM courses are planned to teach pilots on the importance of cognitive and interpersonal skills required to operate and manage flights within a required aviation system (**Flin *et al*. 2008**). The notion of CRM was initiated in the 1970s which was known as "cockpit resource management." It is the real application of different types of human factors, which includes communication, decision making, situational awareness, threat and error management (TEM) and team cooperation within the people that are responsible in flight operations (**Skybrary 2018; Scott 2018**).

Though the idea of CRM is a combination of both non-technical and technical skills. It seeks to effectively manage human resources with the hope of reducing risk and maximising efficiency (**Scott 2018**). Due to numerous aircraft accidents CRM was therefore developed to respond to those insights following the introduction of cockpit voice recorders (CVRs) and flight data recorders (FDRs) into modern jet aircraft.

Information gathered from these two devices revealed that a lot of accidents did not occur because of technical failure of the aircraft or systems, nor was it a failure of aircraft handling skills or lack of technical expertise on the part of the crew officials; rather, most accidents are triggered by the failure of crew members to respond properly to the situation at hand. Such inadequacies involve communication skills, breakdown in teamwork among colleagues, lack of situational awareness, and wrong decision-making leading to accidents (**Skybrary 2010**).

In addition to CRM, other measures taken by the industry to reduce accidents include safety management system; new technology for aviation safety; and simulation in aviation training (**Sabin *et al*. 2012: 180; Airbus 2017; Griffin *et al*. 2015; FAA 2007**). Scott (2018) noted that since the introduction of CRM in the early 80's, it has been made mandatory in most trainings and there have been six 'generations' of CRM (**Scott 2018)**, adding that each successive generation was improved to build upon the successes and lessons learned from previous generations (**Scott 2018**).

2.6.3 The Sixth Generation of CRM

The sixth and present generation of CRM follows previous generations reflecting the fact that pilots should not only cope with human error while in the cockpit but should attend to threats to safety emanating from the entire operating environment (**Scott 2018**).

According to Scott (2018), the sixth generation of CRM is a set of countermeasures against threat and error which is based on empirical evidence gained from positive interventions within the operation. Data generated from the sixth generation CRM is gleamed from the system wide operation itself and widened the threat error management (TEM) through the recognition of the significance in the NTS within the operational environment (**Scott 2018**).

TEM relies on the entire system or process interrogated and probed to possibly identify the systematic threats. The idea is that empirical and active management of the applicable work environment (cockpit) can prevent threats degrading the level of safety (traditional CRM) skills and different methods are applied not only to eradicate, trap, or alleviate errors, but also according to systemic-specific threats to safety before they occur (**Scott 2018**).

2.6.4 Non-Technical Skills

NTS according to Flin *et al*. (2008) comprise cognitive, social, and personal resource skills that underpin technical skills (**Flin *et al*., 2008**). The authors emphasised that cognitive, social and personal resource skills go with technical skills and contribute to safe and well-organised task performance. Quoting Hopkins, Flin *et a*l (2008) stated that organisational safety is influenced by regulators and commercial pressures, the environment and management demands (**Flin, O'Connor, and Crichton 2008; Hopkins 2000**). The seven NTS elements from Flin *et al* are: situation awareness (attention to the work environment), decision making, communication, teamwork, leadership, managing stress and coping with fatigue (**Flin, O'Connor, and Crichton 2008**). There is extensive discussion on these elements as indicated on Table 4.

Table 4: Seven elements of NTS and skill categorisations

NTS Type	**Skill Categorisation**
Situational Awareness	Cognitive Skill
Decision Making	Cognitive Skill
Communications	Interpersonal Skill
Teamwork	Interpersonal Skill
Leadership	Interpersonal Skill
Managing stress	Personal Resource Skill
Coping with fatigue	Personal Resource Skill

Flin *et al* (2008) noted that to avert accident from occurring is to ensure organisational changes are designed to support flow of information, decision-making processes and many others. Turner (1994) believes it is this recent tactic that will probably help in preventing accidents and counteract socio-technical risks (**Turner 1994**). Again, Flin *et al*., referring to Reason (1997), noted that while human fault is unavoidable and inescapable, humans can also be great by providing the indispensable resilience and knowledge capable of creating smooth operation of imperfect technical system in a threatening environment (**Fletcher *et al*. 2003**).

For instance, Barnett *et al.* (2006) said that the use of NTS is a vital ingredient in averting accidents, citing the maritime sector as an example. An accident database drawn from the UK, Canada, USA, Norway and Australia, state that human fault is always a leading influence in maritime disasters (**Barnett *et.al* 2006**); while Fletcher *et al.* (2002), maintained that training has put a lot of emphasis on acquiring basic knowledge and skills to sustain capable practice. They noted that skills such as teamwork, planning, decision-making, communication and resource management are inherently used with medical knowledge and clinical performances (**Fletcher *et al*. 2002**).

NTS can therefore be categorised into two sub-groups, namely: cognitive or mental skills, which comprise planning, situation awareness and leadership; and social or interpersonal skills, which refer to communication, leadership and teamwork (**Fletcher et al. 2002**). (See Table 4 for further explanation).

Endsley (1995) noted that experts must exercise level of control on human work to consider human behaviour in high complex cognitive roles that have high rate of accident. Because of technological development, it has created many multifaceted and dynamic structures that forces people to behave effectively and take timely decisions when operating machines (**Endsley 1995**).

Communication, another element of NTS shows that ineffective communication caused some accidents in different organisations. Enough evidence reveals that the behavioural causes of accidents and tragedies encompasses not just human mistakes and lapses. Turner (1978) stated that pattern of management and failure of some organisations is related to failures of information handling, communication, direction and error analysis of events or activities (**Trim and Caravelli 2008; Turner 1978**).

The US DoE (2009) states that irrespective of how efficient machines or equipment functions, provision of good training, accurate supervision and procedures, staff will never be efficient if they lack organisational support. Therefore, mistakes are not caused by typical human fallibility, but by unsuited management and leadership performances and weakness in work procedures and standards. As a result, having a defence mechanism in place in addition to the human element is required in improving resilience and reducing human error (**US DoE 2009**).

Patey (2015) explained that effective use of NTS is paramount to managing high-risk industries, including the nuclear power plant, as evidence has shown that most accidents that occurred in the nuclear sector are caused by human error (**Patey 2015**). However, when evaluated in an emergency management situation, leadership requires timely selection, application and intervention of non-technical skills; namely situational awareness, decision-making, communication and teamwork, to manage active outcome (**Flin *et al* 2008:134**); where the most effective emergency leaders diagnose the situation and select a soothing leadership approach from an authoritarian scale to align their individual style to the situation (**Flin 1996**).

Examining the Rail Safety and Standard Board (2016) report stated that making mistakes could be unavoidable, but non-technical skills can be developed to help mitigate and manage errors. An instance was when a train dispatcher who is meticulous and has knowledge of situational awareness will be more likely to notice threats as they occur on the train platform (**RSSB 2016**).

If staff are good at making decisions, communicating with other team members and managing workload, they may act to successfully alleviate any danger (**RSSB 2016**). As a result, analyses of accidents in a range of safety critical industries proves that NTS are significant in helping front line/operators' safety critical staff to identify, manage, lessen and improve from threats and errors (**RSSB 2016**).

2.6.5 Human Factor and NTS Elements

Non-technical skills contribute significantly to the management of everyday human error. Thus, it is poor non-technical performance that permits error to compromise the safety of a process (**Thomas 2018**). In any multifaceted industrial facility such as nuclear power plant, a lot of tasks are executed by machines. Nonetheless, humans are still involved to a great degree in designing, testing, maintenance and operation.

How the individual working in that environment perform, depends on the capabilities, limitations and attitudes, and more so on the quality of instructions and training provided. So, the interface between a machine and its operators in any given industrial project is commonly known as the human factor (**NEA 1988**). Additionally, in oil and gas, human factors are recognised as the major contributor to accidents during drilling and operations (**Raza *et al*. 2019)**.

2.6.6 The Seven Elements of NTS

2.6.7 Situation Awareness (SA)

Situation awareness has been noted in many accidents in high-risk industries (**Thomas 2008**). For instance, operators lost SA as while working at Chernobyl and Three Mile Island on a different mental model of the situation; ignored normal safety warnings and override the regular protective equipment (**Flin *et al.* 2008: 18; Kletz 2001**). The incident was not properly identified by staff working on the reactor, which led to the inappropriate operation of the reactor's control rods (**Grishanian 2010**).

SA is the 'perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' (**Endsley 1995**). During World War 1, situation awareness was recognised as a key tool by military aircraft crew. Thereafter, it received global attention when major research on the topic was carried out in the 1980s by aviation and air traffic control (**Salmon *et al*. 2009: 7**).

SA is used to define the cognitive skills which relates to picking and understanding of information to enable people to make meaning of the work environment, which is regarded by psychologists as perception or paying attention. It is a constant observation of the environment, identifying on-going activities and detecting any changes (**Flin *et al*. 2008**). SA also means the knowledge and comprehension of what is happening within a given environment. In a complex situation and working under intense pressure sometimes requires too much information/data to process, as it requires front line staff to sieve information (**Patey 2015**).

Understanding SA helps to form an understanding that is designed to fully explain the reason embedded in human behaviour, which helps in designing human machine borders and gives fresh understanding as to why accidents occur (**van Winsen *et al*. 2015**).

Three Mile Island (TMI) Case Study on Situation Awareness (SA)

In March 1979, some failures contributed to the loss of coolant which affected one of the reactors at TMI nuclear power plant. The loss of coolant and the resultant overheating of the nuclear core caused a serious problem. That chain of events affected the control room operators as they failed to notice that critical valves had remained closed after maintenance work had been completed in the days before the incident occurred (**Thomas 2018: 170**).

The design of displays in the control room misled the control room operators to assume that other valves were closed when they were not. So, the failures of SA caused the loss of coolant to the reactor. This case includes issues relating to SA which have their origins in system design, display locations and formats, also inaccurate mental models of the control operators (**Thomas 2018: 170**).

2.6.8 Models of situation awareness

There are various situation awareness models available in the literature. Endsley's three level model (Endsley 1995); Smith and Hancook's perception cycle model (**Salmon *et al*. 2016**) and Bedney and Meisters' Interactive subsystem approach to SA model (**Salmon *et al*. 2016**). Situation awareness models vary in terms of their basic psychological approach. Endsley's (1995) three level model represents a mental theory model which uses an information processing approach, while Smith and Hancook's model uses the environmental approach and Bedney and Meister's approach is an activity that is based on a model to describe situation awareness (**Salmon *et al*. 2009: 12-13**).

Endsley's (1995) three level generic model in Figure 5 focus on the effect of situation awareness and decisions made by an operator in crisis conditions. Factors that affect situation awareness are recognised in the model. These three levels form a chain of information processing, the first level being perception of the elements in the environment, the second level understands the information gained at the first level and projection of future status forms the third level (**Salmon *et al*. 2009: 10; Flin *et al*. 2008: 23**). Figure 5 showing models of situation awareness.

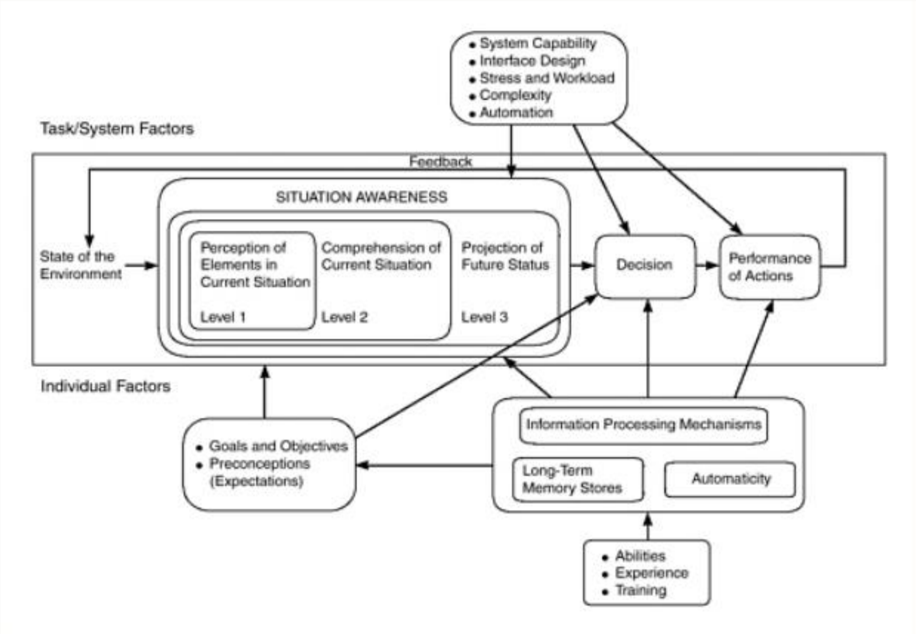


Figure 5: Model of situation awareness (Endsley, 1995: 35)

Level 1: Gathering Information

On Endsley’s (1995b) model, the first stage of situation awareness is regarded as ‘perception of the elements in the current situation’. A pilot would maintain the perception of his information regarding traffic in areas where there are mountains or warning lights (**Endsley 1995**). For situation awareness to be analysed properly, there is a need to obtain the right information. It is common to lose focus from one element or become focused on another, whereas, some key information is overlooked. For instance, in 1978, a United Airlines DC-8 crash was because the fuel ran out as crew were busy trying to fix a landing gear problem and did not observe the fuel indicator reading (**Flin *et al*. 2008: 24**).

Level 2: Interpreting Information

Level 2 of situation awareness needs the operator to go beyond information gathering. At this level the operator needs to process incoming information and evaluate the importance of the information in the light of set goals. Based on the information on level 1, those who take decision should form balanced picture of the situation, appreciating the significance of the objects and the events. Changes in projected results need to be examined by experienced operators. A learner operator may just get the Level 1 situation awareness information but will not be able to get to the level of interpretation. An experienced decision maker will be able to incorporate different data elements together with the desired goals to better assess the situation (**Endsley, 1995; Flin et al. 2008: 25**).

Level 3: Anticipating future status

The last and third level of situation awareness focuses on looking ahead to the future. Based on the current information gathered on the environment and the dynamics, a skilled operator can forecast the future and take needed action to circumvent any event. For instance, if a military pilot gathers that an enemy aircraft is on the offensive in a recognised location, the pilot can calculate the style of attack by carrying out a mental simulation (**Endsley 1995b**).

Three levels of SA are summarised as follows:

Situation awareness is based on more than observing information about the environment. It equally includes understanding the meaning of that information in a cohesive or integrated form, juxtaposing it with operator goals, and providing anticipated future condition of the environment that are essential for decision making. Therefore, situation awareness is a wide construct that is applicable across a variety of application areas, with shared fundamental cognitive processes (**Endsley 1996**).

Jones and Endsley (1996) study of the Aviation Safety Reporting System (ASRS) database was used to determine situation awareness related accidents. It was found that 76.3 per cent of the accidents were related to level 1; 20.3 per cent were related to level 2 and 3.4 per cent were related to level 3. The high proportion of level 1 accidents show that training system is essential to increase the basic level of situation awareness in safety critical industries (**Jones and Endsley 1996**).

2.6.9 Team working

Teams are a set of two or more individuals that relates work toward achieving a shared goal, objective, and or mission (**Salas *et al*. 2015)**; for teams to record success, they must accomplish particular tasks (**Morgan Jr *et al*. 1986**); communication, co-operation and co-ordination are crucial to achieving tasks, which is dependent on effective team-working. As failure of applying teamwork to the situation caused the USS Greeneville of 2001 nuclear submarine accident (**Flin *et al*. 2008: 94**).

Team working depends mostly on the collective behaviours and what the team members are doing. It focuses on attitudes, how staff feel or behave and depends on cognitions which rely on what the team members think and or what they know that is needed for the teams to achieve tasks. Therefore, it is important to note that both task-work and teamwork are important to achieving positive team tasks and relying on each other to be effective. Teamwork is a changing, lively and sporadic process that could compromise thinking, feelings and attitudes within members of a team to be effective. It helps staff members to understand how tasks and goals are achieved within a team (**Salas *et al*. 2015; Wildman *et a*l. 2012**).

2.6.10 Teambuilding and maintaining

Psychologists have concluded that giving support to other team members contributes to team performance and promotes members comfort (**Zaccaro *et al*. 2001**)

Four aspects of team support are identified as:

(1) Emotional: This implies encouraging one another and being sympathetic to each other.
(2) Informational: Team members are expected to exchange vital information needed for the work.
(3) Instrumental: This is practical support that team members give each other, which has to do with being useful during either sickness or unforeseen challenges.
(4) Appraisal: Providing alternative ways to solving problems (**Darch-Zahavy 2004**).

2.6.11 Conflict resolution

Although conflict has negative connotations and has the possibility of leading to poor teamwork, or even teams breaking up, however, constructive conflict can be helpful to teams (**Flin *et al*. 2008; cited from West 2004**). The skills for conflict resolution are promotion of useful debate, while eradicating dysfunctional conflict; combining the conflict management strategy to the source and nature of the conflict and using integrative strategies, instead of distributive strategies (**Flin *et al.* 2008**). Conflict can occur due to task, team processes and interpersonal changes. However, explanation of roles and responsibilities has the tendency of reducing team process conflicts, and sustaining an unbiased, non-emotional focus which reduces the potential for interpersonal and role conflict (**Lingard *et al*. 2002**).

2.6.12 Communication

Communication is a vital skill to effective and safe task procedures in any safety critical or high-risk industry (**Clarke 2012**). Clear and succinct communication has the capability of eliminating any information that will affect successful operation (**Kleij 2009**). Communication is a shared procedure of team members that sends and receives information which tends to shape and re-shape a team's way of behaviours, and thoughts (**Connaughton and Daly 2004; Craig 1999**). It is about giving and receiving information, response, thoughts and feelings. It gives understanding, establishes contacts, creates predictable behaviour forms, upholds attention to tasks and serves as a tool for management (**Wiener, Kanki, and Helmreich 1995)**. Cobley and Schulz said communication means sharing or have a relationship with somebody, an act of doing something in common (**Cobley and Schulz 2013**).

Patey (2015) explained that healthcare personnel are told that 90 per cent of making a good diagnosis is to take a good medical history of the patient. However, what is not taught is how to communicate effectively and safely in the work environment. Another missing point is how to be assertive when someone senior to you is making mistakes, listening attentively, and being open. She said being rude hinders communication as studies have shown that being rude in the work environment reduces cognitive skills (**Patey 2015**). Figure 6 shows effective feedback in communication, while Table 5 show barriers to communication in high-risk industries.

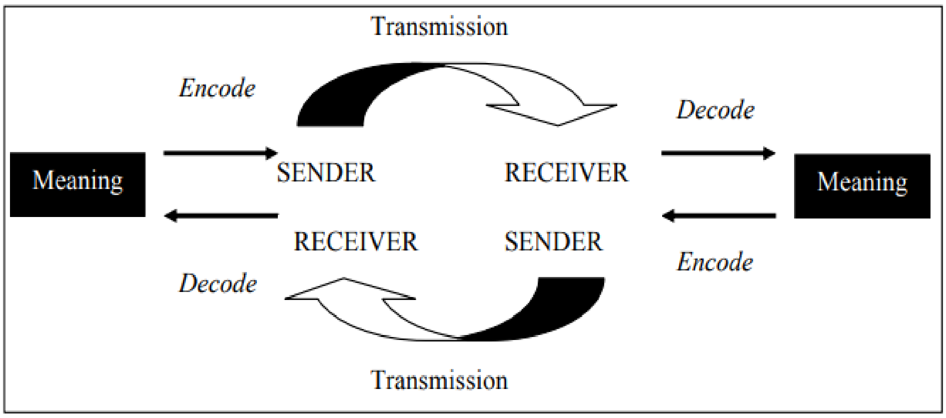


Figure 6: Effective feedback in communication (Flin *et al*. 2008)

Table 5: Barriers to effective communication in high-risk industries (Thomas 2018)

BARRIERS	**DESCRIPTION**
Cultural	Often, teams are comprised of individuals from different disciplines, which bring their own historical professional cultures. The professional cultures, when misaligned, can prevent barriers to effective communication and teamwork.
Technical	Sometimes the different disciplines have very different technical knowledge and expertise. This makes communication about non-normal situations more difficult due to constraints in establishing a shared mental model and in using appropriate terminology.
Physical	The physical barriers that are present in any distributed teamwork can constraints communication.
Organisational	Having teams comprised of individuals from separate departments in an organisation can also be present barriers to effective communication.
Hierarchical	Institutionalised hierarchies, such as chain of command, can present significant barriers to communication, as junior team members often feel unable to speak up when something goes wrong.

2.6.13 Leadership

Leadership has been defined as a process of social influence that inspires people to pursue targeted goals (**Quinn and Quinn 2015: 8**). Effective leadership is vital for maintaining safe performance in the workplace (**Hofmann and Morgeson 2004; Glendon *et al*. 2006**). Leaders influence main worksite safety behaviours such as compliance with rules and procedures (**Thompson *et al*. 1998**) and manage serious incidents (**Flin 1996**).

The term 'safety leadership' is commonly used in industry which refers to managers and supervisors' leadership behaviours in relative to safety outcomes. It is expected that safety leaders should create an atmosphere in which unsafe acts are confronted, while safe behaviours are promoted to achieve a workplace free of harm (**Step Change in Safety 2006**).

Flin and Yule (2004) recorded examples of safety leaders as follows: monitoring and supporting workers' safe behaviours; partaking in workforce safety activities; being supportive of safety ideas; and emphasising safety over productivity or profit (**Flin *et al*. 2004**); as safety leaders are meant to create an environment in which unsafe acts are questioned, while safe behaviours are promoted to achieve a safe workplace (**Flin *et al*. 2004**).

Example of leadership failure was Occidental Petroleum (Caledonia) Ltd's Piper Alpha oil and gas production platform, which suffered an explosion on the production deck of the platform in 1988. It is believed that the crisis on Piper Alpha could have been well managed, but 'it seems the whole system of command had broken down'. Lord Cullen's official inquiry report revealed that 'the failure of the offshore installation managers (OIM) could not cope with the problems they faced on the night of the disaster which clearly demonstrated that conventional selection and training of OIMs is no assurance of capability to cope if the manager is not able in the end to take serious decisions and lead those under his command in a time of dangerous stress' (**Cullen 1990**).

2.6.14 Decision Making

Decision making is an important talent especially in high-risk industries especially when the individuals involved are working under time pressure and stress. It is a procedure of reaching a judgement or selecting a course of action designed at meeting certain needs (**Flin *et al.* 2008**); as operators are constantly challenged with non-normal and in some case unexpected situations in which they must efficiently respond for them to maintain safe and efficient operations (**Thomas 2018**).

Nutt and Wilson (2010) noted that decision making is about making choices from different alternatives that are often unclear, but in an attempt to choose wisely for the interest of the organisational and its stakeholders (**Nutt and Wilson 2010**). There are different types of decision-making techniques (**Flin *et al*. 2008: 41**); however, these techniques are dependent on situations and circumstances, while some of those are relevant to safety critical decisions (**Flin *et al.* 2008**).

Patey (2015) twin process theory said there are two forms of decision making. One is intuitive decision making, which depends on context. Most mistakes happen with this form of decision-making. The second type of decision making is based on analytical theory. This mostly occurs when people come across a new challenge. This type takes too much time, hard work, and human nature is to return to intuitive decision making as quickly as possible (**Patey 2015**). Figure 7 shows both intrinsic and extrinsic ways decision-making is taken.

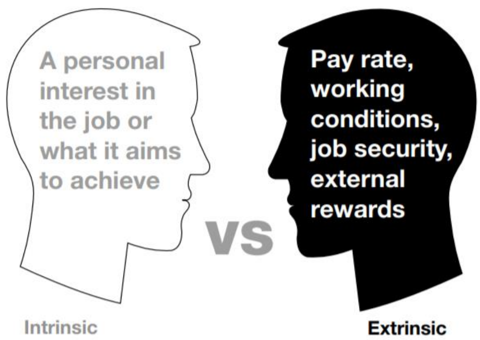


Figure 7: Intrinsic and Extrinsic decision-making

Thomas (2018) noted that in high-risk industries decision-making is done in a highly controlled environment, where a decision is taken in a time-critical way with often quite limited information available. It also highlights that decision-making is always in a team-based operation, as there are a lot of complexities from information transfer, shared mental models and influences surrounding decision-making. There are also contextual factors such as time pressure and stress accorded to decision making (**Thomas 2018**).

2.6.15 Traditional decision-making theories

There are basically two types of decision making, the slower and the faster (**Kahneman 2012: 13**). Slower decisions should be taken where those taking the decision have a lot of time and all useful information is accessible to execute a decision. In a dynamic environment, a decision may be required promptly because of time constraint to create options and then evaluate each of those options and choice made. In such a situation, decisions are made based on the individual's knowledge. To arrive at the appropriate decision some complex thinking takes place in the mind of the person involved in taking the decision based on his/her feeling or instinct (**Flin 1996: 141**).

2.6.16 Naturalistic Decision Making (NDM)

Since the mid-1980s, interest has risen by applied psychologists and researchers in naturalistic decision making. Its purpose in research is to explain how decision makers arrive at decisions under uncertainties, stress and limited information and time available at their disposal. It is noted that NDM has been useful in a lot of high-risk safety industries such as military, aviation, nuclear power generation and acute medicine (**Flin *et al.* 2008: 44**). Research conducted on NDM was to find out which approaches people used to make decisions and how tough decisions under uncertain conditions are arrived at. It revealed that while taking decisions, options and evaluating options were not generated. Instead, experience was used to match the situation then followed by decision making (**Klein 2008**).

2.6.17 Model of NDM

In a work environment, there is a continuous cycle of monitoring the situation, assessing/checking the state of events and then taking proper actions and re-evaluating the results. This is occasionally referred to as dynamic decision-making

(**Flin 1996**). Figure 8 explains how NDM is applied to a range of operational work settings, as the model portrays a two-stage process by carrying out a situation assessment and secondly uses a decision method for choosing a course of action (**Flin *et al*. 2008**).

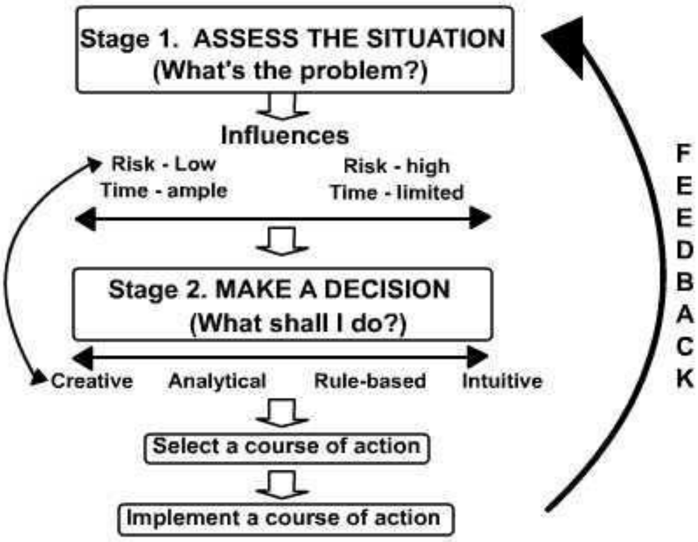


Figure 8: Decision Making Model (Flin *et al*. 2008: 44)

2.6.18 Managing stress

Gray (1998), quoting Hans Selye in his book 'The Stress of Life' (1956), gave a definition of stress as a condition revealed by a precise condition of biological actions. Gray suggests that it was not "nervous tension," or "discharge of hormones from the adrenal glands," nor "basically the influence of some negative occurrence," but maintained that it was "not an entirely bad event." Stress, according to Selye (1956), is the general response of the body to any request on it for change or adaptation, any kind of normal action capable of producing significant stress that cannot cause any damaging effects (**Gray 1998**).

Similarly, the Health and Safety Executive (**HSE 2005**), defined stress as the adverse response people give due to extreme pressure or load they receive (**HSE 2005**). Quoted in Flin *et al*. (2008), Lazarus and Folkman (1984), defined stress as a type of association between someone and environment which is recognised by the individual as going beyond limits and equally risking his or her comfort (**Flin, O'Connor, and Crichton 2008**). According to Scott (2018), stress sometimes arises due to the seeming gap between the demands of a situation and an individual's capability to manage those challenges (**Scott 2018**). It is believed that stress has been associated with safety outcomes, such as accident involvement (**Cooper and Clarke, 2003**). Therefore, the ability to diagnose and manage stress in oneself and others is a vital NTS (**Flin *et al*. 2008**). Indicated in Figure 9 are examples of stress.

Figure 9: Examples of stress (DFSB 2018: 114)

2.6.19 Coping with fatigue

Fatigue has been defined as the condition of being tired which is related to long working hours, continued periods of not sleeping, or needing to work at odd hours (**Flin, O'Connor, and Crichton 2008**). Fatigue is a complex condition considered as a lack of awareness which can reduce mental and physical actions or alertness and often associated by tiredness. Fatigue is described as not one basic event that could be easily explained, instead, it is the combination of multiple features linked to biological sleep requirements (**Nesthus 2009**).

According to Foster et al (2015), fatigue is a complicated issue, with physical signs such as having low energy or the need to have rest. There is also the cognitive aspect of fatigue which is reducing awareness and affecting inspiration; it is considered to be experiencing the sensation or feeling of heavy eyelids, lack of concentration, reduced energy, nodding heads constantly, grogginess or unsteadiness (**Foster *et al*. 2015; Flin *et al*. 2008**).

Stress and fatigue equally have effect on people in a working environment. It is believed that 24 hours of non-sleeping has the same effect as one blood containing 0.1 per cent of alcohol. Other possible causative reasons include extreme workload, dealing to mistakes made by oneself, others, and inadequate professional assistance and training (**Patey 2015**).

These seven elements were critically assessed using an online survey to test if the three organisations, especially the nuclear sector are in any way using them to manage safely. The findings are contained in the result analysis of this report.

2.7 Measuring NTS in the Workplace and its Limitations

There are several methods which relate to or contain references to NTS such as personality measures, psychometric assessments, structured and unstructured interviews, group activities, and work sample tests. These criteria have different advantages and disadvantages and purposes. For instance, psychometric assessments can be used to measure or determine the cognitive skills which can influence the demonstration of NTS such as reasoning, attention and being vigilant (**RSSB 2016**).

Structured interviews and personality measures like situational judgement exercises can be used to measure NTS such as co-operation and teamwork, communication, carefulness and managing oneself (self-management). See Table 6 on how to measure NTS and characteristics to observe (**RSSB 2016**).

Table 6: Measurement for NTS (RSSB 2016)

Opportunity	Benefit	Weakness
Observations	Can be used on the job and during simulated scenarios.	Can be distracting. Not all NTS can be observed, for example those relating to decision making.
Talk throughs	Staff asked to talk through actions as they complete them so more NTS can be measured. 'What if' questions can be used to help understand how staff would demonstrate NTS if different situations occurred.	Staff can find it hard to carry out tasks and explain them at the same time. Some NTS can be difficult to articulate.

Interview	Staff talk through actions and NTS can be explored in detail.	Interview is not carried out while the person is completing the task and so it can be difficult to clearly relate NTS to the technical tasks.
Review of performance, including review of incidents, accidents and/or near misses	Information is readily available. Investigations of incidents, accidents and near misses can draw out NTS. When a staff member has dealt with an unusual event you can use a structured interview to understand the demonstration of NTS.	There can be a risk of assumptions being made about an individual's behaviour. Review needs to be supplemented with observations or talk throughs.
Team measurement	NTS is measured within a team activity to understand how individuals and teams demonstrate NTS.	May need more than one assessor to be able to measure individual and team NTS.
Simulated measurement	Use of simulators, role plays, emergency drills, and desk top exercises can help to simulate events that staff may not experience regularly. Observations and talk throughs can be used to help measure NTS.	Still an artificial environment and can be costly to organise.
Peer measurement	Staff NTS are measured by their peers to help facilitate personal development.	Peers will need detailed training. Should only be used for personal development and not used to inform competence decisions.
Self-assessment	NTS self-assessment questionnaire to facilitate awareness and personal development. (see Figure 6)	Should only be used for personal development and not used to inform competence decisions. Best to combine with another assessment method as individuals tend to overestimate their ability.

2.8 Organisational Learning (OL)

2.8.1 Introduction

Organisational learning (OL) is the third pillar used to determine if high-risk industries such as the nuclear, aviation and oil and gas are learning organisations which could be used to effectively manage workplace safely. The three sectors were engaged in this research and assessed using an online survey.

2.8.2 OL

Organisational learning is an effective procedure to process, interpret and respond to internal and external information of a largely clear nature (**Easterby-Smith *et al*. 1999**); it also helps organisations to change individual knowledge into organisational knowledge (Basten and Haamann 2018a). Maybey and Salaman (1995) explained that organisational learning is concerned with the expansion of new knowledge or understanding as organisations have the potential to influence behaviour; it occurs within the wide institutional setting of inter-organisational relationships (**Mabey and Salaman 1995; Geppert 2000**).

Argyris and Schon (1978) said organisational learning refers broadly to an organisation's acquisition of understanding, know-how, techniques and practices of any kind and by any means (**Argyris and Schön 1978**). Cohen and Levinthal (1990), quoted in Alonso and Austin (2017) noted that the significance of organisational learning is for organisations to exploit external sources of knowledge and positively affect internal innovation processes. Despite many academic contributions, numerous knowledge gaps concerning OL have been recognised (**Hsu and Pereira 2008; Lichtenthaler 2009**).

Cartwright *et al.* (2001) noted that organisational learning is a process that requires coordinated systems change with mechanisms built in for individuals and groups to achieve, build and use organisational memory, structures and culture to develop a longer term organisational goal (**Cartwright et al. 2001**). One important key aspect to organisational change as suggested by Argyris (1977) and Senge (1990) is the ability of an organisation to learn. Both maintained that organisational learning is sometimes recognised as an organisation that is adjusting to environmental change **(Argyris 1977; Senge 1990**).

Somehow, OL is equally seen as a development in the sense that people in that industry adhere to changes both internal and in the external environments. Errors are immediately corrected to sustain the structures or ideas of the organisation. According to proponents of change, they believe that change follows mistake detection and being inquisitive of fundamental policies and goals as in “generative” or so “double loop-learning” (**Argyris 1977**).

OL gives different pattern for systems to cause change by allowing people to interpret the economy and society in a different way (**Probst and Buchel 2000**). The chief reasons why organisations should learn is due to increased demand on organisations to change; and the fact that change accelerates speedily, therefore, organisations are supposed to find their footings in an environment that is becoming more complex. Any organisation that refuses to learn, has the potential to be a loser; and learning is the only lasting solution to achieving viable advantage (**Probst and Buchel 2000; Geus 1988**).

Toft and Reynolds (2006) said organisational learning is a collective, thoughtful and saturating procedure that all personnel in the organisations learn to comprehend and continuously reinterpret the environment they work in through acquiring experiences (**Toft and Reynolds 2006**). If accidents re-occur due to the same reasons, then it could be assumed that organisational learning that took place after an event occurred have the possibilities of retaining similar characteristics. If there is better understanding of the process of reporting events back and learning from it, chances are they could be design procedures and strategies that will help organisational learning and reduce great losses (**Toft and Reynolds 2006**).

However, Tsang (1997) thinks differently. He said organisational learning is better described as attempts by individual organisations to tilt towards becoming learning organisations by simply encouraging learning in a sensible, methodical and synergistic manner that involves all people in the organisation. A learning organisation is the peak of organisational learning whereby an organisation has attained the skill to always transform itself by developing and involving all members of the entire team (**Tsang 1997**).

Argyris (1990) recognised that traditional methods to learning are a barrier against promoting organisational learning, that failure to have centralised learning gives the justification for organisation to learn. Argyris (1990) stated that because environment is changing at a fast rate, and the responses required are varied, therefore, organisations should not wait for handful of senior managers to recognise what needs to be changed in an organisation; by the time they realised the need for change, the opportunity would have gone (**Argyris 1977, Wilson 1992**).

In contrast, organisational learning relates to the connection between the speed, repetition and degree of change in the society and the ability to learn. This affords the basis to which an organisation desires to move completely away from archaic method of learning and relies at the speed and nature that takes place in that environment **(Bateson 1972, Revans 1982**).

Though different authors gave the basis for organisational learning, this is still debated in different quarters that it is in no way closer to defining what organisational learning is. Conceivably, the most acceptable meaning is that learning is bringing everyone in the same organisation to accept change (**Stata 1989**). Friedlander (1984) stated that learning empowers people to determine choosing from different variables or choice in whether to change, such an action may not lead in any noticeable changes in attitudes. Nevis et al. (1995) said procedure of how organisations learn could be very complex and does not happen in a linear progression, somehow it could occur intentionally, unintentionally and informal (**Friedlander 1984; Nevis *et al.* 1995**).

Drawing upon these statements, it can be said that before organisations and people can accept new characters or changes, the first thing that happens is for them to "unlearn" former behaviours and procedures which they had acquainted themselves with before they can become accustomed to or adopt to change new behaviours (**Nystrom and Starbuck 1984**). Most authors, certainly the sceptical school of thoughts view organisational learning as an intricate development that unfolds over a period of time, instead they believe it is linked with knowledge acquisition and improved performance (**Nystrom and Starbuck 1984; Garvin 1993**).

Garvin (1993) however gave reasons why organisations refuse to learn. He said except there are changes to the way work is planned and completed, obviously there will be no significant improvement to learning, which is likely to happen and invariably hinders organisational existence. Garvin's view corroborate with Bateson (1972), Argyris and Schon (1978) observations (**Garvin 1993**).

Debunking all assertions attributed to organisational learning, Vicker (2013) noted that organisational learning is contradictory. To him, if organisational learning means anything, it is rather on the side of the individuals that function in that organisation. Organisational learning is said to be important as it improves safety culture and recognises that individuals working in an organisation learn new methods or ways of reasoning through varied understanding for a long period of time (**Vickers 2013; Kim 2015**).

Pidgeon (1998) holds a divergent view on organisational learning. He said learning is paramount to managing organisations safely, that the issue of politics and power is conspicuously missing in most academic models of organisational disasters and many discussions of safety cultures likewise. Politics and power Pidgeon (1998) pointed out, are however serious to determine if a good amount of results of safety values are met, and most importantly organisational learning (**Pidgeon 1998)**.

Despite several arguments by different authors on organisational learning, this research tends to align with EDF (2017) which clearly incorporates human performance, nuclear safety culture and corrective action programme as organisational learning. The organisation further stressed that organisational learning emphasises minimising the frequency and consequences of human errors achieved through training, active use of human error prevention tools and serious supervision, performance teaching and the identification and reduction of organisational weaknesses through proper investigations into events, incidents, near-misses and performance trending of sub-standard situations (**EDF 2017)**.

Nevertheless, Bell and Healey (2006) noted that effective organisational learning requires not only innovations and new processes but also their adoption and diffusion to other parts of the organisation (**Bell and Healey 2006**); while Toft and Reynolds (2006) maintained that active foresight should be the goal of organisational learning process that should combine foresight of the possible causes of disaster, with action to remove or reduce the risk of those causes taking place (**Toft and Reynolds 2006**), as disasters must not be seen as meteorite that falls out of the sky on an innocent world; disaster, most often, is expected on multiple occasions (**Toft and Reynolds 2006**).

However, Vicker (2013) noted that organisational learning is contradictory. That, if organisational learning means anything, it is rather on the side of the individuals that functions in that organisation (**Vickers 2013**). This opinion is supported by Wang and Ahmed (2002) that learning commences from individuals (**Wang and Ahmed 2002**). OL is said to be important as it improves safety culture and recognises that individuals working in an organisation learn new ways of reasoning through diverse understanding for a long period of time (**Kim 2015**).

Pidgeon (1998) stated that OL is paramount to managing organisations safely, that the issue of politics and power is noticeably missing in most academic models of organisational disasters and many discussions of safety cultures likewise (**Pidgeon 1998**).

2.8.3 Types of Learning

Toft and Reynolds (2006) suggest that two types of learning are most likely to take place in an organisation: “passive learning and active learning.” Passive learning according to the duo is knowing or having an understanding about something; while active learning is understanding something and following it up by taking corrective actions to shortcomings that are seen to exist. Irrespective of the type of lesson learned after an inquiry into a disaster is published, without putting the lesson learned into practice is tantamount to learning nothing. There is no sense in understanding how to stop accidents if there are no active moves made to stopping it (**Toft and Reynolds 2006**).

2.8.4 Organisational Learning Theory

According to (**Argyris 2012**), they are two types of organisational theories which organisations should be conversant with to achieve success, vis-a-vis safety practices. They are single- and double-loop learning and single-loop and double-loop learning (**Chris Argyris 2012**) as indicated in Figure 10.

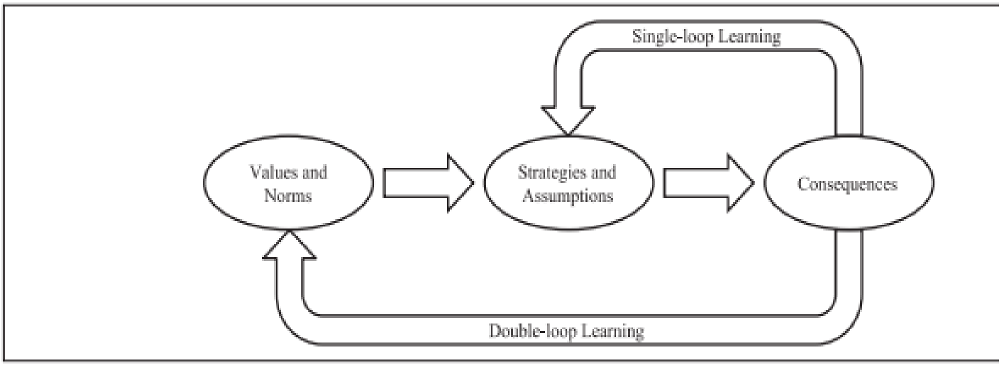


Figure 10: Single-loop and double-loop learning (Argyris & Schön, 1996: 22).

Single-loop learning: Single-loop learning theory is instrumental learning which changes strategies of action or assumptions underlying strategies in ways that leave the values of a theory of action unaffected (**Argyris 2012**). An instance is the identification and subsequent correction of a production defect. Engineers change the respective product specification to avoid the flaw in the future. Single-loop learning compares existing problems and organisational values and norms to develop an adequate solution (**Argyris 2012**).

Double-loop learning: In this case, if defect correction requires adaptations of organisational values and norms, then double-loop learning is required. It is a learning that results and focuses in value change of theory which is being used both in strategies and assumptions (**Argyris 2012**). This theory refers to two feedback loops that connect observed effects with strategies and values served by those strategies. Possibly, divergent organisational performance requirements could cause conflicts among different people in the organisation. Nonetheless, double-loop learning could be executed by persons, when it is obvious that inquiry could lead to change in the values of the theory used by organisations (**Argyris and Schön 1978**).

2.9 Isomorphic Lessons (Cross-System Learning)

2.9.1 Isomorphic Lessons (IL)

Evidence abounds from case study examples which indicate there are links between organisational change and accidents (**Bell and Healey 2006**). If organisations should be safe as reasonably practicable, they should learn (change) from their own experiences, and where suitable, learn experience from others through isomorphic lessons and organisational learning (**Toft and Reynolds 2006**). Put differently, accidents and disasters are unique, which may be the reason why the 'lesson learned' from such incidents are somehow not implemented in most organisations; as analysis of the outcome of events could indicate that the same lessons and recommendations keep re-occurring (**Symon and Cassell 2012; Kletz 2001; Toft and Reynolds 2006**).

However, accidents sometimes seem to have similar characteristics at some point or levels of analysis (**Toft and Reynolds 2006**). This observation when linked to Von Bertalanfy's hypothesis on the nature of systems, provokes questions about how far organisational learning can occur through the isomorphic features of an accident (**Toft and Reynolds 2006**). Therefore, isomorphic learning is a form of realistic strategy applied to manage accident with regards to organisation and management practice (**Toft and Reynolds 2006**). Moore (2009) noted that lessons could have been learnt when there is a corrective measure put in place to prevent future re-occurrence of the same event (**Trim and Caravelli 2008**).

Bowerman (2002) stated that organisations should take initiative to pattern themselves after an organisations sometimes during a period of uncertainty, or when achieving goals seems to be unclear (**Bowerman 2002**); as isomorphic is a responsive procedure, which comprised of analysis of past understanding to shape a 'hazard model' of what is expected to happen in the foreseeable future (**Kirkwood 1999**).

However, other views are that uncertain situations are the main circumstances that stimulate organisations to learn from others (**Cyert and March 1964**); when organisational machineries are not well understood; when it is confusing to achieve goals or possibly the environment creating some kinds of uncertainties, then an organisation may change pattern to be like other organisations (**Cyert and March 1964**). Though DiMaggio and Powell (1983) argued that sometimes organisations appear not to understand how to deal with some new challenges, and instead search for organisations to learn from (**DiMaggio and Powell 1983**).

Conversely, isomorphic learning as advocated by Toft and Reynolds (2006) is the ability of organisations to learn from similar experiences of others. They argue that lesson learned from different events or organisation could be applied to another setting to manage disasters effectively (**Toft and Reynolds 2006**).

Toft and Reynolds (2006) suggests that there are at least four separate ways through which organisations can learn using isomorphic study: event-based incidents; cross-organisational incidents; common-mode incidents; and in-house events (**Toft and Reynolds 2006**). Lessons derived from isomorphic learning can generate useful ‘insight’ with the advantage of hindsight, which provides and increases foresight in another organisation. More so, increase in foresight leads to changes in organisational safety values leading to where workers can speedily learn from unwanted accidents and better the company’s chances of survival (**Toft and Reynolds 2006, Kim 2015**).

But Trim and Caravelli (2008), referred in Moore (2009), noted that “lessons learnt” was a frequent contradiction that organisations constantly used in business continuity domains, instead the right word should be “lessons identified”. Moore (2009) stated that a lesson could be said to have been learnt when there is a corrective measure put in place to avert future re-occurrence of the same event. This view according to him was supported by Toft and Reynolds (2005:66) (**Trim and Caravelli 2008**).

On other forms of isomorphism, Bowerman (2002) explained that mimetic isomorphism is when industries or organisations takes an initiative to pattern (imitate) themselves after an organisation sometimes during a situation of uncertainty, or when achieving goals seems to be unclear. In such a situation, a company might use different approaches to improve their acceptability and reveal they are improving; it is a responsive procedure comprised of analysis of past understanding to shape a 'hazard model' of what is expected to happen in the foreseeable future (**Bowerman 2002; Kirkwood 1999**).

Though Krause (2013) and DiMaggio and Powell (1983), explained that IL is a compelling development which enforces an organisation in a given population to look like other organisations which may face almost the same type of environmental challenges (**Krause 2013, DiMaggio and Powell 1983**); still, some organisations have a habit of modelling themselves after the same type of organisations they noticed to be more successful (**DiMaggio and Powell 1983**).

Hannan and Freeman (1977) claim that isomorphism can result due to selection of non-optimal forms from a population of organisations or possibly because those that make decisions in an organisation learn suitable remarks and regulate their conduct appropriately (**Hannan and Freeman 1989**). Three methods were identified in which organisational isomorphic transformation can happen, each relating to a common background. They are coercive or forced isomorphism which emanates from political impact and the problem of legality. The second is mimetic isomorphism, which ensues from normal replies to unclear issues; and lastly, the normative or usual isomorphism which is related to professionalisation (**Hannan and Freeman 1989**).

However, isomorphic lesson is understood as sharing information on what went wrong irrespective of the location, as it is crucial to stop repeating similar mistakes. Somehow, it is believed that what is learned will help to make adequate progress to safety. This progress is applicable to designing new and maintaining or upgrading of current plants (**Christou *et al*. 2012**). The European Parliament and the Council believed that when there is exchange of information on past events and accidents, it will be of immense importance to avoid similar accidents repeating itself (**Christou *et al*. 2012**). The European view agrees with the idea this research holds, hence the need to find out if organisations are learning from past mistakes.

For organisations to learn, managers have a role to play in isomorphic lessons, which is, to increase safety by promoting learning from previous mistakes or experience (**Gordon 1996**). Managers should also provide an environment in which it is safe to work, and commitment to safety by senior management who must be seen at strategic and policy levels in communication, training, promoting positive safety policy and learning from other organisations and experience (**Gordon 1996**).

Kletz's (2001) said an organisation can learn from itself and not necessarily from others. He cited an instance at Three Mile Island where there were concerns with major accident failures, such as cracking of a primary water pipe, while smaller incidents and possible accidents were somehow ignored (**Kletz 2001**).

Kletz (2001) noted that there is a belief that if significant accidents could be controlled, therefore minor accidents could be controlled likewise. On the contrary, he insisted that it is not true as minor accidents could become major accidents. Equally, in most process industries, a lot of injuries and damage are rather caused by let-downs or failures, and failures of whatever source should be given attention (**Kletz 2001**).

Isomorphism: Case study

Toft and Reynolds (2006) noted that isomorphism had underlying similarity in the failure of systems of two seemingly disparate types, a bridge and nuclear power plant (NPP). The West Gate Bridge at Melbourne, Australia collapsed after a structural failure. It was later confirmed that the collapse was caused by the unsatisfactory nature of a computer program which was used to calculate the size and nature of steel required for the bridge's construction (**Toft and Reynolds 2006**).

In March 1976, it was revealed that five NPP in the USA were closed due to a seemingly 'simple mathematical error' identified in a computer program used to design the reactor cooling system (**Toft and Reynolds 2006**). In these two scenarios, there are quite different system, but approximately similar problem-defective design software caused to unwanted results (**Toft and Reynolds 2006**).

Another example of isomorphism was the loss of coolant water at the Crystal River NPP in Florida USA. An identical valve to that which malfunctioned at Three Mile Island (TMI) in 1979, stuck open and water-logged the reactor basement with 190,000 litres of very highly radioactive water (**Toft and Reynolds 2006**). In this case the Nuclear Regulatory Commission, which had conducted the inquiry into the TMI incident, had permitted the plant operators two exemptions from the recommendations which they themselves had suggested. According to some nuclear scientists, those two examples allowed the Crystal River incident to develop into an emergency (**Toft and Reynolds 2006**).

An identical valve to that which stuck open at both TMI and Crystal River malfunctioned again in precisely the same way at Davis-Besse in Ohio in 1985. Fortunately, on this occasion an operator noticed the drop in pressure and prevented the reactor from entering a dangerous condition. In the period between the two incidents, a report was published in Britain on an incident at the Heysham nuclear power stations, Lancashire, which discussed mistakes that were almost the same as the incident that occurred at TMI (**Toft and Reynolds 2006**).

2.9.2 Isomorphism: Ways Organisations Learn

According to Toft and Reynolds (2006), there are four different ways an organisation can learn by using isomorphic study. These are:

2.9.3 Event isomorphism:

This relates to where two different events occur in two entirely diverse ways which eventually lead to similar dangerous results. An instance of this was a train accident at Clapham Junction, where the driver passed a signal set at danger and occupied a track meant for another on-coming train. This is called a ‘signal passed at danger (SPAD) occurrence and classified under human error. Another event was when a train enters a track and the signal regulatory access did not change to red and equally allows other trains to rail on the same track at the same time. This was described as ‘wrong-sided signal failure’ (WSF) because the signal system was left in danger (**Toft and Reynold 2006**).

2.9.4 Cross-organisational isomorphism:

Cross-organisational isomorphism occurs when an organisation belongs to different ownership. The management and staff are recruited by different agencies or people but functions as one sector. That is, the organisations could be dissimilar in nature, have unrelated company names, settings, but on the other hand can be regarded as being identical because each produces the same goods or supplies similar services.

2.9.5 Common-mode isomorphism:

This describes organisations belonging to separate industries, but using almost the same or related tools, components and techniques to produce products. This practice could lead to having the same kind of challenges should accident occur. An example is the use of polyurethane foam in producing aircraft and furniture organisations to create seats, sofas and other furnishing materials.

2.9.6 Self-isomorphism:

This is where an organisation in question is big and has several organisational sub-units which produce different services. Most of the working units will be exposed to internal and external emergencies and therefore facing the same type of failure. (**Toft and Reynolds 2006**).

2.9.7 Learning from Past Events - Systems Approach to Isomorphism (Benefits of Publishing Accident Reports)

Kletz (2009) suggests that accident reports should be published to enable other organisations to learn from such incidents. He gave five reasons why it is beneficial.

a. Moral reason*:* If people or organisations have information that is capable to prevent an accident, then there is need to let others know about it.

b. Pragmatic reason: This relates to telling people/organisations about the accidents they have had, as they in turn will tell theirs; if people learn from others without giving information in return, then such an organisation that holds back information is known as "an information parasite." This is a term used by biologists to describe birds that rely on other species of birds to give warning of forthcoming dangers.

c. Economic reason: Many companies spend more on safety plans than other competitors, which is regarded as self-imposed tax. If other competitors know about the action their rival took after an accident, then they may spend as much as their rival has done to prevent that accident happening again.

d. Image loss: If one company has a serious accident, the entire industry suffers in loss of public respect, and these may be new legislation by which the whole industry is affected.

e. Impact of an accident report: If people or organisations read reports that inform them of modifications, they will agree and forget (**Kletz 2009: 587**).

2.10 Examples of Accidents in Nuclear, Aviation and Oil & Gas Sectors

2.10.1 Introduction

This research studied one accident that occurred in each of the three sectors, that is nuclear, aviation and the oil and gas sectors, with the hope of determining possible causes, relationships and lapses it has on NTS, isomorphic lessons, organisational learning and risk characterisation.

The three notable accidents are: Fukushima Daiichi NPP of March 2011 in Japan, the Hudson River Landing of a Passenger Plane US 1549 in January 2009 in North Carolina, USA and the Deepwater Horizon Oil Spill of 2010 in Houston, USA. Furthermore, this research likewise discussed low level or near-miss incidents across the three sectors. These are: Sellafield Sump Tank Levels Nuclear near miss incident of 2019; the Beech-200 King Air registered EC-KNP incident 2012 and EnQuest and Odjfell Drilling Sling Failure of 2018.

Analysis of these events were drawn using literature, publications from government related agencies, and video recordings aimed at linking possible causes to non-use of NTS, isomorphic lessons, organisational learning and risk characterisation to managing safely. Findings from these sectors served as lessons, that is, where there is no adequate application of NTS, such organisation will be prone to accidents due to limited understanding in humans (**Flin *et al*. 2008**); organisational learning, isomorphic lessons and risk characterisation also becomes important to safety management (**Toft and Reynolds 2006; Stern and Fineberg 1996**).

2.10.2 Summary of Fukushima Daiichi Nuclear Accident of 2011, Japan

Opinions are still divided on whether the failure of Fukushima Daiichi nuclear facility could have been prevented from happening (Khan, A. H., Hasan, and Sarkar 2018). People still believe that it was a twin natural disaster that caused the accident, which invariably no one could have predicted. However, others argued that lack of precautions was the main reason behind the disaster which could have been surely prevented (**Khan, Hasan, and Sarkar 2018**).

The Fukushima Daiichi NPP accident occurred by the Great East Japan Earthquake and tsunami. A report by the National Police Agency revealed that 15,884 persons were killed and 2,633 persons were still missing, as of March 2014 (**Nagasaki 2016**). The earthquake deactivated off-site power to the plant and caused the automatic blackout of the three functioning reactors - Units 1, 2 and 3 (**IAEA 2017**). The accident measured Level 7 on INES (**Power Tech 2017**). The accident led to complete destruction of the local communities and gave rise to conflicts between original residents and evacuees. These adversely gave serious physical, health and mental impacts on the residents in Fukushima (**Nagasaki 2016**).

The tsunami waves wrecked most of the safety and power systems, leaving only one diesel generator at Unit 6. (**Power Tech 2017**). This incident caused the damage of the cooling reactor cores, which led to the meltdowns of three reactors**.** The accident also caused the discharge of substantial quantity of radioactive materials which affected the environment, as hydrogen that exploded at the facility led to further destruction of the outside concrete and triggered the evacuation of people occupying at 20km zone (**Power Tech 2017**). The reactor pressure vessels (RPVs) which enclose the reactor cores were breached in the units, which caused radioactive material to escape from the reactors (**IAEA 2015**).

However, from the engineering point of view, the direct cause of the accident is the submergence of all metal clad switchgears and many power centres (**Nagasaki 2016**). The Tokyo Electric Power Company (TEPCO) investigated the sediments carried by the tsunami along the Pacific coast of Fukushima region. The study found that sediments at the altitude of approximately 4 meter in the north area of Fukushima but could not find in the south area of Fukushima Daiichi (**Nagasaki 2016**).

Technically, in Fukushima there are six units of Boiling Water Reactors (BWRs). These reactors are the oldest generation, which are BWR 3 and 4 (**Khan *et al*. 2018**). Each reactor unit had a reactor pressure vessel, a containment vessel and a reactor building. It also had a pool for spent fuels on the top floor of the reactor building. When the earthquake occurred, Units 1-3 were still in operation and Units 4-6 were shut down for normal inspection. This led reactor Unit 4 to stop, and fuels then moved into spent fuel pool. The fuels in the spent fuel pool of Unit 4 had high decay heat. This led to three reactors in operation of Units 1-3 to stop automatically due to the earthquake and emergency diesel generators that supposed to carry out emergency cooling and passive cooling system (**Khan *et al*. 2018**).

Transmission line towers and other equipment on the plant grounds stopped working because of the earthquake which also deactivated Units 1 through 6 from receiving external AC power. The Emergency Deiseal Generator (EDG) came up automatically, and the Isolated Condenser (IC) in the Unit 1 which is driven by battery became operational for core cooling. Though the IC was operated intermittently to avoid too rapid temperature change (**Khan *et al*. 2018**). Figure 11 shows the areas affected by the Great East Japan Earthquake.

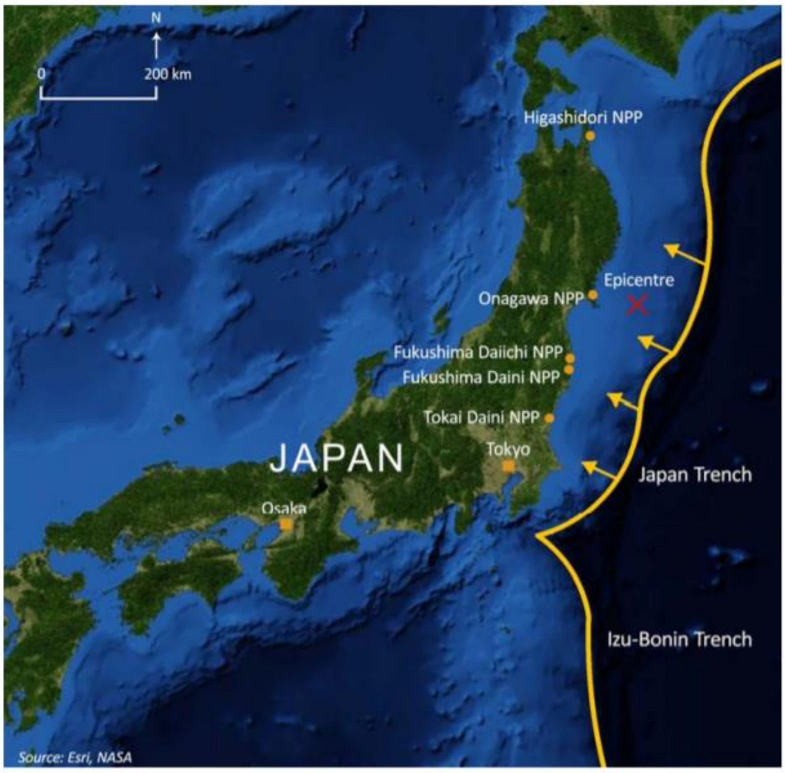


Figure 11: The Great East Japan Earthquake (IAEA 2015)

Apart from technical errors, human errors, apparently due to NTS lapses further worsened the accident (**IAEA 2017**); as the number of staffs at the plant were not enough to manage the accident due to the scope that affected several reactor units and the long duration that it lasted (**NCBI 2014**). This research scrutinised various publications from different authorities such as International Atomic Energy Agency (IAEA) on possible causes relating to the research areas. Table 7 shows possible to causes of Fukushima accident related to the four pillars.

Table 7: Possible causes of Fukushima Daiichi accident and relationship to NTS lapses, isomorphic lessons, organisational learning and risk characterisation

Lapses on all the four cardinal pillars leading to the accident					
S/No	**Possible causes**	**NTS**	**Isomorphic Lesson**	**Organisational Learning**	**Risk Characterisation**
1	How natural disaster - earthquake combined to cause continued power failure and complete damage of heat sink (IAEA 2017; NCBI 2014). Fukushima accident was caused by the Great East Japan Earthquake and tsunami (Nagasaki 2016).	No knowledge of situation awareness (attention to work environment) and poor leadership contributed to the accident (Flin *et al*. 2008).	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.
2	Worsened by human failure which further impaired operator's accident management ability (IAEA 2017). In Unit 2, the Reactor Core Isolation Cooling system was not stable, and the reactor core was not cooled suitably, and the Reactor Core Isolation Cooling system equally stopped functioning (Khan et al. 2018).	Lack of knowledge of situation and poor leadership to manage safely.	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.
3	Power plant operators did not have enough equipment to monitor vital safety components and parameters that linked to reactor temperature and coolant level (IAEA 2017).	Poor leadership quality and lack of knowledge on situation awareness worsened the accident.	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.

4	The backup generators which was planned to start-up after off-site power had failed, started to provide electricity to pumps circulating coolant to the six nuclear reactors (IAEA 2011).	Lack of knowledge on either situation awareness, communication and or leadership worsened the accident.	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.
5	Disconnection of the energy supply and three cooling Fukushima reactors leading to the accident (WNA 2017).	No knowledge of situation awareness worsened the accident.	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.
6	Operators and staff on on-site emergency response centre did not have suitable procedures and training required for accident that involves extended loss of all on-site AC and DC power to manage water levels and pressures in reactors and containments and hydrogen that were generated during reactor core degradation ((NCBI 2014).	Communication problem at Fukushima as the organisation had to find translators, many calls from professionals and members of the public to the three units, distribute various messages and documents (IRSN 2011).	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.
7	The number of staff at the plant were not enough to manage the accident due to scope that affected several reactor units and long duration that it lasted (ibid). Malfunctioning of nuclear disaster robots (Khan *et al.* 2018).	Coping with fatigue, situation awareness and leadership problems.	No trace of isomorphic lesson.	No trace of organisational learning.	No trace of risk characterisation.

2.10.3 Analysis of Fukushima accident Focusing on NTS and other Pillars

This analyses on Fukushima Daiichi accident did not essentially focused on what past literature have done, instead, it focused on how lapses of NTS, isomorphic lessons, organisational learning and risk characterisation contributed to the accident. As identified in Table 7, there are reasons to believe that knowledge of NTS was not adequately utilised to ensure safety was managed at Fukushima NPP (**NCBI 2014**). At the same time, there was no trace of isomorphic lesson, organisational and risk characterisation in the materials consulted to ascertain possible causes of the accident. This presupposes that none of the four pillars used in this research formed part of safety management criteria.

Though it could be argued that perhaps NTS which is virtually a new terminology or idea in safety management in high-risk industries, however, could have meant something different or rather interpreted differently. Nonetheless, this work was able to identify some NTS gaps that perhaps contributed or worsened the Fukushima accident. Another possible cause of the accident was lack of preparedness (**Khan *et al*. 2018**); which is associated to situation awareness and poor leadership (**Flin *et al.* 2008**).

The main reasons behind the tragic consequences in Fukushima Daiichi were the lack of communication between the government and TEPCO, and the lack of preparedness from both sides (Khan *et al*. 2018). Also, it was gathered that TEPCO lacked sufficient communication capability to report on the progress status of the accident punctually and accurately to the appropriate organs and local governments (**Nihon Genshiryoku Gakkai 2015**); while on safety awareness, TEPCO was confident that no severe accident of that magnitude would occur, therefore had insufficient and formal training plans, and failed to fully prepare the necessary materials and equipment needed to combat any eventuality (**Nihon Genshiryoku Gakkai 2015**).

Other problems that manifested during the accident and that was visible was confusion and want of information among the management and higher authorities. They did not have enough information and they could not act promptly and effectively (**Khan *et al.* 2018**), and indication of leadership problem (**Flin *et al.* 2008**).

However, not much could be said on isomorphic lesson, organisation learning and risk characterisation. It is believed that most of the high-risk industries including the nuclear sector have no spirit of learning from past events (isomorphic and organisational learning) to manage safely. For instance, it was after the Fukushima accident that an international fact finding mission was able to address the issue of learning from past mistakes (**IAEA 2017**); as there was a set of preliminary conclusions and identified lessons learned in three broad areas: external hazards, severe accident management and emergency preparedness (I**AEA 2017**).

Mike Weightman, UK chief inspector of Nuclear Installations (**IAEA 2017**) remarked that:

> *"It is of fundamental importance for all with responsibility for nuclear safety across the world to seek to learn from this unique event," continuing, "for me, to maximize nuclear safety you must work on learning lessons and continuously improving throughout time. Therefore, we'll use our opportunity here to come to Japan, gather information to see how the world can learn lessons from these unique events." (IAEA 2017).*

2.10. 4 Hudson River Landing

2.10.5 Introduction

Another accident examined was the Hudson River Landing in which all the 150 passengers, including a child, and 5 crew members on-board survived (**NTSB 2010**). The US Airways Flight 1549 was an Airbus A320. After the flight took-off from New York City's LaGuardia airport on January 15, 2009, the flight struck a flock of Canada geese less than 5 miles northwest of the airport and eventually lost all engine power (**NTSB 2010**).

Both engines had operated normally until they each ingested at least two Canadian geese birds that weighed about 8 pounds each (**NTSB 2010**). One of the birds was ingested into each engine core, causing mechanical damage which prevented the engines from being able to supply adequate thrust to sustain flight. The size and number of the birds that went into the accident engines exceeded the current bird-ingestion certification standards by the US Airways (**NTSB 2010**). Because both engines could not operate effectively, it was unable to complete the engine dual failure checklist (**U.S.NRC 2011**).

This study focused on how the mishap was successfully managed which led to no loss of lives, and perhaps understanding of NTS, isomorphic lesson, organisational learning and risk characterisation to manage safely.

The National Transportation Safety Board 2010 official document on: “Loss of Thrust in Both Engines after Encountering a Flock of Birds and Subsequent Ditching on the Hudson River, US Airways Flight 1549, Airbus A320-214” was used. Reason for focusing on the document was the comprehensive report was conducted by an independent federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety (**NTSB 2010**). Some findings relating to good use of NTS and risk characterisation are tabulated on Table 8.

Table 8: Possible causes of Hudson River Landing accident and relationship to NTS lapses and others

S/No	Possible Causes	NTS Understanding	Isomorphic Lesson	Organisational Learning	Risk Characterisation
1	The probable cause of the accident was the ingestion of large birds into the two engines that led to an almost total loss of thrust in both engines, thereby ditching the flight into the Hudson River (ATSB 2013).	Good understanding of situation awareness (attention to work environment) after recognising something went wrong.	No trace of isomorphic lesson	No trace of organisational learning	The un-planned use of an aircraft that was equipped for an extended overwater flight, including the availability of the forward slide/rafts, though it was not required to be so equipped.
2	Each engine ingested at least two Canada geese weighing about 8 pounds each, which significantly exceeded the certification standards, and neither engine was able to produce enough power to sustain flight after ingesting these birds (Ibid).	Good understanding and immediate use of communication to inform the control room of the hazard.	No trace of isomorphic lesson	No trace of organisational learning.	No further trace of risk was characterised.
3	De-accelerate of speed according to FDR data immediately after the bird encounter, both engines' fan and core (N1 and N2, respectively).	Good and quick decision-making skills to turn around the aircraft for possible landing	No trace of isomorphic lesson	No trace of organisational learning.	No further trace of risk was characterised.
4	Losing thrust in both engines (Ibid).	Good knowledge of situation awareness.	No trace of isomorphic lesson	No trace of organisational learning.	No further trace of risk was characterised.

5	Unplanned start of generator by first officer (Ibid).	Good knowledge of situation awareness	No trace of isomorphic lesson	No trace of organisational learning.	No further trace of risk was characterised.

2.10.6 Analysis of Hudson River Landing Accident Focusing on NTS and other Pillars.

This analysis revealed how good use of NTS elements by the captain, first officer and crew members culminated in saving the lives of all the occupants in the aircraft. Good understanding of situation awareness was brought to the fore which commenced from after the aircraft took off and within seconds after ditching the plane on the Hudson River. The crewmembers and passengers-initiated evacuation of the airplane. According to the flight attendants, the evacuation was relatively orderly and timely (**NTSB 2010**).

There was good understanding on the use of communication, as the captain was constantly communicating with Air Traffic Control (ATC) and later to passengers to brace for impact (**NTSB 2010**). According to the NTSB report, it stated that the cockpit voice recorder data (CVRD) indicated that communication between the captain and first officer were excellent (**USNRC 2011**). The captain credited his flying prowess to the US Airways CRM training for providing him and the first officer the skills and tools required to build a team. Both pilots quickly open lines of communication, shared common goals, and worked together. The first officer and the captain had specific roles, knew what each other was doing, and communicated effectively (**NTSB 2010**).

Communication was extended to ATM's and ATCT cab coordinator, as they advised the Los Angeles Airport (LGA) departure controller that "runway 4 is also available. They contacted the LGA Port Authority to advise that the Port Authority of NY and NJ needed to be alerted, that an airplane was going to ditch in the Hudson River, which was relayed by a nearby helicopter pilot. Both LGA ATCT and New York TRACON personnel immediately contacted the U.S. Coast Guard (USCG), the New York Police Department (NYPD) and various other search and rescue operations. (**NTSB 2010**).

Teamwork, which is another element of NTS was vital, as the captain confirmed that the crew coordination was "amazingly good" in view of how suddenly the event happened, its severity, and the little they had at their disposal. The captain further revealed that they had no time to consult all the written guidance or complete the appropriate checklist, therefore, they had to work almost intuitively in a very close-knit fashion (**NTSB 2010**).

Decision-making was also in use, as flight attendant ‘B’ stated that she improvised commands and told “young, able-bodied” passengers to climb over the seats to get people away from the water. There was further support from the captain and first officer as they helped the flight attendants with the evacuation in the airplane (**NTSB 2010**); captain and the first officer supported a number of passengers that had evacuated the airplane with life vests; and obtained more life vests from under the passenger seats in the cabin and passed them out to passengers outside of the airplane (**NTSB 2010**).

Managing stress and coping with fatigue was another crucial NTS element that was successfully handled, as the captain, first officer and other crewmembers revealed that they always had 7-9 hours sleep before the next flight (**NTSB 2010**).

Risk was adequately characterised on the US Airways Flight 1549 before take-off. The airplane met the structural ditching certification regulations in effect at the time of its certification, while the engine met the bird-ingestion certification regulations in effect at the time of its certification, as well as an anticipated additional regulation that it was not required to meet at that time (**NTSB 2010**).

Likewise, the decision of the captain to ditch the airplane on the Hudson River rather than landing at an airport, provided the highest probability that the accident would be survivable (**NTSB 2010**); and the professionalism of the flight crew members and their excellent crew resource management during the accident sequence helped to their ability to maintain control of the airplane, configure it to the extent possible under the circumstances, and fly an approach that increased the survivability of the impact (**NTSB 2010**).

According an information published by the United States Nuclear Regulation Commission (USNRC), there were evidence of strong safety culture traits and evidence of positive culture traits that contributed to managing safety in the aviation sector (**USNRC 2011**). The Captain demonstrated high level of leadership safety values and commitment to safety in his decisions and behaviours. On safety culture traits, even after the captain successfully landed on the Hudson River, he was still committed to the safety of others as he twice walked up and down aisle to make sure everyone was out. Even when he was out of the cabin, he told the rescue boats to take care of the people on the wings first as those in the rafts were already safe (**USNRC 2011**).

Though human error accounts for 75 per cent of accident, which has always being the main threat to flight safety (**CASA 2012**). However, aviation industries are progressively introducing safety management systems (SMS) that surpasses legal compliances with rules and regulations, instead, they emphasise on continuous improvement by identifying hazards and risk management (**ATSB 2008**).

From the above analysis, it is evident that almost all the elements of NTS were used to successfully manage the Hudson River landing by Captain Chesley Sullenberger which saved the lives of all the passengers in the aircraft. However, there was no mention of isomorphic lesson and organisational learning which the research had expected as part of the pillars used to manage safely, but risk was characterised before the plane took off.

2.10.7 The Deepwater Horizon Oil Spill of 2010

2.10.8 Introduction

The Deepwater Horizon rig, was owned and operated by offshore-oil-drilling company Transocean, but leased by BP Plc. The rig was situated in the Macondo oil prospect in the Mississippi Canyon, a valley in the continental shelf, hence the name, Macondo Well blowout. The oil well was located on the seabed 4,993 feet or 1,522 metres below the surface and extended almost 18,000 feet, or 5,486 metres into the rock. On April 20, 2010, there was a surge of natural gas which blasted through a concrete core installed by Halliburton, the contractor that was asked to seal the well for later use (**OSC 2011**).

The accident claimed the lives of 11 crew members, while others were seriously injured as fire destroyed the entire drilling rig (**OSC 2011**). The Deepwater Horizon spilled over 4 million barrels of crude oil into the Gulf of Mexico. The spill disrupted the entire region's economy and damaged fisheries and caused destruction at the habitats (**OSC 2011**).

The Gulf Oil Disaster and the Future of Offshore Drilling Report to the President by the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling of January 2011 was used for the study. The report was considered useful because of its national outlook and the impartial judgement it produced and recommendations made in a constructive spirit (**OSC 2011**). The report was scrutinized to determine the probable causes of the accident and if there any evidence of lapses on the use of NTS (good or bad use) isomorphic lesson, organisational learning and risk characterisation. Table 9 shows possible causes of the accident related to the four pillars discussed in the research.

Table 9: Possible causes of Deepwater Horizon Oil Spill accident and relationship to NTS lapses and others

S/No	Possible Causes	NTS	Isomorphic Lesson	Organisational Learning	Risk Characterisation
1	The failure to contain hydrocarbon pressures in the well (OSC 2011:115).	Indication of poor situation awareness (attention to work environment) and leadership	No trace of isomorphic lesson.	No trace of organisational learning.	Risk was not adequately categorised.
2	Systematic failures (ibid).	Indication of poor leadership, and communication.	Transocean failed to sufficiently communicate to its crew members lessons learned from similar near-miss on one of its rigs in the North Sea four months prior to the Macondo blowout.	Transocean failed to sufficiently communicate to its crew members lessons learned from an eerily similar near-miss on one of its rigs in the North Sea four months prior to the Macondo blowout.	Before the Macondo blowout, neither the industry nor the government adequately addressed identified risks.
3	The accident was caused by several individual missteps and oversights by BP, Halliburton, and Transocean, as government regulators lacked the power, necessary resources, and technical expertise to prevent Macondo Well Blowout (OSC 2011:115).	Indication of poor leadership, situation awareness and lack decision-making.	No trace of isomorphic lesson	No trace of organisational learning.	There were recurring themes of missed warning signals, failure to share information, and a general lack of appreciation for the risks involved.
4	Failures of management and communication gaps.	A lack in situation awareness, communication and leadership.	No trace of isomorphic lesson.	No trace of organisational learning.	There were several separate risk factors, oversights, and outright mistakes combined to overwhelm the safeguards meant to prevent such an event from taken occurring.
5	The process to use only six centralizers illuminates the flaws in BP's management and design procedures, as well as poor communication between BP and Halliburton (Ibid).	Decision-making and poor communication; lack of teamwork.	No trace of isomorphic lesson.	No trace of organisational learning	Risk was not adequately categorised based on either the use of 15 or 6 centralizers in the well.

6	BP's team again failed to take time to consider whether and to what extent the anomalous pressure readings may have indicated other problems or increased the risk of the upcoming cement job. BP's team appears not to have seriously examined why it had to apply over four times the 750-psi design pressure to convert the float valves (Ibid).	Situation awareness.	No trace of isomorphic lesson.	No trace of organisational learning.	Risk not categorised or characterised.
7	Absent of significant reform in both industry practices and government policies. The events were rooted in systemic failures by industry management which also affected the contractors in the industry; also, the failures of government to provide effective regulatory oversight of offshore drilling (Ibid).	No trace of isomorphic lesson.	No trace of isomorphic lesson.	No trace of organisational learning.	Risk not categorised or characterised.
8	BP Well Site Leaders did not consult anyone on-shore about the anomalous data observed during the negative-pressure test (Ibid).	No trace of isomorphic lesson.	No trace of isomorphic lesson.	No trace of organisational learning.	Risk not categorised or characterised.

2.10.9 Analysis of Deepwater Horizon Oil Spill Focusing on NTS Lapses and other Pillars

As stated by the committee that investigated the accident, the Macondo blowout was as a result of several individual mistakes and oversights by BP, Halliburton, and Transocean, as government regulators lacked the authority, the necessary resources, and the technical expertise to avert the accident (**OSC 2011:115**). However, the fundamental cause of the accident was a bad safety culture from BP and its contractors (**Konstantinidou *et al*. 2012: 20**). On the other hand, the situation was caused by series of human mistakes through all stages the project lasted, leading up to the blowout and subsequent explosion (**Smith *et al.* 2013**).

These oversights by those involved are termed to a lack of situation awareness which eventually culminated into the accident. Many critical aspects of drilling operations were not monitored appropriately and were left to industry to decide without agency assessment. For instance, there was no requirement, let alone protocol, for a negative pressure test. The inaccurate information was considered a major contributor to the Macondo blowout. Nor, were there detailed requirements related to the testing of the cement essential for well stability (**OSC: 2011**). This was an indication of lack of situation awareness in safety management.

The accident was also accelerated by lack of internal decision-making process as BP personnel did not appear to have insisted that Halliburton complete its foam stability tests, let alone report the results to BP for review before ordering primary cementing to start the work (**OSC 2011**). The issue of decision making was further increased when it was established whether the failure to use 15 additional centralizers was a direct cause of the blowout, as against using six centralizers (centralizers are a cage-like steel device attached to the casing string being lowered into the drilling hole after it had reached a total depth and the drill string withdrawn), which exposed the flaws in BP's management and design procedures (**OSC 2011**).

Another element of NTS lapses that caused a negative effect on the Macondo Blowout was poor communication. There was evidence that BP, Transocean, and Halliburton failed to communicate adequately. Information appeared to have been unreasonably compartmentalized at Macondo due to poor communication (**OSC 2011**). BP refused to share useful information with its contractors, or even internally with members of its own team. On the other hand, contractors also did not share significant information with BP or with each other. This led to individuals often finding themselves having to make serious decisions without a full understanding of the situation in which they were being made, or even without recognition that decisions made were critical **(OSC 2011; Konstantinidou *et al*. 2012: 20**).

Still on communication failure, a lot of BP and Halliburton workers were aware of the difficulty of carrying out the primary cementing of the well-bed. But most of the issues identified were not communicated (shared) to the rig crew members that conducted the negative-pressure test and monitored the well (**OSC 2011**). Furthermore, there was lack of communication between operators and service providers; and gaps in communication that existed between the silos of expertise in the Deepwater oil and gas industry (**OSC 2011**). BP did not put adequate controls in place to make sure that key decisions in the months leading up to the blowout were safe or sound from an engineering viewpoint (**OSC 2011**).

Another aspect of this research was organisational learning, as it also formed the focus of this finding in the accident examples. There have been evidence to suggest that there were lapses on organisational learning as it later emerged that a related incident had occurred on a BP owned rig in the Caspian Sea on September 2008 before the Deepwater Horizon disaster of 2010. Both cores were likely too weak to withstand the pressure because they were composed of a concrete mixture that used nitrogen gas to accelerate curing (**Pallardy 2010**).

Transocean failed to communicate to its crew lessons learned from a similar near-miss on one of its rigs in the North Sea four months prior to the blowout. In 2009, gas entered the riser on the rig while the crew was dislodging a well with seawater during a completion operation (**OSC 2011**), and it is believed that the basic facts of both incidents are the same. Had the rig crew been conversant of the prior event and trained on its lessons, events at Macondo might have occurred differently (**OSC 2011: 124**).

BP lacked learning culture. In 2000, BP’s Grangemouth Complex in Scotland suffered three possible life-threatening accidents. A power distribution failure led to the emergency shutdown of the oil refinery due to a rupture of a main steam pipe; and a fire in the refinery’s fluidized catalytic cracker unit that turns petroleum into gasoline.

Subsequent investigations revealed several weaknesses in the safety management systems on-site over a period which had led to the series of events that caused the power distribution failure (**OSC 2011**).

Still on failures of organisational learning, BP's refineries had problems at the North Sea platforms in 2003, as a gas line ruptured on BP Forties Alpha and methane flooded on the platform. BP admitted breaking its rule as it allowed pipes to corrode on the Forties Alpha. Eventually, BP paid a sum of $290,000 as a fine (**OSC 2011**).

Another failure on organisational learning was the BP's Texas City refinery explosion. According to the report examined, this was a deficient on safety culture. In 2005, a blast at the refinery, the third largest refinery in the United States, killed 15 people and injured more than 170. It was established that BP Group did not steadily review its refinery operations and corporate governance worldwide with the aim to implement needed changes identified in the Health and Safety Executive (HSE) report and BP's Task Force report, despite what the group chief executive had told staff in one of the 2000 edition of BP's in-house magazine that the organisation would learn lessons from Grangemouth and other incidents (**OSC 2011**).

The Safety Board's report on Texas city stated that while most attention was focused on the injury rate, the overall safety culture and process safety management program of BP had serious gaps. And despite many previous fatalities at the Texas city refinery that recorded 23 deaths in past 30 years prior to the 2005 disaster, and many hazardous material releases, BP did not take active steps to curtail the growing risks of a disastrous event (**OSC 2011**); a lack of organisational learning culture.

Grouping all NTS, organisational learning and risk characterisation lapses, the report pointed out that BP Texas city lacked a reporting and learning culture. Reporting negative news was not allowed, and often managers did not efficiently investigate incidents or take suitable corrective action (**OSC 2011**). The report went further to reveal that BP Group and Texas city managers provided weak leadership and oversight (situation awareness). And the management did not implement adequate safety oversight, provide needed human and economic resources, or consistently model adherence to safety rules and procedures. On risk classification, the organisation did not effectively assess the safety effects of major organisational, personnel, and policy changes (**OSC 2011**).

With a long history of failure on organisational learning**,** the Baker panel (**OSC 2011**) faulted BP for failing to learn the lessons of Grangemouth by allowing them in the events that caused the Texas city refinery explosion. BP did not use any opportunity to make and sustain company-wide changes that would have led safer workplaces for its employees and contractors (**OSC 2011**).

Again, one year after the Texas city refinery accident occurred, BP had another significant accident known as the Prudhoe Bay pipeline leak in 2006, as 212,252 gallons of oil spilled into the tundra environment (**OSC 2011**); regarded as the worst spill ever recorded on the North Slope. The leak went unnoticed for as long as five days. During analysis, it was revealed that the pipes were found to have been poorly maintained and inspected. BP paid more than $20 million in fines and restitution (**OSC 2011**).

On risk characterisation, which is also one of the pillars of this research, the report noted that none of BP's or even the decisions made by other companies seem to have been subjected to a full and systematic risk-analysis, either by peer-review or management of change process (**OSC 2011**). Evidence however revealed that the BP team members and personnel from the other two companies responsible for most of the decisions had not conducted any form of formal analysis to evaluate the relative riskiness of available alternatives (**OSC 2011**); and in the years before the Macondo blowout occurred, neither BP nor government adequately addressed most of the risks within the rig (**OSC 2011**).

This was due to the fact that regulatory oversight alone was not sufficient to ensure adequate safety, as the oil and gas industry will need to take its own independent steps to increase safety throughout the industry, including self-policing mechanisms that complement governmental enforcement (**OSC 2011**). The accident under review was similarly triggered because several separate risk factors. However, most of the mistakes and oversights at Macondo Well were traced back to a primary failure of management (**OSC 2011**).

Better management by all the three key players would certainly have prevented the blowout if they had improved the ability of individuals involved to be bold to identify the risks they faced, properly evaluate, communicate, and address them. A blowout in deep-water was not a statistical inevitability (**OSC 2011**).

It has been argued in different quarters that if properly managed, the presence of risk does not mean that accidents must happen. According to Magne Ognedal (2011):

> *"Risk must be managed at every level and in every company involved in this business. In this way, risk in the petroleum sector can be kept at a level society is willing to accept. And we can reduce the probability that major accidents will hit us again."* *(**OSC 2011: 219**).*

Subsequent analyses on the accident indicated that BP did not have consistent and reliable risk-management processes, thus, has not been able to meet its avowed commitment to safety. BP's safety lapses have been enduring (**OSC 2011**). The three companies did not sufficiently identify or address risks of an accident, not in the well design, cementing, or temporary abandonment procedures (**OSC 2011**); and underscoring the complexity of the organisational problem challenging BP, the report singled out for blame BP's general approach to accident analysis. BP's investigation system had not introduced effective root cause analysis procedures to identify systemic causal factors (**OSC 2011**).

2.10.10 Conclusion on the Three Accidents

It is evident that NTS incorporates a wide range of skills which are critical to sustaining safe performance in high-risk industries. Fukushima Daiichi and Deepwater Horizon accidents have revealed that knowledge of NTS had the potential of saving lives (**Flin *et al*, 2008**), as lapses of NTS led to several disaster. More so, some high-risk industries reviewed did not apply organisational learning, isomorphic lesson, while risk was not adequately characterised to manage safely as indicated in Deepwater Horizon risk characterisation (**OSC 2011**).

However, some of the NTS elements were interchangeably used to mean different things in various organisations. For instance, oversight could have been used to mean situation awareness, which was constantly used in Macondo Well Blowout (**OSC 2011**). However, other NTS elements such as communication, teamwork, decision-making, leadership were referred to as such, while managing stress and coping with fatigue were referred to as stress in general terms.

In the three accident examples reviewed, it was only Hudson River Landing that the pilot and the captain and by extension crew members constantly used virtually all the NTS elements to successfully land the aircraft safely on the Hudson River without no life lost (**NTSB 2010)**. See evidence on Table 8. Whereas in Fukushima Daiichi accident and the Deepwater Horizon Oil Spill, both organisations lacked the use of NTS elements to successfully manage risk.

On organisational learning, isomorphic lessons and risk characterisation were not regarded as such in the three organisations, especially in the oil and gas sector. In Deepwater Horizon oil spill, it was clear that the oil and gas sector, especially BP never considered to learn from past incidents (**OSC 2011**). Deficiency in learning culture also affected the nuclear sector (TMI) did not learn from a similar accident (**Trigilio 2006**); while in the airline industry is well aware that the industry as a whole suffers if the public lacks trust in the safety of any one company (**0SC 2011**).

Therefore, it is worth mentioning that even the most naturally risky industry can be made much safer, if staff are given the right incentives and disciplined systems, sustained by dedicated leadership and active training to manage safely (**OSC 2011**); as NTS are vehicles by which technical skills and knowledge can be applied and acquired through training (**Thomas 2018**).

2.11 Examples of Low-level Incidents in Nuclear, Aviation and Oil and Gas

2.11.1 Introduction

A basic understanding in recent safety management is that accidents are avoidable through effective feedback control, and through mechanisms by which information about accidents and near misses is employed as a basis to increase the level of safety. This research has discussed examples of notable accidents in nuclear, aviation and oil and gas. Conversely, this section is focused on low-level or near-miss incidents to establish similarities or differences that triggered both notable and low-level incidents in the three sectors. Findings helped to determine if lessons could be learned and transferred to the nuclear sector in the UK.

The three low-level of incidents discussed are: Sellafield Sump Tank Levels Nuclear near miss incident of 2019; the Beech-200 King Air registered EC-KNP incident 2012 and EnQuest and Odjfell Drilling Sling Failure of 2018.

2.11.2 Summary of Sump Tank Levels Near-miss Incident at Sellafield

2.11.3 Introduction

Sellafield nuclear site was licensed under the Nuclear Installations Act 1965. It is owned by the Nuclear Decommissioning Authority. The organisation is responsible for cleaning-up the country's (UK) highest nuclear risks and hazards to safeguarding nuclear fuel, materials and waste (**Gov. UK 2020**). Sellafield is located in West Cumbria and regarded as one of the most complex and hazardous nuclear sites in the world (**Sellafield Ltd 2019**).

The probable cause of the sump tank level incident according to Sellafield Ltd was because of the detection of liquid levels in a concrete sump tank in the legacy ponds area of the Sellafield site. The primary cause of the loss in levels of the liquor was because of a maintenance work on the tank (**Sellafield Ltd 2019**).

However, ONR noted that in 2019, Sellafield Ltd reported it had sign of a loss of radioactively polluted water which emerged from the Redundant Settling Tank (RST) facility. The indication of a leak was based on the irregular frequency of water top-ups required to maintain water level within the sump of the RST (**ONR 2020**). Table 10 shows the possible causes of Sump tank near miss incident and inadequacies of the four pillars used in this research.

Table 10: Possible causes of Sump Tank near miss incident and lapses on the four pillars

Lapses of the four cardinal pillars leading to the near miss					
S/No	**Possible causes**	**NTS**	**Isomorphic lessons**	**Organisational learning**	**Risk characterisation**
1	Loss in levels of the liquor was because of a maintenance work on the tank (Sellafield Ltd 2019).	Lack of situation awareness, communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
2	Sign of a loss of radioactively polluted water which emerged from the Redundant Settling Tank (RST) facility (ONR 2020).	Lack of situation awareness, communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
3	Irregular frequency of water top-ups required to maintain water level within the sump of the RST (ONR 2020).	Lack of situation awareness, communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
4	Historic leak paths to ground from small cracks in the structure of the sump.	Lack of situation awareness and communication.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.

2.11.4 Analysis of the Sump Tank Level Near Miss at Sellafield Limited

From what has been reported by Sellafield Ltd and ONR, there is evidence to believe that there were lapses of NTS, isomorphic lessons, organisational learning and risk characterisation leading to the near miss. According to ONR in 2019, Sellafield Ltd reported it had sign of a loss of radioactively polluted water which started from the Redundant Settling Tank (RST) facility. The loss of the liquor occurred continuously, but investigation established that the movement of the liquor was not through engineered route; as near miss incidents has been occurring in the organisation, regarded as historic paths, with small cracks in the structure of the sump (**ONR 2020**).

After the incident, an engineering team was put together to assess the tank and investigate the primary cause of the liquid reduction. This supports the fact that there were NTS lapses in the organisation. Sellafield Ltd stated that: "As a precaution we have increased the local monitoring and detection systems around the tank. There is no risk to the public or the workforce. The relevant regulators have been notified." As a near miss, the organisation rated the event at Level 1 according to INES (**Sellafield Ltd 2019**). The active failure that led to the near miss was workers lacked NTS skills (Situation awareness) to monitor the movement of liquors.

2.11.5 The Beech-200 King Air registered EC-KNP incident

2.11.6 Introduction

The aircraft, known as the Beech-200 King Air registered EC-KNP incident of 10 May 2012 is managed by Air Taxi et Charter International at Paris le Bourget (93) Airport. The aircraft developed landing gear extension problem. During the landing roll, the nose landing gear malformed (collapsed). The aircraft collapsed on the runway. The damage that was observed was on the lower forward section of the aircraft and the propellers on both engines (**BEA 2014**).

The plane had just gone through a maintenance operation, though did not include the nose landing gear which had just been carried earlier by the Blois Aéro Services maintenance. The aircraft took off from Blois aerodrome and headed to Paris Le Bourget airport. During landing roll, the initial Instrument Landing System (ILS 27) gear was extended, the crew heard an uncommon noise and observed that the red landing gear indicator light was on (indicating that landing gears are not locked down), while the green down-and-locked light were still off (indicating that the three wheels are not down and locked) (**BEA 2014**).

The controller stated that the nose landing gear was extended. In that situation, the crew did a go-around and withdrew the landing gear. Because the red landing gear indicator light was still on, the pilot used the emergency landing gear extension procedure but found the same signs as during the first attempt. The crew continued to runway 21, took advantage of the headwind and to avoid blocking the main runway 27 should there be a problem. The nose landing gear collapsed during the landing process. The plane eventually stopped on the runway. The damage that occurred on aeroplane was observed on the lower forward section, and the propellers on both engines. Table 11 shows lapses of the four pillars used in this research as possible causes of Beach-200 King Air incident.

Table 11: Possible causes of Beach-200 King Air serious incident and lapses on the four cardinal pillars

Lapses of the four cardinal pillars leading to the near miss					
S/No	**Possible causes**	**NTS**	**Isomorphic lessons**	**Organisational learning**	**Risk characterisation**
1	When the kinematics was inspected, the nose landing gear revealed a malfunction of the actuator (BEA 2014).	Lack of situation awareness.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
2	No information given that lubrication was added as part of the work done in the section of the work files for future maintenance procedures.	Lack of communication and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
3	There was no internal clearance included in work file when measured.	Lack of communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
4	There was a mixture of greases that potentially reduced the effectiveness of the lubrication.	Lack of situation awareness.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
5	There was incorrect alignment of the actuator during coupling. This raised the	Lack of situation awareness.			

	temperature of the actuator when in operation that led to the wear on the threads and reduced the lubricating performance of the grease.				
	Use of "FAA PMA" type parts which was not recommended or poor quality.	Lack of situation awareness.			

2.11.7 Analysis of the Beach-200 King Air

The analysis of the incident revealed that maintenance work was not properly coordinated. There was evidence of leadership failures, lack of situation awareness, communication and teamwork. This suggests that operators did not have a comprehensive understanding of NTS to carry out work effectively to manage safety. The report equally noted that there was no internal clearance included in the file.

Lack of communication existed during the maintenance work, as the lubrication of the actuator related to the maintenance check which supposed to be on internal clearance was not stated on the technical intervention sheet delivered by the workshop. There was no indication concerning lubrication included in work carried out on the work section files for preceding maintenance operations.

Possibly, provision of such relevant information could have averted the incident. Also, there was evidence of cutting corners during the maintenance operation. Information from Hawker Beechcraft Corporation (HBC) maintenance manual informed that only original HBC parts must be used. This was a clear indication of lack of situation awareness, as the maintenance team would have known the repercussion of using inferior materials for such work.

Inspecting the actuator revealed that the stripping of the threads on the threaded sleeve made it difficult for it to drive the actuator rod. Before stripping, the threads of the sleeve had started to wear due to abrasion (friction) between the threads on the threaded sleeve and the threads on the threaded rod during nose landing gear extension and retraction stages. Another point to consider is the clearance between the threads on the threaded rod and the threads of the sleeve was measured at 0.6 mm (about 0.025 in); while the actuator rod was not mentioned by the manufacturer but matched to an FAA-approved replacement part ("FAA PMA" part). There was presence of grease throughout the actuator.

On the other hand, HBC had no statistics on the number of actuators rejected after a check of the internal clearance (situation awareness). HBC maintained that the possible contributory factors to actuator failure are unsuitable lubrication due to mixture of greases that can potentially reduce the effectiveness of the lubrication. There was also incorrect alignment of the actuator (rod) during assembly, which raised the temperature of the actuator during operation which led to the wear on the threads and reduced the lubricating performance of the grease.

Therefore, it is believed that the use of NTS and other pillars to manage risk and equally train staff is bound to reduce accidents, as workers will know and understand how and when to apply NTS elements in workplace activities.

2.11.8 EnQuest and Odjfell Drilling Sling Failure on Magnus Platform

2.11.9 Introduction

EnQuest is a production and development oil company. It has operations in the UK North Sea and Malaysia. The organisation was formed in conjunction with the UK North Sea assets of Petrofac and Lundin Petroleum (**EnQuest 2020**). According to the Institute of Occupational Health and Safety (IOSH), the North Sea operator exposed their staff to what was described as “serious risk” when a sling used to lift a riser (a large-diameter pipe which connects the subsea BOP stack to a floating surface rig that carries mud to the surface failed and fell on the section around 1.5 metre on to the platform. It was observed that no one was injured during the incident. Actions were taken and learnings identified to prevent future re-occurrence (**IOSH 2020**). Table 12 indicating inadequate use of the four pillars to manage EnQuest and Odjfell drilling sling leading to the incident.

Table 12: Possible causes of EnQuest and Odjfell drilling sling serious incident and lapses on the four cardinal pillars

Lapses of the four cardinal pillars leading to the near miss					
S/No	**Possible causes**	**NTS**	**Isomorphic lessons**	**Organisational learning**	**Risk characterisation**
1	EnQuest did not ensure that the contractor, Odjfell Drilling's lifting plans had active measures in place.	Lack situation awareness, communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
2	Deck crews had not followed pre-approved lifting plans.	Lack of situation awareness and leadership.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.
3	The Magnus sling failure incident is one of the several EnQuest have had in 2018.	Lack of situation awareness, communication, leadership and teamwork.	No trace of isomorphic lessons.	No trace of organisational learning.	No trace of risk characterisation.

2.11.10 Analysis of the EnQuest and Odjfell Drilling Sling Failure

The near-miss incident of a piece of an equipment that weighed more than two-and-a-half tonnes could have turned catastrophic had the riser (equipment) not fell about 5 feet and landed just 2ft feet away from one member of the deck crew and 15 feet of the other member of the same deck crew on a North Sea platform (**IOSH 2020**). The incident occurred on the Magnus installation 100 miles (160km) north east of Shetland.

The polypropylene sling is used to lift the flange riser section that weighed about 2.6 tonnes. A notice claimed that EnQuest failed to certify that Odjfell drilling lifting plans had no effective measures in place. This is an indication that the organisation lacked knowledge of NTS, especially on the use of situation awareness by workers.

Other possible lapses were worker's failure to effectively communicate and the use of teamwork when work was on going. This was indicated when the Health and Safety Executive (HSE) noted that if deck crews had followed pre-approved lifting plans, the two workers of the deck crew would not have been exposed to grave risk to their safety when the polypropylene sling failed (**IOSH 2020**).

Despite no one was injured, the organisation stated that they have taken the learnings identified to prevent re-occurrence. The Magnus incident is said to be one of the near misses of several incidents the organisation had in 2018 which involved lifting incidents. Equally, the incident has been regarded as a reflection in a change of culture in the offshore in terms of low morale of workers and casting question marks over adherence to procedures, which the organisation believes are recurring around the fear of employment and the pressures of the job.

The near-miss incident shows how no knowledge of NTS, isomorphic lesson, organisational learning and risk characterisation could lead to accidents or near-misses in high-risk industries.

2.11.11 Conclusion on the three incidents

The three near-miss incidents which are Sellafield sump tank level; the Beach 200 King Air registered EC-KNP; and the EnQuest and Odjfell drilling sling failure on Magnus platform discussed in this section have indicated that safety could be achieved where technical skills of workers is complemented with NTS, and by extension the use of isomorphic lessons, organisational learning and risk characterisation to manage safely.

2.12 Regulation of the UK Nuclear Sector

In the nuclear sector, each country tends to regulate its sector as it suits them, whereas, in the aviation and the oil and gas sectors, there is international guidance that guides the sector. While the Office for Nuclear Regulation (ONR) regulates or control nuclear sites in the United Kingdom, the legal responsibility for safeguarding the nuclear sector rests with the duty-holder. It is the responsibility of the government to establish nuclear policy through a legislative regulatory framework (**ONR 2016**). Similarly, the IAEA promotes and supports the establishment of inclusive regulatory frameworks to ensure the safety of nuclear installations throughout their lifetime (**IAEA 2019**).

In the UK nuclear sector, the UK government has no hand to set regulatory standards or even make regulatory decisions. These matters are the duty of ONR. What the UK does is to operate a goal-setting regime instead of being more prescriptive. Standards-based regimes applied in some other countries. This means that ONR gives wide regulatory requirements, and it is for licensees (operators) to decide and defend how best to achieve them (**ONR 2016**).

It is expected that this method allows an operator to be creative and realise the required high levels of nuclear safety by implementing practices that meet its circumstances. It equally contributes to continuous improvement and the implementation of appropriate good practices. There are 36 conditions attached by ONR to each nuclear site licence within which the licensees are expected to operate within those licence conditions. These conditions were put before the operators of nuclear industry to make and implement appropriate arrangements for compliance with the licence condition and some more prescriptive requirements (**ONR 2016**). See licence conditions on Table 13. To this end, IAEA (2019), noted that countries introducing or expanding nuclear power for the first time can benefit from the knowledge of those that are far ahead in nuclear power programmes to devise a regulatory framework **(IAEA 2019**).

Policing the entire process, ONR's evidence-based judgement is that the nuclear operators' arrangements for the management of nuclear safety meet the high-quality standards anticipated of the nuclear industry in both the UK and globally. There is a combination of ONR's assessment and inspection functions that allows ONR to judge whether nuclear operators are functioning with risks reduced to as low as reasonably practicable (**ONR 2016**).

To ensure an acceptable level of safety is achieved, a substantial body of information is naturally considered by ONR, for example: safety cases; reports on the licensees' periodic reviews of safety; annual reviews of safety at each site, and information from start-up meetings at the end of each reactor life span; insights and intelligence gained from the nuclear operators' senior management and internal regulator; results of on-site compliance inspections, including joint inspections with the nuclear operators' own regulatory compliance teams; findings from investigations of incidents and events; and the yearly demonstration of emergency exercises at each site (**ONR 2016**).

Ensuring general safety

In addition to nuclear safety, ONR is also authorised to regulate non-nuclear, or conventional, health and safety on nuclear approved sites. The purpose of regulation is to make sure that risks to employees and the public are reduced to so far as is reasonably practicable, including fire safety (**ONR 2016**). Table 13 shows ONR license categories of nuclear sectors in the UK.

Table 13: License categories in the UK nuclear sector

1	Interpretation
2	Marking of the site boundary
3	Control of property transactions
4	Restrictions on nuclear matter on the site
5	Consignment of nuclear matter
6	Documents, records, authorities and certificates
7	Incidents on the site
8	Warning notices
9	Instructions to persons on the site
10	Training
11	Emergency arrangements
12	Duly authorised and other suitably qualified and experienced persons
13	Nuclear safety committee
14	Safety documentation
15	Periodic review
16	Site plans, designs and specifications
17	Management systems
18	Radiological protection
19	Construction or installation of new plant
20	Modification to design of plant under construction
21	Commissioning
22	Modification or experiment on existing plant
23	Operating rules
24	Operating instructions
25	Operational records
26	Control and supervision of operations
27	Safety mechanisms, devices and circuits
28	Examination, inspection, maintenance and testing
29	Duty to carry out tests, inspections and examinations
30	Periodic shutdown
31	Shutdown of specified operations
32	Accumulation of radioactive waste
33	Disposal of radioactive waste
34	Leakage and escape of radioactive material and radioactive waste
35	Decommissioning
36	Organisational capability

2.13 Conclusion of Chapter 2

In conclusion, chapter two has identified the following points as significant to the direction of this research, which has critically appraised key areas of controversy and disagreement in the literature. For instance, as claimed in different quarters that NTS is widely used by high-risk industries to manage safety, literature revealed that there is still need for the nuclear sector to imbibe the skills for safety management.

NTS: High-risk industries require a skilled operator, but more importantly, there is a need to ensure cognitive, interpersonal, and personal coping skills alongside technical competences if full safety is to be achieved. The seven elements of NTS, therefore have proved in literature sources to be highly valued (**Flin *et al*. 2008**).

Isomorphic lesson: Isomorphism represents hidden opportunity for comparative learning between different systems with underlying similarities. The challenge here is the inability of organisations to demonstrate effective learning. In most cases, lessons may be identified, but not always learned.

Organisational learning: Organisational learning is a fundamental requirement for continuous improvement: however, organisational culture can profoundly affect the degree to which organisations are open and able to learn.

Risk characterisation: Risk characterisation reflects three key requirements for effective risk assessments and the correct risk appetite. Characterisation includes effective discourse with the right range of stakeholders and meticulous attention to analytical approaches if risk is to be managed at the optimal ALARP levels.

CHAPTER 3
3 RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is a broad style to carry out research topics (**Silverman 2015**). While methods represent the approach used to ensure the research is properly carried out in detail (**Mason 2002**). Data was gathered from sample population within the nuclear, aviation and the oil and gas sectors in the UK. Different or more independent sources of data-collection methods within a specific study was used to ensure that the data collected are accurate (**Saunders *et al*. 2009**).

3.2 Research Design

The conceptual structure with which this study is conducted is known as research design (**Kurmar 2005**). This was planned to meet the aim and objectives of this study. Several methods are used to gather research data, however, this research used mixed methods, which comprised of both quantitative and qualitative methods **(Saunders *et al.* 2009**).

3.2.1 Quantitative data

This research used quantitative data approach to gather respondents view (questionnaires), which were analysed using statistical method. Quantitative data is mostly used as a substitute for data collection to complement findings. Technique, using either questionnaire, or data analysis procedure using graphs or statistics which produces or uses numerical data to analyses information gathered (**Saunders *et al*. 2009**).

3.2.2 Qualitative data

Equally, this research used qualitative data in form of interviews as another method of data collection, or data analysis process like categorising data without the use of numbers. Qualitative data can also refer to data other than words such as pictures and video clips. An example of this is the use of participant observation to gather information. However, this research used focus groups as substitute to participant observation. Its emphasis is based on determining meanings people attach to actions (**Saunders *et al*. 2009**). Table 14 shows the difference between quantitative and qualitative data.

Table 14: Distinction between qualitative and quantitative data (Saunders *et al*. 2009)

Quantitative data	Qualitative data
• Based on meaning derived from numbers	• Based on meaning expressed through words
• Collection of results in numerical and standardised data	• Collection of results in non-standardised data requiring classification into categories
• Analysis conducted through the use of diagrams and statistics	• Analysis conducted through the use of conceptualisation

3.2.3 Mixed methods approach

Basically, this is a general term when qualitative and quantitative data collection techniques and analysis measures or procedures are used in a research design, which is the case in this research. It could be at the same time (parallel), or one after the other (sequential or successive), and they are not combined. Although, mixed method uses both approaches, however, quantitative data are quantitatively analysed, and qualitative data are qualitatively analysed (**Saunders *et al*. 2009**).

While mixed-model research is the combination of both quantitative and qualitative data collection methods, using the same analysis processes and combining quantitative and qualitative methods at other stages of the research. This means that quantitative data can be converted into narrative or discussion which can be analysed qualitatively. Likewise, quantitative data, can be converted into numerical codes or numbers for it to be analysed statistically (**Saunders *et al*. 2009**).

Tashakkori and Teddlie (2003) noted that multiple methods are valuable as they give better opportunities for the researcher to answer research questions and allow to better evaluate the extent to which the research findings can be relied upon, and inferences or extrapolations made from them. Interviews could be employed, as they will be used as an examining stage to be acquainted with key issues before giving out questionnaire to collect data. This will boost researchers' confidence that most important issues were addressed (**Tashakkori and Teddlie 2003**). Therefore, this research employed mixed method approaches that is, quantitative and qualitative methods to harness possible means and gather enough information and critically evaluate how safety is manged across the three sectors using the four pillars.

3.2.4 Initial Pilot Study

An initial pilot study was carried out (**Silverman 2015**), targeted at Coventry University students and lecturers. It was carried out as part of the research design to test participants understanding of the questionnaire and areas that would requires changes before it is launched using Bristol Online Survey (BOS). As a result, hard copies of the questionnaire were printed and handed to selected students in the related industry being researched, which are in oil and gas, HSE, aviation and disaster management departments. Furthermore, some of the lecturers in those related departments were served with the same sets of questionnaires. Results received were not analysed but were used as a guide to fine-tune the survey online and questionnaires. The pilot study engaged a total of 25 students and lecturers as a reasonable sample size for a test.

3.2.5 Research objectives

The objective of the research was to undertake a critical evaluation of the UK nuclear industry safety practices, focusing on the use of NTS from an online survey on non-technical skills, isomorphic lessons, organisational learning, and risk characterisations in aviation and oil and gas.

This research has three objectives.

(i) To critically evaluate and benchmark non-technical skills and their values in achieving workplace safety in the UK nuclear power industries.

(ii) To investigate the extent to which isomorphic lessons, organisational learning and risk characterisations derived from approaches used in safety-critical industries such as aviation and oil and gas informed and/or added value to the resilience practices undertaken in nuclear industry.

(iii) To design and create a holistic framework (with key processes, principles, terms, and toolkits) to support isomorphic lesson opportunities, optimise and benchmark NTS capabilities, risk characterisations, and organisation learning in the nuclear industry within the UK.

3.3 Data Collection

Primary data were used to seek respondents' views on the use of non-technical skills (NTS), isomorphic lessons, organisational learning and risk characterisation in the nuclear, aviation and the oil and gas sectors; as primary data provide first-hand information to the researcher. Secondary data were used as a complementary method (**Kumar 2011**).

Data were gathered using a wide range of methods (survey tools) such as online questionnaires, interviews, focus groups, accident/incident examples and industry regulatory data. The first online survey focused on the four key pillars used to assess this research, which are: NTS, isomorphic lessons, organisational learning and risk characterisation. The second survey was necessitated due to the emergence of Covid-19 pandemic. Therefore, it was designed to gauge the impact Covid-19 pandemic will have on the four pillars, either positively or negatively in the workplace. The third line of inquiry used in this research was interviews, as 15 industry experts were interviewed, five from each sector.

On secondary data, industry regulatory documents were scrutinised to produce lexicons on language used in each sector as it relates to the four pillars. Additionally, notable past accidents/incidents events were examined across the three sectors to determine if causes of accidents and or incidents have any lapses of NTS, isomorphic lessons, organisational learning and risk characterisation. Then, focus groups were used to test the validity of the online results and if some of the toolkits produced will be of any significance to the three sectors. Each of these components has been explained in detail and their relevance to the research.

The online survey used in this research combined both descriptive quantitative and qualitative questions for data gathering. The questions had direct link to the research objectives. Surveys are common ways to collect large amounts of data from a substantial group of people or population in a reasonable way (**Saunders *et al*. 2009**); using a questionnaire administered to a sample population and later standardized for easy assessment (**Saunders *et al*. 2009**). See appendix 2 for questionnaire sample.

3.3.1 Use of Questionnaires

This research observed the needed protocols, sought participants consent to collect data using questionnaires which are used in survey research as the primary data collection method. It is equally referred to as a survey tool (**Leavy 2017)**; as the use of a questionnaire to collect information in the workplace is very common (**Flin, O'Connor, and Crichton 2008**). Data collection or sample from a particular population uses questionnaire or interviews as part of the survey tools (**Robison 2005**). Therefore, this research designed a questionnaire and employed an online survey method (BOS) to recruit 232 respondents that examined the use of NTS, isomorphic lesson, organisational learning and risk characterisation and its applicability to risk reduction in workplace.

The research population (**Kumar 2011**) are safety experts from nuclear, aviation and the oil and gas sectors. The research involved the use of representative sample survey, as questionnaire was randomly sent to a combination of staff and key stakeholders in the related industries (**Walliman 2011**).

In all, the questionnaires were designed and shared to:

1. **Nuclear Power Plant:** Safety managers/officers; safety trainers**;** operators**;** risk managers.
2. **Aviation sector:** Pilots; Air Safety Controllers; safety managers/officers; safety trainers and risk managers.
3. **Oil and Gas:** Safety managers/officers**;** safety trainers**;** operators, drillers and risk managers.

3.3.2 Advantages of using a questionnaire

- They are economical and efficient way to gather information from respondents.
- No known risk.
- Inexpensive way of data collection.

- It saves time and financial resources.
- The use of questionnaire is reasonably convenient.
- Because there is no face-to-face interaction, it offers anonymity (online).
- Information is not biased or subjective.
- It gives accurate information to the researcher (**Flin *et al*. 2008; Kumar 2011**).

3.3.3 Disadvantages of using a questionnaire

- Application of questionnaire is restricted to a study population or group.
- Questionnaire cannot be used on groups that is uninformed (uneducated), very young, old or handicapped respondents.
- Response rate using questionnaire is usually low therefore affecting the sample size.
- There is bias in selecting questionnaires especially online version of it.
- There is difficulty in given clarifications as different respondents have different understanding of questions which will affect the quality of feedback (**Kumar 2011**).
- Mostly requires technology such as computer, internet and software for analysis.

3.3.4 Bristol Online Surveys (BOS)

To ensure data was collected across the three sectors using the four pillars, Bristol Online Surveys (BOS) was used to recruit 232 respondents. It is a Coventry University online survey tool designed for education and research to gather responses from participants. The survey tool is monitored by the researcher, who can decide how long the survey will last. Online surveys are easy to use, cost-effective, support collaboration and safeguards survey data.

To recruit responses using BOS, the candidate (researcher) had to send questionnaires to respondents using an email addresses obtained or provided by respondents. However, this research largely used LinkedIn to recruit responses from participants. Although an online method used to recruit participants directly, completed questionnaires are sent directly to BOS for analyses. Further explanation is provided in Chapter 4.

3.4 Interviews

This research focused on structured and unstructured interviewing and gathered respondents' views on issues that were helpful to solving research questions. The research equally sought participants consent before conducting interviews and they have right to withdraw from the interview at any given time. The research used predetermined questions to interview 15 safety experts (5 expert each) in the nuclear, aviation and oil and gas sectors. The interview was designed to ascertain if NTS are a strong feature of an organisation's practice and its entire contribution to staff training. Other research instruments used are organisational learning, isomorphic lessons and risk characterisation which helped to put together valid and reliable data appropriate to the research question(s) and set objectives (**Saunders *et al*. 2009**).

A total of six questions were asked to participants, at the typical length of an interview lasted for 45 minutes. Interviews were conducted via face-to-face interaction, and data was stored on a digital tape-recorder.

Interviewing is a frequently used method by researchers to collect information from people or respondents. Information is collected in the form of interaction with others (**Kumar 2011**). It is a focused and planned discussion between two or more people (**Saunders, Lewis, and Thornhill 2009**).

However, interviews could be any discussion or interaction between person-to-person, either face-to-face or otherwise, and involving two or more individuals with a definite objective in mind (**Kumar 2011**). The procedure of asking questions to respondents could either be flexible, where both the interviewer and interviewee are at liberty to think about and frame questions as they come to mind on issues under investigation, or where questions are not flexible, and has to be strictly followed as planned (**Kumar 2011**).

According to Monette *et al*. (1986: 156), an interview comprises an interviewer asking questions to respondents or sample population and recording their feedback or answers (**Wilgus 2007, cited Monette *et al*. 1986**); while interviews are rather more suitable for inquiries that need probing to obtain satisfactory data or information (**Walliman 2011**). Kumar (2011), noted that interviews are classified into different groups, though that depends to its degree of flexibility (**Kumar 2011**).

3.4.1 Structured interviews

This research used a pre-arranged set of questions to interview managers, and systematically follow the order of questions as stated in the interview plan (**Kumar 2011**). Additionally, this research also used face-to-face and questions via email to gather information (**Kumar 2011; Walliman 2011**) across the three sectors.

3.4.2 Unstructured interviews

This type of interview is informal in nature. In most cases, it is used to discover in-depth understanding on a wide area in which the researcher is interested. This research adopted this method as it had questions and a clear idea of what was needed (**Saunders *et al*. 2009**). Unstructured interviews are common in both quantitative and qualitative research. The variance however is how data obtained from them in reply to the questions are used. Quantitative research develops feedback categorisations from responses that are then coded and quantified or counted. But in qualitative research feedback are used as descriptors, often written exactly the way it is said, and can be integrated with further arguments or opinions and the logic involved. (**Kumar 2011**); but there are no closed format questions (**Walliman 2011**).

3.4.3 Advantages of using interviews

Using interviews is good for compound or complex circumstances, as it gives detailed description of an event or situation (**Luton 2010**). The most conducive method of learning situations that are complicated areas, as the interviewer has the time to plan before interviewing respondents on sensitive issues. It is a useful way to collect in-depth information or data. An interviewer can ask follow-up questions and gauge contacts received from observation of non-verbal responses (**Kumar 2011**). In a case where questions are not understood, it can be re-explained or reiterated for clarity purposes. Similarly, interviewing has broader application. Unlike a questionnaire, an interview can be applied to different population, be it the literate or illiterate, children, the handicapped or very old people (**Kumar 2011**).

3.4.4 Disadvantages of interviews

On the other hand, using interviews is said to be time and money consuming (**Kumar 2011**). This is particularly so as possible respondents could not be concentrated in one location. Though, if there is a place, office or organisation where possible respondents are gathered, then using interviewing in that situation will not be considered as expensive (**Kumar 2011**). The quality of information or data received from respondents is dependent on the quality of discussion and the interviewer. Because discussion during interview is sometimes private, the quality of feedbacks received from having separate interviews may differ. There is also the possibility of researchers being bias in framing questions and different interpretations could always be applied. (**Kumar 2011**).

Wilgus (2007) noted that some challenges can affect an interviewee (person interviewed) which could include, failure to comprehend questions, memory lapses, embarrassment, or making information due to the presence of others. Also, an incompetent interviewer may book the wrong person, misjudge a query, give incomplete and salient information, transcribe data incorrectly or completely misconstrue the interviewee. An unguided interviewer could purposely make some remarks that are unacceptable, deliberately omit or retell questions incorrectly, or even interview another respondent. Sometimes, respondents could offer erroneous information not relevant to the information needed. A lot of variables can combine to impact the correctness of data or information which the researcher is seeking (**Wilgus 2007**).

3.5 Data Analysis

3.5.1 The use of (SPSS)

Statistical Package for the Social Sciences (SPSS) software was used to analyse data collected online. Descriptive statistics were generated, and chi-square tests used to analyse categorical responses, while Kruskal-Wallis (KW) nonparametric one-way ANOVA tests were used to analyse ordinal responses and test if responses from the three different sectors had any statistically significant difference. Nonparametric statistics, for example the Kruskal Wallis test, are appropriate for data which are ordinal, such as the responses to the online questionnaire. In these tests, the null hypothesis was that there were no differences between the responses from the three industry sectors. The threshold for statistical significance was taken as $p = 0.05$, i.e. the null hypothesis was rejected when $p < 0.05$.

3.6 Examining of Past Accidents

Three past accidents and three past incidents (**Zainal 2007**) in nuclear, aviation and oil and gas were examined in this research. The aim was focused on if knowledge or lack of knowledge of NTS, isomorphic lessons, organisational learning and risk characterisation contributed in managing safely or wrongly in the events that were examined.

Examining of past accidents/incidents can be considered a strong research method particularly when a full, in-depth investigation is conducted **(Gülseçen and Kubat 2006**). With case study methods, a researcher can go away from the quantitative numerical results and understand the behavioural conditions through other perspectives. By including both quantitative and qualitative data, case studies (past accidents) help to explain both the process and outcomes of an occurrence through broad observation, reconstruction and analysis of the cases under investigation (**Zainal 2007**).

However, Yin (1994) noted there are three categories of examining past accidents, which are exploratory, descriptive and explanatory **(Yin 1994**). The advantage of using case studies (past accidents) as a research method is primarily the examination of the data (**Yin 1994**). Also, study of past accidents/incidents allows for both quantitative and qualitative analyses of the data (**Yin 1994**). Another reason for case studies (of past accidents) is that they help to discover or describe the data in real life environment, but also help to explain the difficulties of real-life circumstances which may not be captured through survey research (**Zainal 2007**).

However, despite the advantages accredited to case studies (past accidents), they have criticisms. They are three types of argument against case studies (past accidents) research (**Yin (1994**). Case studies (past accidents) are often accused of lack of rigour, investigators being sloppy and has allowed misleading evidence or biased views to affect the direction of findings and conclusions (**Yin 1994**). Case studies (past accidents) also provide little basis for scientific generalisation as they use a small number of subjects (**Yin 1994**). They also produce a large amount of documentation or large amount of data over a period; and it depends on a single case exploration thereby failing to reach a generalised conclusion (**Zainal 2007; quoted Tellis 1997**).

3.7 Secondary Data Method

There are two methods of secondary data (**Johnston 2014**) used as line of inquiries in this research. The first was the industry regulatory data of past accidents/incidents across the three sectors (see Section 2.10). The second one was past accident records that occurred in the nuclear sector. It was collected to determine which aspect of human factor led to accidents causation in the nuclear sector from 1998 to 2018. The first set of data was collected from 1998-2010 (**Sovacool 2010**), while complementary data was obtained from 2011-2018. See Section 4.7 for HFACS analysis.

3.7.1 Industry Regulatory Data

Use of regulatory data was another research method used to look at documents from the regulators point of view between nuclear, aviation and oil and gas. Documents were explored to determine if NTS, isomorphic lessons, organisation learning, and risk characterisation had the same meaning (language) within the three sectors.

Some of the regulators documents used are from the Office for Nuclear Regulation (ONR), which is the safety regulator for the nuclear industry in the United Kingdom; the Civil Aviation Authority (CAA), which is the statutory authority that oversees and regulates civil aviation in the UK; and the Oil and Gas Authority (OGA), whose role is to regulate, influence and promote the UK oil and gas industry, with the purpose of achieving the industry statutory principal objective of maximising the economic recovery of the UK's oil and gas resources. (See Appendix 13 (A1) on lexicon for explanation).

3.7.2 Human Factor Classification System (HFACS Analysis)

3.8.3 The Coding Process

Publicly available nuclear sector accident reports from 1998 to 2018 were used. The accident data were inputed into Microsoft Excel and later imported into the SPSS software for coding. It was coded with 1 and 0 as being present and absent (accident) respectively for different years, as shown in Appendix 6. After the coding, it was then analysed. All human factor components (levels) of the HFACS framework were loaded into separate columns, according to their hierarchy in the framework.

Data were analysed for different active and latent causal factors that prompted the accidents using information from their incident descriptions. To codify the results using the HFACS taxonomy, the HFACS event description worksheet was used to understand the various events in each accident that could aid in determining each human factor that played a role in accident causation.

The accident data was analysed using descriptive statistics in SPSS and crosstabs analysis selected. Chi-square tests and correlation options were selected as the statistical tools displayed in the results and only the significant relationships with $p < 0.05$ were selected for analysis. See Appendix 6 for Chi-square test. See result on Trend analysis on Figure 28 (Section 4.7.2).

Subsequently, a bivariate correlation test was carried out with the years selected that served as independent variables and the human factors selected as the dependent variables. Two levels of significance were chosen for the hypothesis test on human factors, which was selected at $p < 0.05$. It implied that any Pearson's r-value gained after the analysis is significant as it is < 0.05 and 0.01. All significant human factor relationships were symbolised with one and two stars, where one star is significance at < 0.05- and two-stars meaning significance at 0.01. Positive values indicated a progressive or linear relationship between two human factors, while the negative values indicated the strength of inverse relationships also between two human factors. See appendix 6 for Pearson's Correlation.

Pearson's chi-square test was used to indicate the effect each level of HFACS had on the lower level (**Siu, Phillips, and Leung 2004**). It was adopted by this research to gauge the level of independence of various human factor levels on each other in the HFACS framework (**Agresti and Kateri 2013**). A chi-square p < 0.05 justifies that there is significant relationship between two human factor levels (**Restrepo, Simonoff, and Zimmerman 2009**).

3.8 Focus Groups

Focus groups (**Silverman 2015**) were used to test the validity of the online results gathered. This research invited 15 experts (5 from each sector) and were asked to examine if online survey findings from different sectors truly represent industry practice, and proffer solutions where necessary.

All focus groups were conducted via MS Teams with the assistant of one of the supervisory team who introduced the concept to the participants. Permission was asked and granted for the recording of the sections which typically lasted 45 – 60 minutes in length. The focus group interaction was conducted in two days for the purpose of receiving effective feedbacks from participants. (See Section 4.9 for further explanation).

3.9 Research Approaches

Research approaches depend on what has been stipulated at the beginning of the research, especially as they relate to what kind of design approach is used for the research project. This implies if the research will use the deductive approach, which means developing a theory and hypothesis and designing a research strategy to examine the hypothesis; or either the inductive approach, that is expected to collect data and develop theory using data analysis (**Saunders *et al*. 2009**).

3.9.1 Deductive approach

This research adopted deductive approach to gather and analyse results. Deduction approach is using a scientific method of carrying out research. This involves developing a theory which is subjected to continuous or rigorous test. Based on that, it is believed to be a leading research method in the field of natural sciences, where laws exist as the basis of interpretation, allowing the expectation of phenomena, predicting their occurrence and therefore permitting them to be controlled (**Collis and Hussey 2003**).

Robson (2002) listed five successive steps in which deductive research can progress.

These are:

- Deducing a premise (a testable plan about the relationship between two or more ideas or variables) from the theory.
- Expressing the hypothesis (theory) in operational or functioning terms (this means indicating precisely how the ideas or variables will be measured), which recommend a link between two definite variables.
- Testing the operational hypothesis (will involve one or more of the strategies).
- Examining the exact result of the investigation (it will also tend to confirm the theory or show the need for its change).
- If necessary, the theory will be modified from what is obtained from the findings (**Robson 2002**).

3.9.2 Inductive approach

Also, this research largely used inductive approach method of data gathering and analysis. Reason being that it helped to gain meaning respondents attached to events. However, to have a wider scope and view from participants, the research combined deductive and inductive methods to gather data. Inductive approach is targeted at getting a feeling of what is happening, enabling the researcher to understand or have a clearer picture of the problem (**Tashakkori and Teddlie 2003**). Therefore, there is need to make sense of the interview, data collection and analysis. Result findings from the analysis would then be formulated into a theory. Table 15 shows the distinction between deductive and inductive approaches in research.

In summation, a deductive approach to research is associated with scientific investigation. It tries to study what others have done, in terms of existing theories, and then tests hypotheses that emerges from those theories.

Whereas, inductive approach is a systematic procedure for analysing qualitative data whereby the analysis is likely to be guided by specific evaluation objectives and concerned with the generation of new theory developing from a data.

Table 15: Deduction and Induction emphasis in research (Saunders *et al*. 2009).

Deduction emphasises	Induction emphasises
• Science principles.	• Gaining an understanding of the meanings human attach to events
• Moving from theory to data.	• A close understanding of the research context
• The need to explain causal relationships 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 progress
• 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 need to generalise.
• A highly structured approach	
• Researcher independence of what being researched.	
• The necessity to select samples of sufficient size in order to generalise conclusions.	

3.9.3 Research Population

The population researched (**Lee Abbott and McKinney 2012**) were safety experts from nuclear, aviation and oil and gas sectors within the UK. Some of the nuclear respondents (safety managers, operators and safety trainers) were recruited from the World Nuclear Association Symposium held in London in 2018, while LinkedIn was mostly used to recruit respondents from the aviation (Pilots, crew members, air traffic controllers, safety managers and operators). In the oil and gas sectors, safety managers, operators, drillers and safety trainers were reached. Respondents that received the questionnaire answered the same set of questions in the same predetermined order **(Saunders, Lewis, and Thornhill 2009**).

The population for this research was 232 respondents (**Saunders *et al*. 2009**). Which means the people the research is interested in, as size sample is meant to be the population (**Leavy 2017**). Though in sampling, the word 'population' is not used in its usual or normal sense, as the full set of respondents may not essentially be people (**Levy 2017**). It also means the whole set of entities or objects that the decision or action is concerned with **(Easterby-Smith, Araujo, and Burgoyne 1999**).

3.9.4 Sampling Method and Size

Sampling methods provide an array of approaches which allows a researcher to condense or reduce the quantity of data needed to be collected, by considering only data or information from a sub-group instead of all possible cases (**Saunders *et al*. 2009**). Therefore, this research shared questionnaires to safety experts across the three sectors. The sample size gathered across the three sectors are nuclear (n=124, 54%); aviation (n=59, 25%) and oil and (n=49, 21%). Figure 12 indicates an example of a sample population method in research.

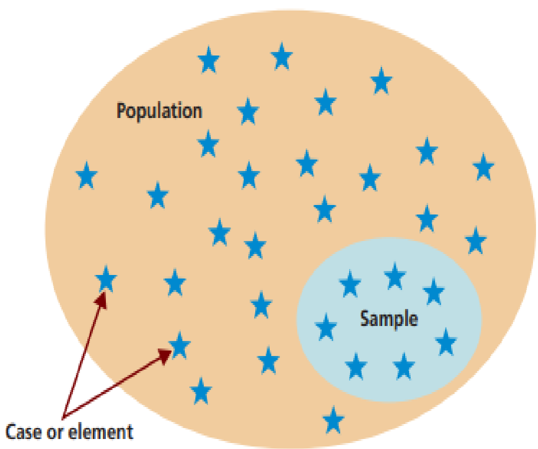


Figure 12: Sample method in research (Saunders et al. 2009)

3.9.5 Need to sample

In some research, there is the possibility of collecting data from an overall population to a controllable size. Still, it should not be assumed that a census would necessarily offer useful information instead of collecting figures from a sample that signifies the whole population. Sampling method provides a valid substitute to a census when it is difficult to investigate the whole population. Budget constraint is another issue that could prevent surveying the whole population; in addition to that is time constraints to gather all the data and analyse it on time (**Saunders *et al.* 2009**).

The four main types of probability sample methods are sample random, systematic, cluster and stratified sampling methods (**Levy 2017 and Sunders et al. 2009**).

This research used random sampling method and mixed design methods to recruit respondents in answering the research questions. Reason being that the research population was not grouped in a particular location. Qualitative research depends on probability sampling methods which involve using any strategy that relies on collecting samples in a way that each element in the population has either known or non-zero chance of being selected. Each person or element in the population possibly had a chance of inclusion in the sample and can be determined statistically with a number above zero for every person or element (**Leavy 2017**).

3.9.6 Assessing validity

Focus group was used to test for validity in this research. Further explanation for this is on section 4.9. Bryman (2012) said assessing validity is whether an indicator that is designed to measure a concept, really measured the concept or what it was intended for (**Bryman 2012**). Content validity is about the extent to which the measurement questions contained in the questionnaire can provide adequate coverage of the research questions. Decision of what is 'adequate coverage' can be made in several ways. One is by careful definition of the research through the literature review and, where suitable, past discussion with other people. Another method is using a group of individuals to measure if each measurement or research question in the questionnaire is 'important', 'useful but not essential', or 'not necessary' (**Bryman 2012**). The research also used an initial pilot study determine content validity.

While predictive validity is concerned with the ability of the questions to make correct predictions or forecast. For instance, if a researcher is using the measurement questions within the questionnaire to forecast customers' future buying behaviours, then using a test of such nature will be the degree to which they predict customers' buying attitude. To assess criterion-related validity, the researcher will be comparing the data from the questionnaire with that stated in the standard in some way. Sometimes, this is assumed using statistical analysis such as correlation (**Bryman 2012**). This research did not consider it useful to predictive validity.

Construct validity is the degree to which measurement questions gauge the presence of constructs being intended to measure. Construct validity is used when referring to constructs such as attitude scales, aptitude and personality tests (**Bryman 2012**).

3.9.7 Testing for reliability

Reliability is concerned with consistency of measures (**Bryman 2012**). For a questionnaire to be valid, there must be reliability, which is not satisfactory on its own. Respondents may misconstrue a question in the questionnaire in one way, when it means something else (**Saunders *et al*. 2009**). This exactly happened in one of the questionnaires on isomorphic lessons which many participants did not initially understood until an explanation was given.

Saunders *et al*. (2009), noted that reliability is about the strength or robustness of the questionnaires and if it will produce constant findings at different times and different conditions, using different samples, especially using different interviewer-administered questionnaire with different interviewers. Three basic methods to assess reliability, and comparing the figures collected with other figures from different sources. The interpretation for each of these is carried out after data must have been collected, which must be considered when the questionnaire is being designed (**Saunders *et al.* 2009**).

3.10 Research Philosophy

Research philosophy relates to the development of knowledge and the nature of that knowledge (**Saunders *et al*. 2009**). As a result, the purpose of this research is geared towards the relatively modest ambition to answer some specific problems relating to the three sectors carried out in this research, thereby developing new knowledge. Though some research questions have been asked in this research and answers sought, however, the reality is that a research question rarely falls precisely into only one philosophical domain as indicated and suggested in the 'onion' in Figure 13 (**Saunders et al. 2009**), and hence, there is need to look at other research philosophies.

There are two major ways of thinking about research philosophy, these are: ontology and epistemology, as each contains vital differences that will influence the way in which researchers think about research process, and how it enhances understanding of the way in which people approach the study of a particular field of activity (**Saunders *et al*. 2009**).

3.10.1 Pragmatism

The pragmatist argues that the most significant determinant of epistemology, ontology and axiology a researcher adopt is the research question, as one may be more appropriate than the other to answer. Likewise, if the research question does not suggest explicitly that either a positivist or interpretivist philosophy is accepted, this confirms the pragmatist's view that it is possible to work with variations in epistemology, ontology and axiology (**Saunders *et al*. 2009**).

Tashakkori and Teddlie (1998) stated that it is important for the researcher in a specific study to think of the philosophy adopted as a range rather than opposite positions. They noted that at some points, the 'knower and the known' must interact, while one may easily stand apart from what one is studying (**Tashakkori, Teddlie, and Teddlie 1998**).

They said that pragmatism is naturally appealing, mainly because it avoids the researcher from engaging in what is seen as rather pointless debates about such concepts as to what is truth and reality. In their view, a researcher should in what he/she is interested in and of value to the researcher; study in the different ways in which it deems appropriate, as result will be used to bring about positive consequences within the value system' (**Tashakkori and Teddlie 1998:30**). As a result, this research concentrated on those ideas that are regarded to be interested in solving the research questions and contribution to knowledge.

3.10.2 Ontology

This branch of knowledge is concerned with the nature of reality, as it raises questions of assumptions researchers have about the way the world functions and the commitment held to particular views.

3.10.3 Objectivism

They are two aspects of ontology, which are objectivism and subjectivism. Objectivism reveals the position that social beings exist in reality to external social actors concerned with their existence. For instance, the way people are managed in an organisation. Therefore, one may argue that management is an objective entity (**Saunders *et al*. 2009**).

3.10.4 Subjectivism

Subjectivism contends that social phenomena are fashioned from the perceptions and consequent actions of the social actors concerned with their existence. This is a constant process in that through the process of social interaction, social phenomena are in a constant state of adjustment (**Saunders *et al.* 2009**). Remenyi *et al*. (1998:35) said this is often associated with the term social constructionism. Social constructionism views reality as being socially created (**Remenyi *et al*. 1995:35**). This research took a subjective approach because participants view and reasoning during the online survey could have been subjected to different debates and arguments.

3.10.5 Epistemology

This is the second way of thinking about research philosophy as it concerns to what constitutes acceptable knowledge in a field of study. This research would rather believe that the data collected are far less open to bias does not agree that it is objective, but subjective. However, the researcher will tend to rely more on epistemological philosophy to conduct the research. Figure 13 shows research philosophy used in this research.

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.

Figure 13: Research philosophy (Saunders *et. al*. 2009)

3.10.6 Comparison of Four Research Philosophies

Table 16 further illustrates the comparison that exist between four research philosophies in management of research.

Table 16: Four philosophy areas

	Positivism	Realism	Interpretivism	Pragmatism
Ontology: The researcher's view of the nature of reality or being.	External, objective and independent of social actors.	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist).	Socially constructed, subjective, may change, multiple.	External, multiple, view chosen to best enable answering of research question.
Epistemology: The researcher's view regarding what constitutes acceptable knowledge	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements.	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts.	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions.	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data.
Axiology: The researcher's view of the role of values in research.	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance.	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research.	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective.	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view.
Data collection techniques most often used.	Highly structured, large samples, measurement, quantitative, but can use qualitative.	Methods chosen must fit the subject matter, quantitative or qualitative.	Small samples, in-depth investigations, qualitative.	Mixed or multiple method designs, quantitative and qualitative.

3.11 Ethical Issues on Data Collection

Ethical measures were considered in carrying out the research work; as participant informed consent was sought, and further explanation given to the sample population as to why the research was carried out. Respondents were treated with courteousness (**Walliman 2004**). However, irrespective of the data collection method used, there were still lots of ethical principles that were adhered to. Harm was not caused, or participants' privacy intruded upon. Also, participants had the right not to participate in the research even if they had agreed to do so. They reserved the right to withdraw.

The research guaranteed confidentiality and anonymity of respondents, as it is important to gain access to organisations and individuals. And since such promises have been given, it is paramount to mention that they were maintained (**Saunders *et al*. 2009**).

Coventry University utilises an online ethics applications system. It is a requirement for any research to be approved prior to data collection. One of the requirements for primary data collection is to use approved Participant Informed Consent (PIC) and Participant Information Leaflets (PIL). Additionally, requirements can include completion of a risk assessment form. All primary data collection requires the researcher to provide details on survey questions, interview questions and focus groups activities in advance. For the further clarification on the approval system for ethics, see Appendix 2 for ethical application consent form.

3.12 Conceptual Framework

The conceptual framework of this research provided a theoretical overview of the research and order within the research process. According to Weaver-Hart (1988) conceptual framework is defined as a structure for organising and supporting ideas; a mechanism for systematically arranging abstractions; sometimes revolutionary or original, and usually rigid. Miles and Huberman (1984) stated that conceptual framework is a researcher's territory being investigated. The definition accommodates purpose (boundaries), with flexibility (evolution) and coherence of the research which is plan, analysis and conclusion **(Trafford and Leshem 2008; quoted Miles and Huberman 1984**). Figure 14 is the conceptual framework of this research.

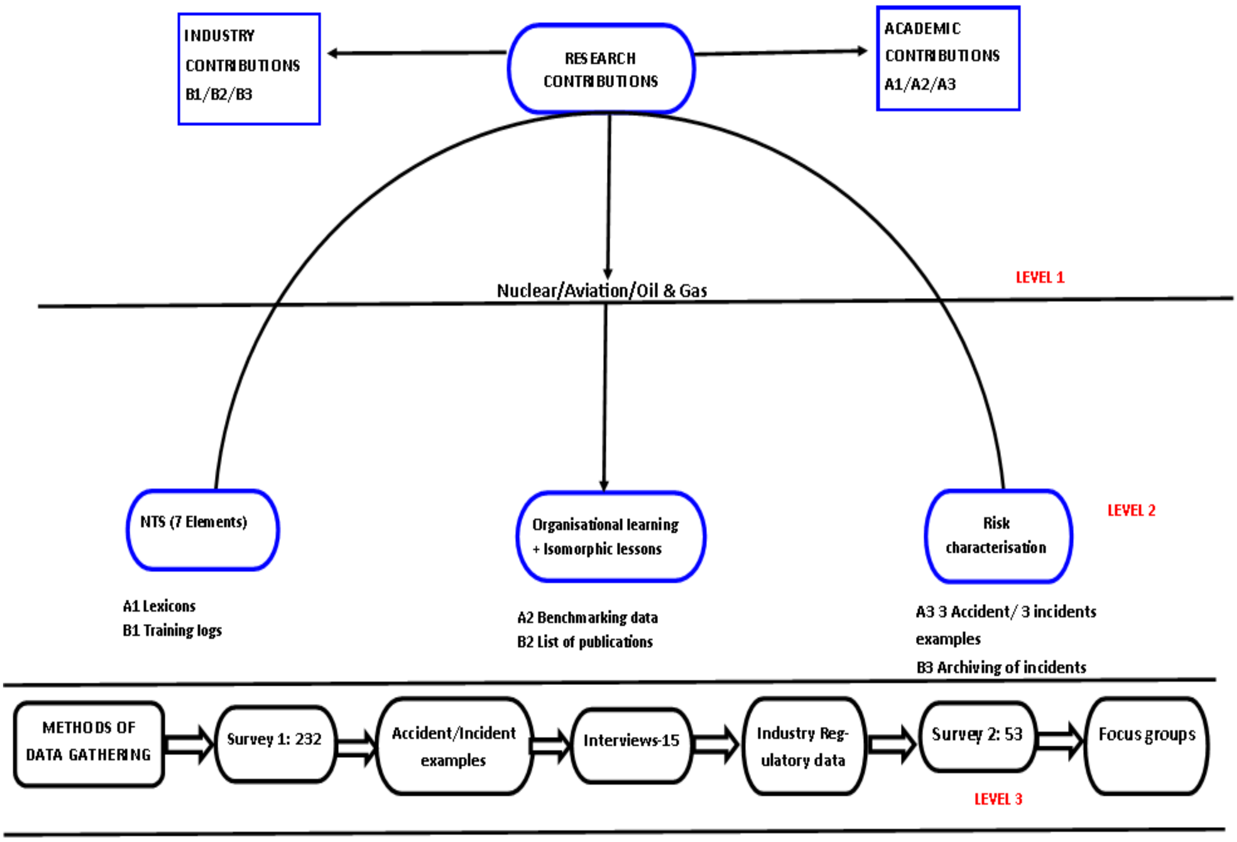


Figure 14: Conceptual framework of this research

3.12.1 Explaining the framework

The conceptual framework in this research comprises three levels of investigations. **Level 1** is both academic (theory) and industry (practice) contributions derived from the three industries examined in this research, namely: nuclear, aviation and oil and gas. **Level 2** is the outputs derived from the four pillars are: NTS, isomorphic lessons, organisational learning and risk characterisation. These in turn are used to produce some toolkits for both academic and industry applications. **Level 3** focused on line of authentication of data gathering.

Level 1

Academic toolkits are represented as **A1 -** Lexicons, which is a comparison of terminology used in different sectors, which invariably could mean the same thing in another sector. **A2** – Benchmarking data, these are findings derived from the online survey on how each sector uses the four pillars to manage safely in various sectors. (Provide information that meets the needs of managers and planners in an unpredictable environment; offer possible solutions gathered from best practices in either aviation or oil and gas; provide a means of improving competence through learning both within and outside organisations and between organisations). The third is **A3**. This includes 3 accidents and 3 incidents examples. A3 is used to indicate that where there are lapses on NTS, isomorphic lessons, organisational learning and risks characterisation, accidents are bound to happen in such sectors. Evidence of these have been shown on the accidents and incidents examples.

The contributions for industries (practical) comprise **B1** – Training/Reflection logs in different sectors to enrich workers understanding on the four pillars used in this research. **B2** – List of publications of different articles relating to the three sectors on the four pillars. The list served as reference points to industries on different types of publications that supports industry learning. And **B3** – Archiving of incidents near-misses. This again served as reference point to industries on the type of low incidents that has occurred in the sectors and contribute to isomorphic lessons or organisation learning.

Level 2

Level 2 focused on the four pillars used to investigate the three sectors. The four pillars have been defined by different authors. For instance, NTS has been defined by Flin *et al*. (2008) as the cognitive, social and personal skills which complements technical skills in job performance (**Flin *et al*. 2008**). While isomorphic lesson is the faculty to learn from similar experience of others or oneself (**Toft and Reynolds 2005**). Argyris and Schön (1978) explained that organisational learning refers broadly to an organisation's acquisition of understanding, know-how, techniques and practices of any kind and by any means (**Argyris and Schön 1978**). Risk characterisation is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (**Stern and Fineberg 1996:1**).

Also, the level contains sub-topic which represent the toolkits for both academic and industry contributions. As discussed on level 1, the 'As' represents the contribution for academic, while the 'Bs' represent the contributions for industries.

Level 3

Level 3 are six layers of authentication or line of inquiry used to justify the framework. Research methodology adopted relates to justification of these layers of both primary and secondary data collection. Overall, there are six methods of data gathering in the entire research work. These are: online research survey (used to test if the three sectors use the four pillars to manage safely) (See section 4 for result analysis); accidents and incidents examples which can be a mode of failures that triggers accidents. (See Table 14 examples). There also 15 interviews to substantiate if industries are conversant with the four pillars and apply them to day-to-day safety management.

Another line of investigation is the industry regulatory data. This helped to understand if various industry regulators are familiar with (lexicons) languages on the four pillars and what they are called. Another online survey carried out was to investigate the impact of Covid-19 pandemic on workers performance due to changing nature of risk across the three sectors. (See Section 4.8 for explanation on result findings and analysis); and finally, a focus group discussion. This is to underpin the views and body of knowledge to show validity on the online result as it affects the four pillars.

Therefore, these six lines of inquiry were the amalgam used to justify the merit of areas tested in this research.

CHAPTER 4
RESULT ANALYSIS & DISCUSSION

4.1 Introduction to Result Analysis

Data should first be collected and prepared before they are analysed (**Sapsford and Jupp 2006**); as data are a raw form of information, and until they have been sieved and analysed they convey very little meaning. To make data useful, they have to be processed and then turned into information (**Saunders, Lewis, and Thornhill 2009**). Data analysis involves reducing information gathered during the survey and presenting them in a clear and understandable form either in tables, pie and bar charts (**Bryman 2012**). With quantitative analysis techniques such as charts, graphs and statistics, it allows and makes it possible to explore, present, describe and examine relationships and trends within data collected (**Saunders, Lewis, and Thornhill 2009**).

There are four result analysis in this thesis. These are: Two online result analysis; interview result analysis and accident data result analysis (secondary data). Each of these analyses were discussed as separate topics but combined in this chapter. Secondary and primary data were two notable methods used for data collection in this research (**Kumar 2011**).

4.2 Online Result Analysis

Bristol Online Survey (BOS) was used to gather respondents' views from nuclear, aviation and the oil and gas sectors. The survey was then hosted on May 23, 2018. Finally, 232 respondents were received from industry experts which achieved a response rate of 77.33% out of 300 respondents that were initially targeted.

4.2.1 Analysis using SPSS

Results were analysed using SPSS to determine to what extent organisations use NTS, organisational learning, isomorphic lessons and risk characterisation in training, exercise and managing safely; and if workers have encountered the four pillars within their working environment in the UK. Table 17 shows breakdown of responses received before they were analysed.

Breakdown of questionnaire fielded and received during the research

Table 17: Breakdown of responses received

	Questionnaire	Total
1	Online respondents received	234
2	Valid questionnaire	232
3	Invalid (undefined response).	2
4	Number of questionnaires analysed	232

In all, 17 questions were fielded to respondents across the three sectors. The questions asked focused on participants experience and position; general questions; practice and closing questions. (See Appendix 2 for the online questionnaire).

4.3. Addressing research questions

Questions were asked to address the following research areas which are in tandem with research objectives:

RQ1: To what extent does the nuclear, aviation and the oil and gas sectors use NTS, isomorphic lessons, organisational learning and risk characterisation in training and managing safety in the UK?

RQ2: To what extent could lessons learned from other organisations, such as aviation and oil and gas, help shape the UK nuclear industry's safety?

4.4 Presentation of Result Findings

The analysis from the online survey produced findings and are summarised as follows:

Q1: Currently work in the following industry

The origin of respondents was nuclear (n=124, 54%); aviation (n=59, 25%); and oil and gas (n=49, 21%). The pie chart in Figure 15 indicates how participants responded according to the sectors they work for.

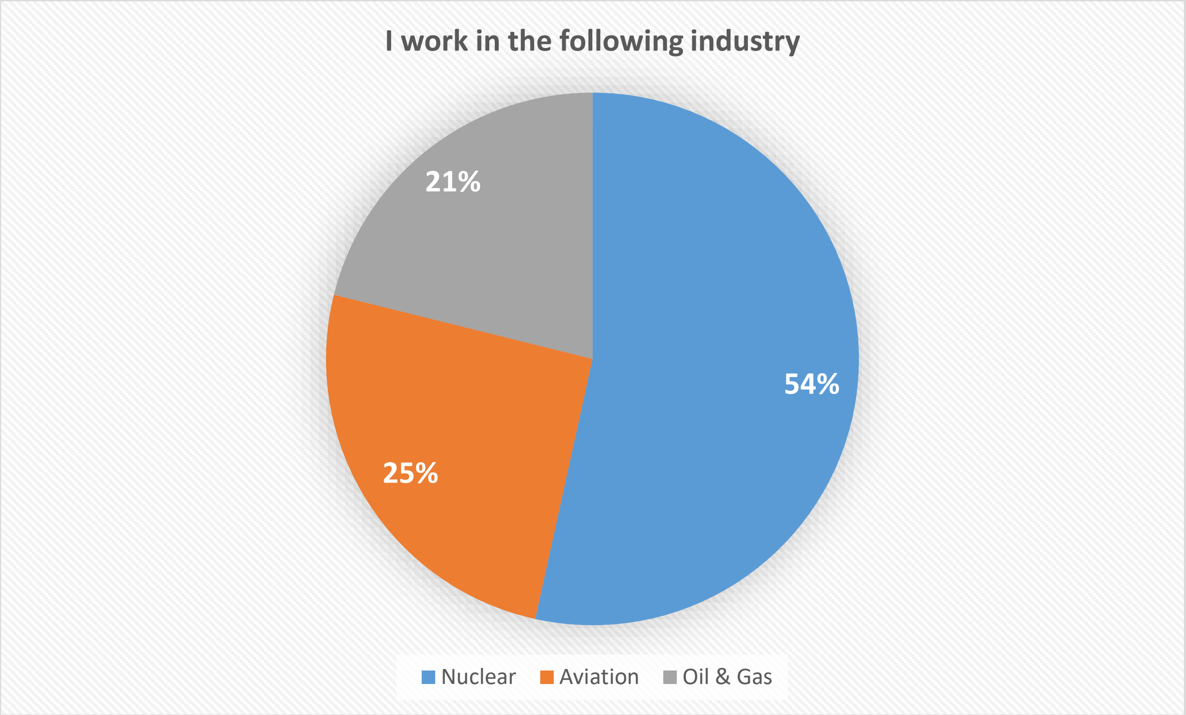


Figure 15: Response according to sectors

Q2: What position do you hold within your company?

Table 18 is a crosstab of Q1 and Q2, which illustrates how each sector responded.

Table 18: Position respondents hold in various sectors

		Senior Manager	Manager	Supervisor	Operator	Technical	Non-technical	Others	Total
Nuclear	**Count**	45	**23**	4	1	**32**	4	15	124
	[%] of Total	**36**	19	3	1	**26**	3	12	100
Aviation	**Count**	11	12	3	18	5	1	9	59
	[%] of Total	19	**20**	5	**31**	9	2	15	100
Oil & Gas	**Count**	7	10	9	2	10	0	11	49
	[%] of Total	14	**20**	**18**	4	20	0	22	100
Total	**Count**	63	45	16	21	47	5	35	232
	[%] of Total	27	19	7	9	20	2	15	100

Q3: Total years of service

Detail of how each sector responded on total years of service is indicated on Figure 16.

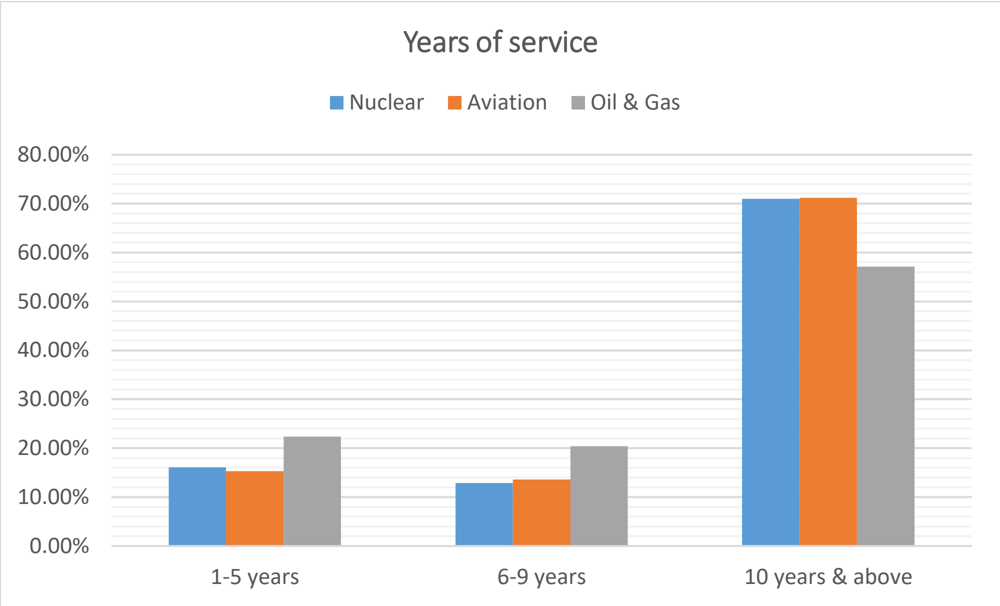


Figure 16: Years of service between the three sectors

Q4a: Have you encountered any of the following (NTS) within your working environment?

Detail of how each sector responded on NTS is indicated on Figure 17.

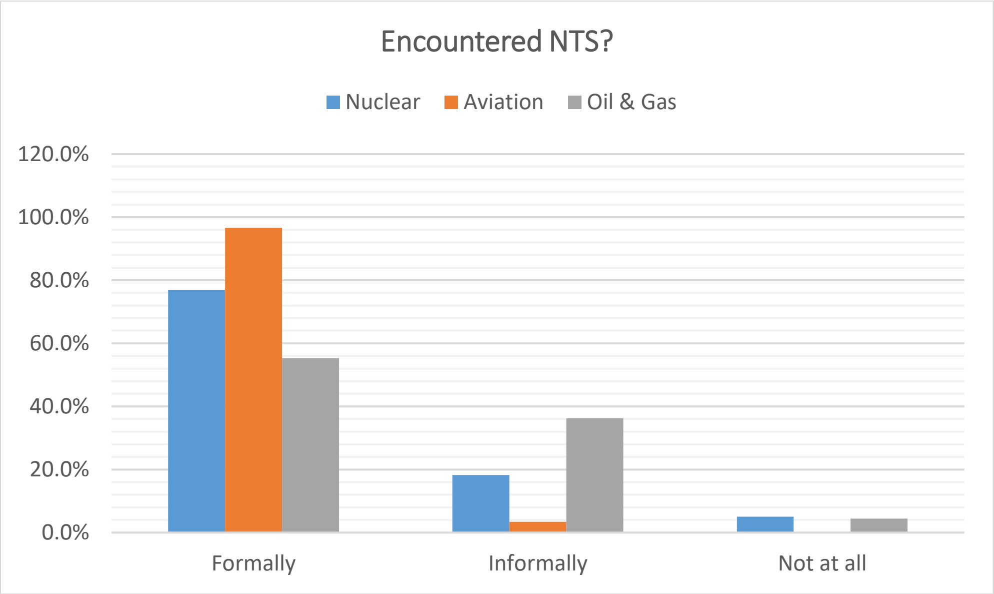


Figure 17: Sectors response on if they have encountered NTS

Q4b: (Isomorphic lessons)

Details of how the three sectors responded is shown in Figure 18.

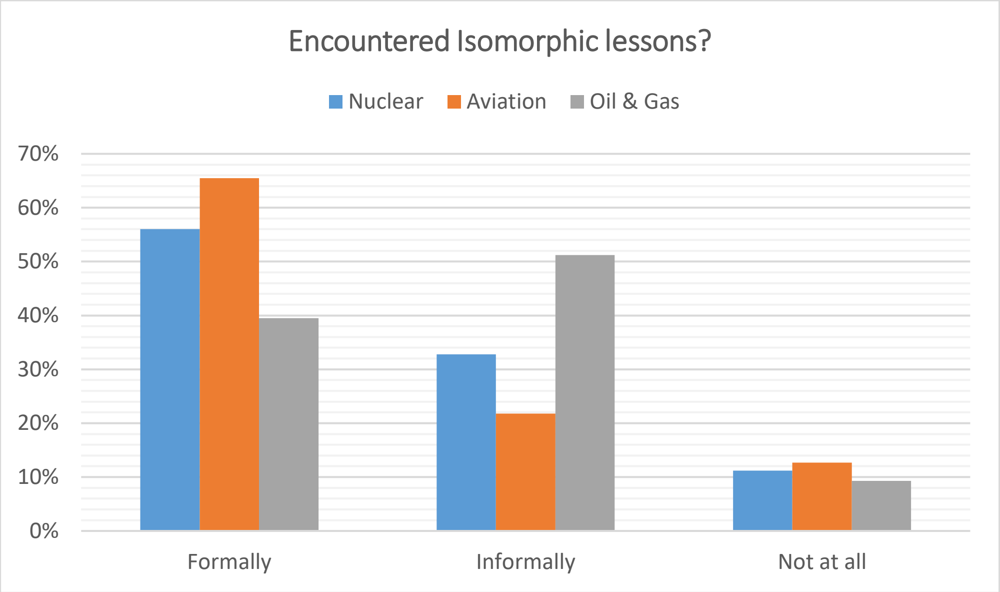


Figure 18: Sectors response on Isomorphic lessons in working environment

Q4c (Organisational learning)

Details on how the nuclear, aviation and oil and gas sectors responded are shown on Figure 19.

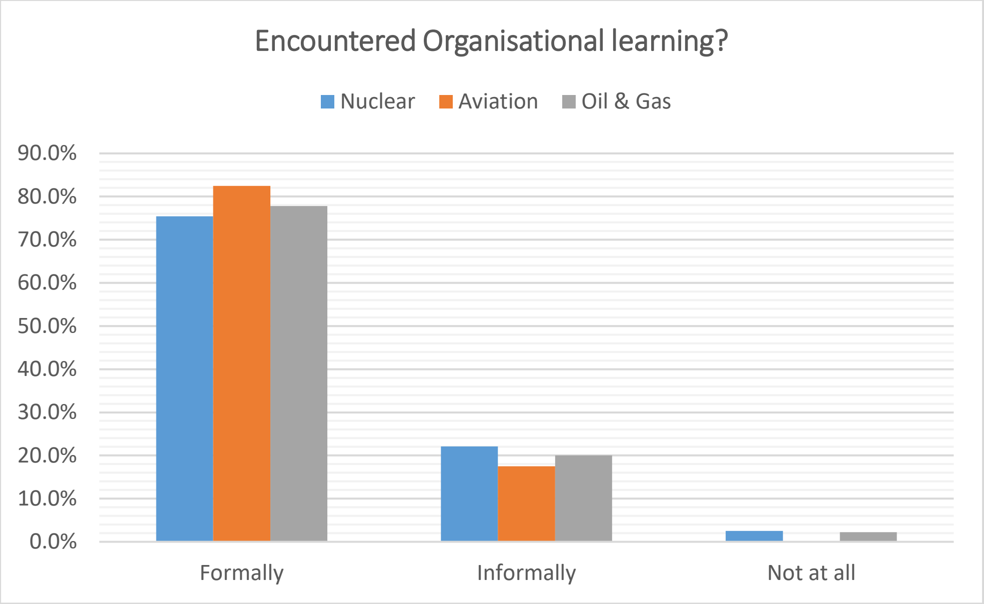


Figure 19: Sectors response on organisational learning in working environment

Q4d (Risk characterisation)

Figure 20 shows how each sector responded.

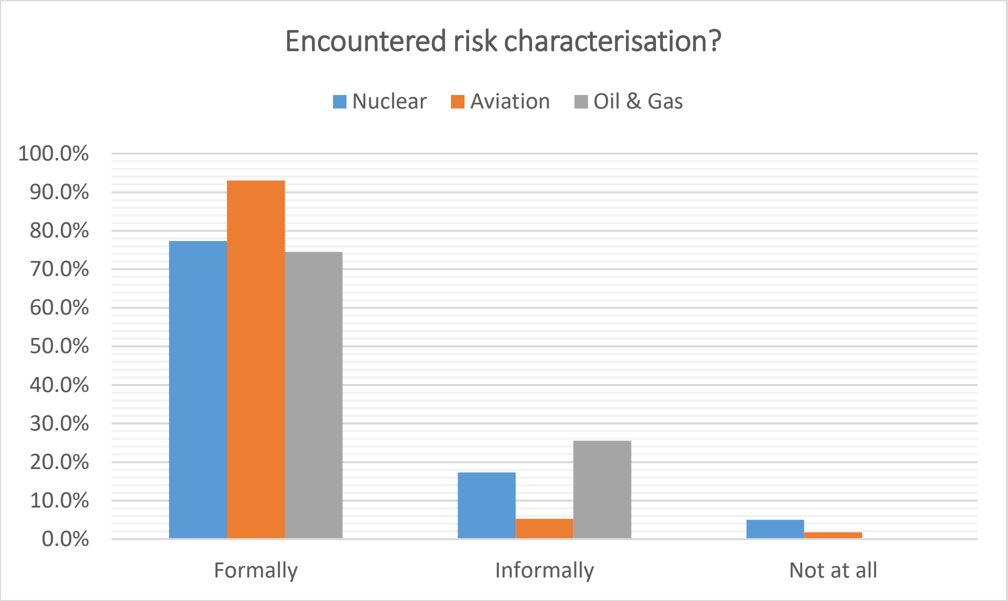
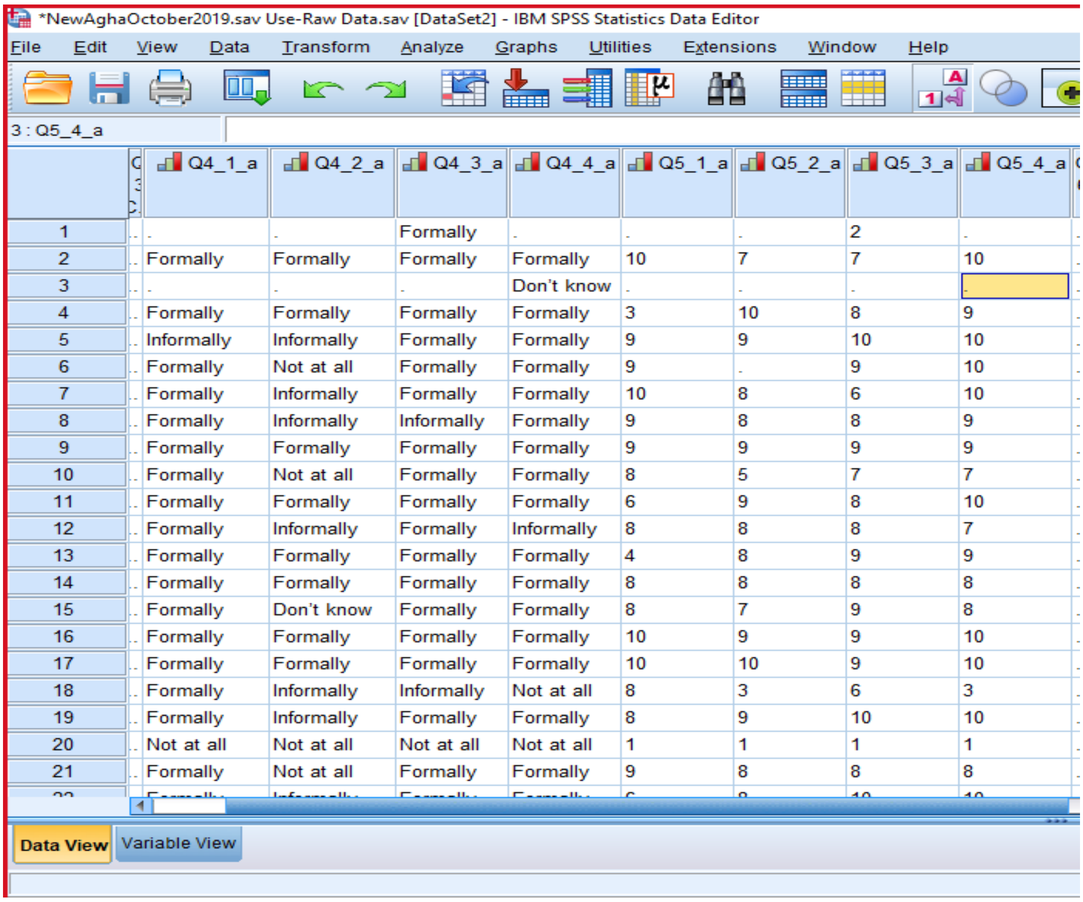


Figure 20: Sectors response on risk characterisation in working environment

Sample of Columns of Raw Data Responses from Questions 4 and 5

This snippet of the data (Table 19) file shows the 3-level ordinal responses to the four parts of Question 4 and the 10-level ordinal responses to the four parts of Question 5. These questions have been compared between industry sectors using Kruskal Wallis tests. Categorical variables with a small number of levels are often compared using chi-square tests and those with a larger number of levels using correlation.

Table 19: Indicating sample of columns of raw data responses from question 4 and 5.



	Q4_1_a	Q4_2_a	Q4_3_a	Q4_4_a	Q5_1_a	Q5_2_a	Q5_3_a	Q5_4_a
1	.	.	Formally	.	.	.	2	.
2	Formally	Formally	Formally	Formally	10	7	7	10
3	.	.	.	Don't know	.	.	.	.
4	Formally	Formally	Formally	Formally	3	10	8	9
5	Informally	Informally	Formally	Formally	9	9	10	10
6	Formally	Not at all	Formally	Formally	9	.	9	10
7	Formally	Informally	Formally	Formally	10	8	6	10
8	Formally	Informally	Informally	Formally	9	8	8	9
9	Formally	Formally	Formally	Formally	9	9	9	9
10	Formally	Not at all	Formally	Formally	8	5	7	7
11	Formally	Formally	Formally	Formally	6	9	8	10
12	Formally	Informally	Formally	Informally	8	8	8	7
13	Formally	Formally	Formally	Formally	4	8	9	9
14	Formally	Formally	Formally	Formally	8	8	8	8
15	Formally	Don't know	Formally	Formally	8	7	9	8
16	Formally	Formally	Formally	Formally	10	9	9	10
17	Formally	Formally	Formally	Formally	10	10	9	10
18	Formally	Informally	Informally	Not at all	8	3	6	3
19	Formally	Informally	Formally	Formally	8	9	10	10
20	Not at all	Not at all	Not at all	Not at all	1	1	1	1
21	Formally	Not at all	Formally	Formally	9	8	8	8

Q5: Using a scale of 1-10, rate the following on their ability to promote a stronger safety culture specifically within your organisation.

Detailed of how each responded is indicated in Table 20 – 23.

Table 20: Response on the use of **NTS** to promote stronger safety culture

	Count (Rating)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	2	0	1	8	8	6	14	35	12	32	118
[%]	2	0	1	7	7	5	12	**30**	10	27	100
Aviation	0	0	3	1	2	2	7	9	9	26	58
[%]	0	0	5	2	3	3	10	16	16	**45**	100
Oil & Gas	1	1	2	0	3	8	3	13	3	11	45
[%]	2	2	4	0	7	18	7	**29**	7	24	100
Total	3	1	6	9	13	16	23	57	24	69	221
[%]	1	1	3	4	6	7	10	26	11	31	100

Table 21: Response on the use of **isomorphic lessons** to promote stronger safety culture

	Count (Rating)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	1	0	3	1	9	7	12	15	28	36	112
[%]	1	0	3	1	8	6	11	14	25	**32**	100
Aviation	2	0	0	1	2	2	4	16	8	18	53
[%]	4	0	0	2	4	4	8	30	15	**34**	100
Oil & Gas	1	2	1	1	2	2	5	11	10	8	43
[%]	2	5	2	2	5	5	12	26	**23**	19	100
Total	4	2	4	3	13	11	21	42	46	62	208
[%]	2	1	2	1	6	5	10	20	22	30	100

Table 22: Response on the use of **organisational learning** to promote safety culture

	Count (Rating)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	1	0	1	2	3	8	14	24	25	42	120
[%]	1	0	1	2	3	7	12	20	21	**35**	100
Aviation	0	1	1	0	1	3	7	20	10	16	59
[%]	0	2	2	0	2	5	12	34	17	**27**	100
Oil & Gas	1	1	1	0	2	2	6	14	8	9	44
[%]	2	2	2	0	5	5	14	32	18	**21**	100
Total	2	2	3	2	6	13	27	58	43	67	223
[%]	1	1	1	1	3	6	12	20	19	30	100

Table 23: Response on the use of **risk characterisation** to promote safety culture

	Count (Rating)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	1	1	3	2	6	3	12	23	22	45	118
[%]	1	1	3	2	5	3	10	20	19	**38**	100
Aviation	2	0	0	1	0	4	5	11	12	21	57
[%]	4	0	0	2	0	7	9	19	21	**37**	100
Oil & Gas	3	0	1	0	0	2	4	14	7	13	44
[%]	7	0	2	0	0	5	9	32	16	**30**	100
Total	6	1	4	3	7	9	21	48	41	79	219
[%]	3	1	2	1	3	4	10	22	19	36	100

Q6: My organisation incorporates NTS effectively into training, exercises and safety practices

Each sector responded to the question as indicated in Figure 21.

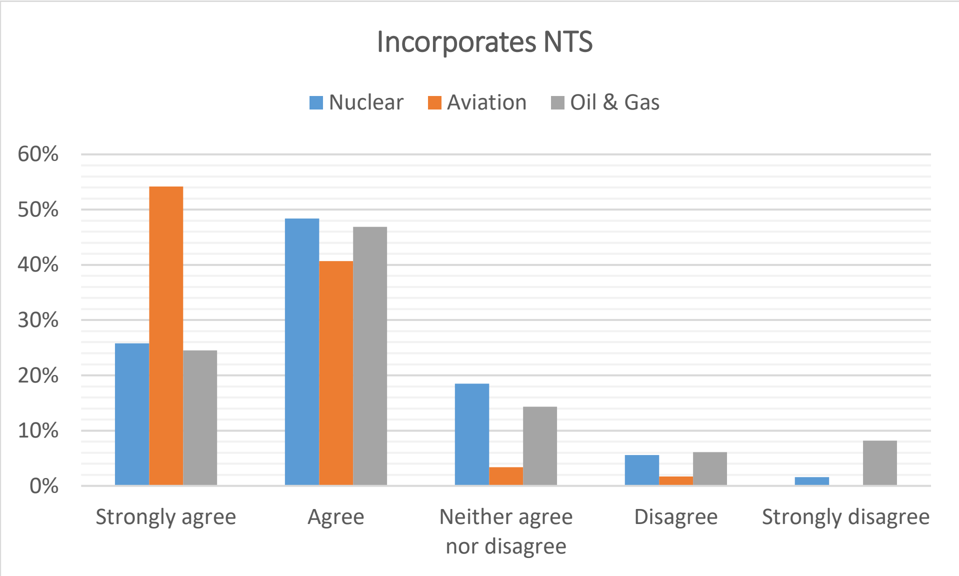


Figure 21: Showing if organisations incorporate NTS effectively into training

Q7: What type of NTS training have you received in your organisation?

Detailed of how each sector responded is indicated on Table 24.

Table 24: Indicating NTS training received by workers in workplace

Training Types (Associated with NTS elements)	Formal training [%]			Informal training [%]			No training provided [%]		
	Nuclear	**Aviation**	**Oil & gas**	**Nuclear**	**Aviation**	**Oil & gas**	**Nuclear**	**Aviation**	**Oil & gas**
1. Situation Awareness	47	**93**	54	27	7	30	26	0	15
2. Decision making	44	**81**	43	31	15	34	24	3	23
3. Communication	56	**88**	55	29	10	23	15	2	21
4. Teamwork	53	**90**	50	30	5	35	17	5	15
5. Leadership	61	**85**	55	20	12	23	19	3	21
6. Managing stress	41	**54**	40	31	27	23	28	19	36
7. Coping with fatigue	24	**69**	38	31	20	28	**45**	12	34

Q8: On a scale of 1-10 (1=lowest, 10 = highest) how effective is your organisation in terms of the following:

Details show how sectors responded to the question on Table 25 – 30

Table 25: Anticipating critical incidents

Anticipating critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	2	3	2	1	9	13	18	31	22	20	121
[%]	1.7	2.5	1.7	0.8	7.4	10.7	14.9	25.6	18.2	16.5	100
Aviation	0	1	2	0	5	5	11	13	9	13	59
[%]	0	1.7	3.4	0	8.5	8.5	18.6	22	15.3	22	100
Oil & Gas	0	1	3	3	4	2	3	15	5	7	48
[%]	0	2.1	6.3	6.3	8.3	4.2	8	31.3	10.4	14.6	100
Total	2	5	7	4	18	20	37	59	36	40	228
[%]	1	2.2	3.1	1.8	7.9	8.8	16.2	25.9	15.8	17.5	100

Table 26: Assessing critical incidents

Assessing critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	2	1	0	4	5	12	13	22	32	30	121
[%]	1.7	0.8	0	3.3	4.1	9.9	10.7	18.2	26.4	24.8	100
Aviation	1	0	1	1	1	3	12	11	14	14	58
[%]	1.7	0	1.7	1.7	1.7	5.2	20.7	19.0	24.1	24.1	100
Oil & Gas	0	0	3	0	3	5	4	13	10	10	48
[%]	0	0	6.3	0	6.3	10.4	8.3	27.1	20.8	20.8	100
Total	3	1	4	5	9	20	29	46	56	54	227
[%]	1.3	0.4	1.8	2.2	4.0	8.8	12.8	20.3	24.8	23.8	100

Table 27: Preparing for critical incidents

Preparing for critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	2	1	3	4	3	9	21	25	28	25	121
[%]	1.7	0.8	2.5	3.3	2.5	7.4	17.4	20.7	23.1	20.7	100
Aviation	0	0	0	5	2	4	11	12	12	12	59
[%]	0	0	0	8.6	3.4	6.9	19.0	20.7	20.7	20.7	100
Oil & Gas	0	1	1	2	3	6	8	12	7	8	48
[%]	0	2.1	2.1	4.2	6.3	12.5	16.7	25.0	14.6	16.7	100
Total	2	2	4	11	8	19	40	49	47	45	227
[%]	0.9	0.9	1.8	4.8	3.5	8.4	17.6	21.6	20.7	19.8	100

Table 28: Responding to critical incidents

Responding to critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	1	1	1	4	5	4	12	21	32	40	121
[%]	0.8	0.8	0.8	3.3	4.1	3.3	9.9	17.4	26.4	33.1	100
Aviation	0	1	2	0	2	6	10	11	14	13	59
[%]	0	1.7	3.4	0	3.4	10.2	16.9	18.6	23.7	22.0	100
Oil & Gas	0	1	1	0	1	1	9	11	12	12	48
[%]	0	2.1	2.1	0	2.1	2.1	18.8	22.9	25.0	25.0	100
Total	1	3	4	4	8	11	31	43	58	65	228
[%]	0.4	1.3	1.8	1.8	3.5	4.8	13.6	18.9	25.4	28.5	100

Table 29: Recovering from critical incidents

Recovering from critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	3	0	3	4	6	9	14	22	34	25	121
[%]	2.5	0	2.5	3.3	5.0	7.5	11.7	18.3	28.3	20.8	100
Aviation	0	0	3	2	2	5	11	16	10	10	59
[%]	0	0	5.1	3.4	3.4	8.5	18.6	27.1	16.9	16.9	100
Oil & Gas	2	0	1	0	2	4	9	15	7	8	48
[%]	4.2	0	2.1	0	4.2	8.3	18.8	31.3	14.6	16.7	100
Total	5	0	7	6	10	18	34	53	51	43	228
[%]	2.2	0	3.1	2.6	4.4	7.9	15.0	23.3	22.5	18.9	100

Table 30: Review and learning from critical incidents

Review and learning from critical incidents (including near miss events)											
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Nuclear	1	3	3	3	4	10	17	18	28	34	121
[%]	0.8	2.5	2.5	2.5	3.3	8.3	14.0	14.9	23.1	28.1	100
Aviation	1	0	1	2	4	3	7	15	12	14	59
[%]	1.7	0	1.7	3.4	6.8	5.1	11.9	25.4	20.3	23.7	100
Oil & Gas	1	1	2	2	1	7	8	8	7	11	48
[%]	2.1	2.1	4.2	4.2	2.1	14.6	16.7	16.7	14.6	22.9	100
Total	3	4	6	7	9	20	32	59	47	59	228
[%]	1.3	1.8	2.6	3.1	3.9	8.8	16.2	14.0	20.6	25.9	100

Q9: NTS are strong feature of my organisation's practice

Detail for Nuclear, Aviation and Oil and gas on if NTS are strong features of individual organisation's practice is indicated on Figure 22.

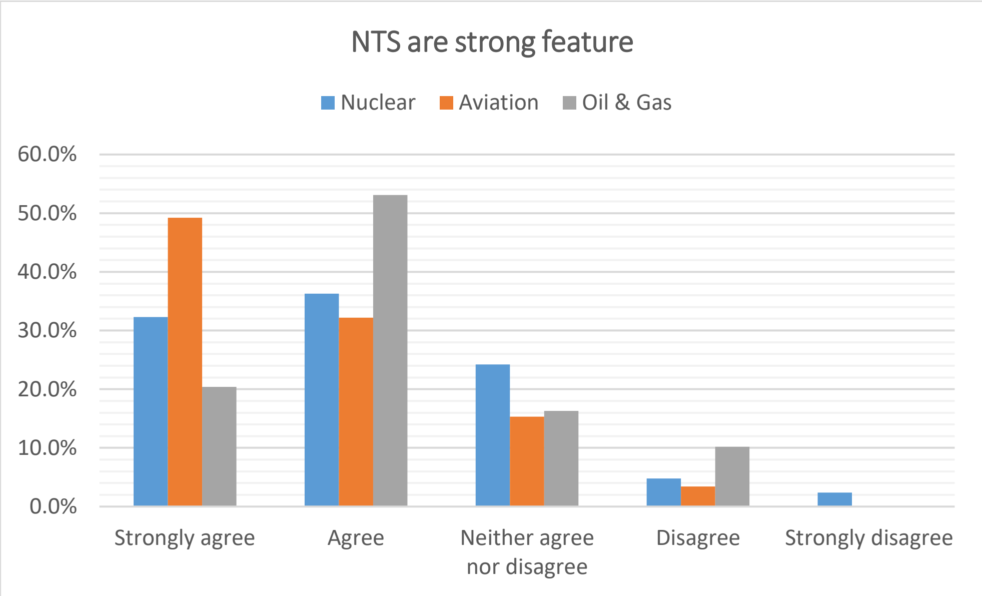


Figure 22: Showing if NTS is a strong feature of organisation's practice

Q10: Isomorphic lessons is a strong feature of my organisation's practice

Detail on how each sector responded in shown on Figure 23.

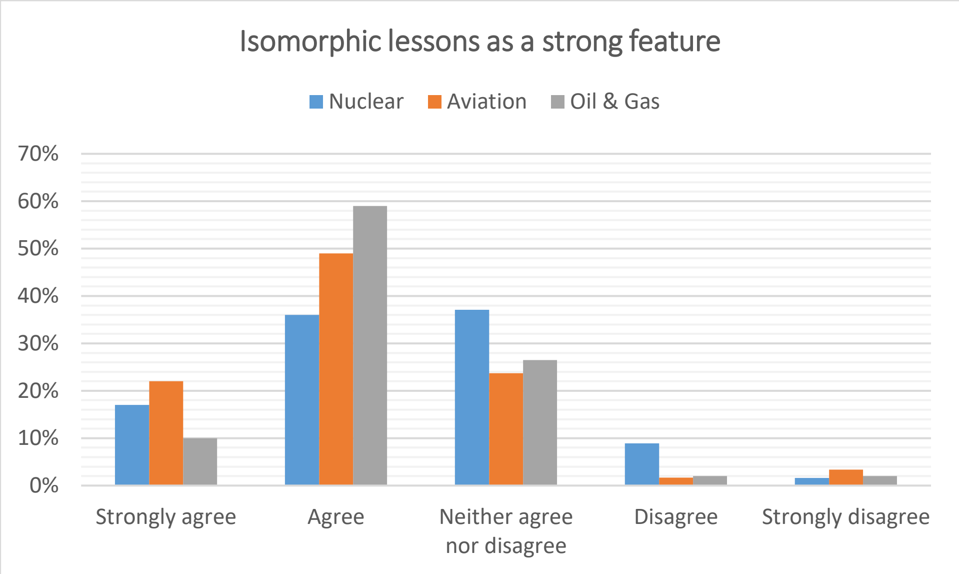


Figure 23: Indicating if isomorphic lesson is a strong feature of organisation's practice

Q11: Organisational learning is a strong feature of my organisation's practice

How each sector responded is indicated on Figure 24.

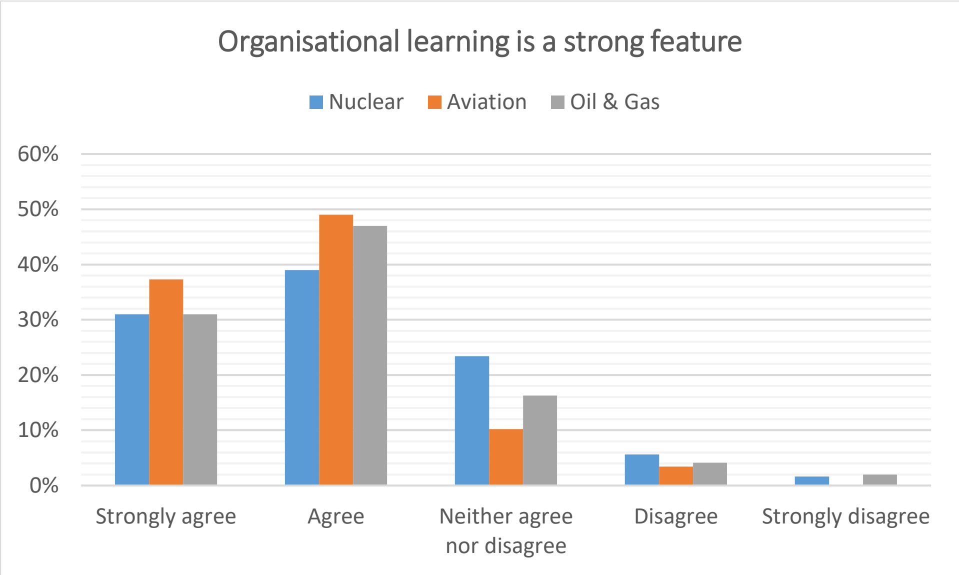


Figure 24: Showing if organisational learning is a strong feature of organisation's practices

Q12: Risk deliberations and analysis are strong feature of my organisation's practice

Details on sectors response is shown on Figure 25.

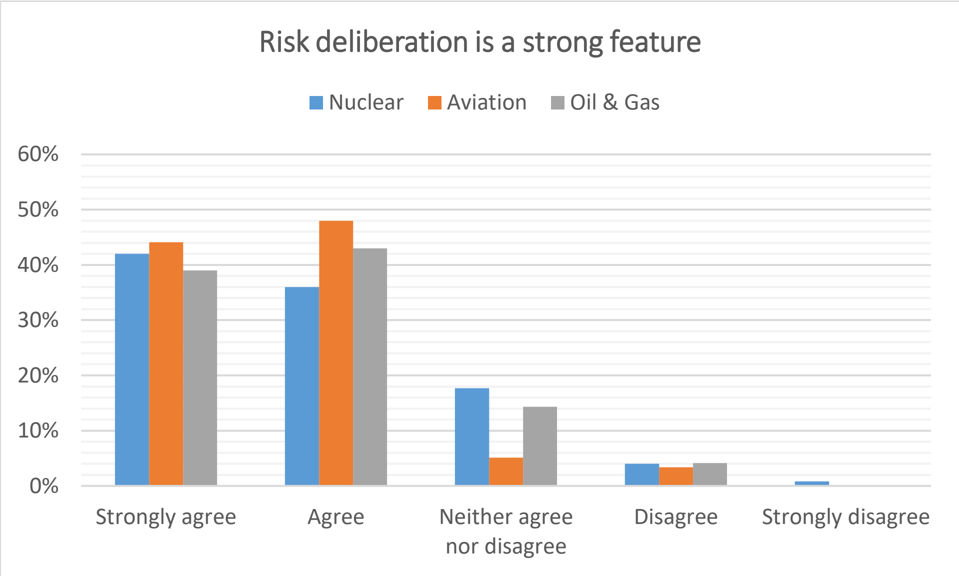


Figure 25: Indicating if risk deliberation and analysis is organisation's practice

Q13: Lessons learned from other high-risk sectors (e.g. aviation, nuclear and oil and gas) can help inform risk-based decisions in my organisation.

Details on sectors response is indicated on Figure 26.

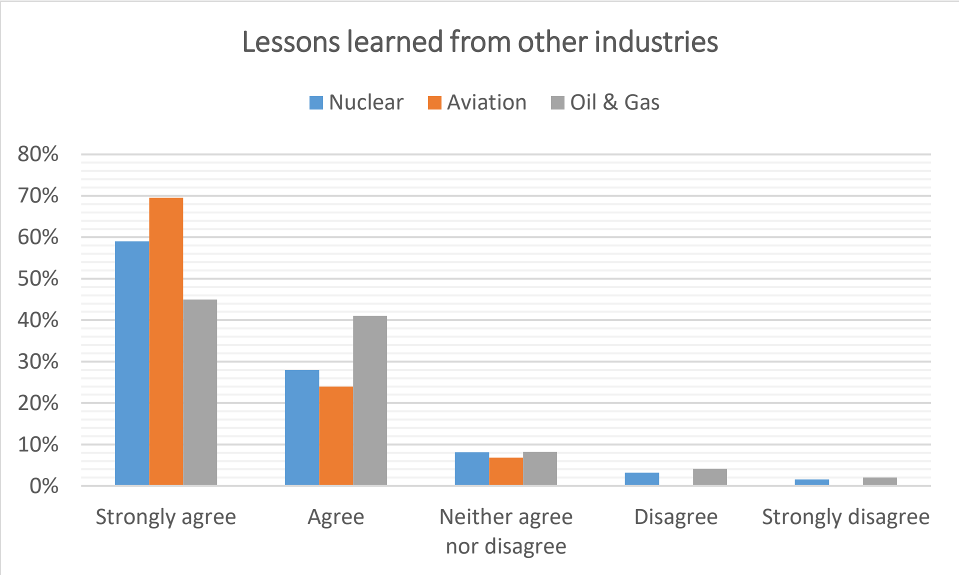


Figure 26: Indicating if lesson learned could inform risk-based decisions

Q14: A combined framework, with benchmarking and a toolkit (between aviation, oil and gas and nuclear) would be useful for cross industry learning on similar underlying risks

Details on sectors response is indicated on Figure 27.

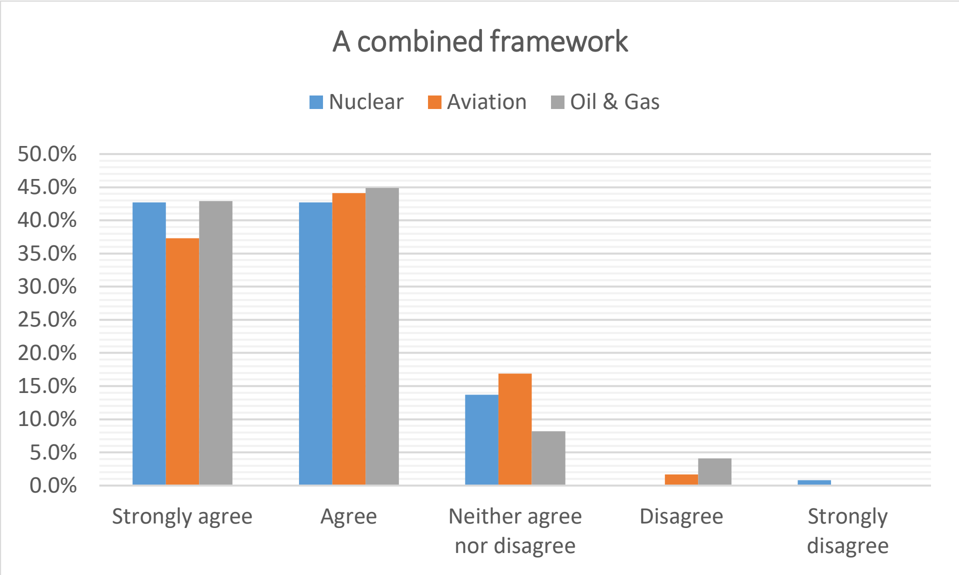


Figure 27: Showing how participants responded on combined framework

Q15: On a scale of 1-10, rate the following options as essential contributions to incidents

Details of how each sector responded is indicated in Table 31.

Table 31: Indicating essential contributions to incidents

Human Factors (Rating)										
Count	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Nuclear [%]	1		0		2	1	3	11	22	**61**
Aviation [%]	8		0		0	0	2	17	22	57
Oil & Gas [%]	0		4		2	8	0	14	31	41
Mechanical Factors										
Count										
Nuclear [%]	1	2	4	5	20	11	20	20	6	12
Aviation [%]	0	5	5	5	10	12	22	20	7	14
Oil & Gas [%]	0	0	6	6	10	8	25	**29**	12	4
Environmental Factors										
Count										
Nuclear [%]	1	1	2	2	13	9	23	21	7	21
Aviation [%]	0	0	0	5	5	5	17	**41**	10	17
Oil & Gas [%]	0	2	6	14	10	16	12	25	8	6
Natural Factors										
Count										
Nuclear [%]	12	23	16	12	15	**7**	7	0	3	6
Aviation [%]	7	24	12	14	22	3	3	**9**	3	3
Oil & Gas [%]	25	25	10	12	8	2	4	**8**	4	2

Q16: Which human analysis framework will be most suitable for the management of safety in your industry in the UK (For senior managers only)

Details of how each sector responded is indicated in Table 32

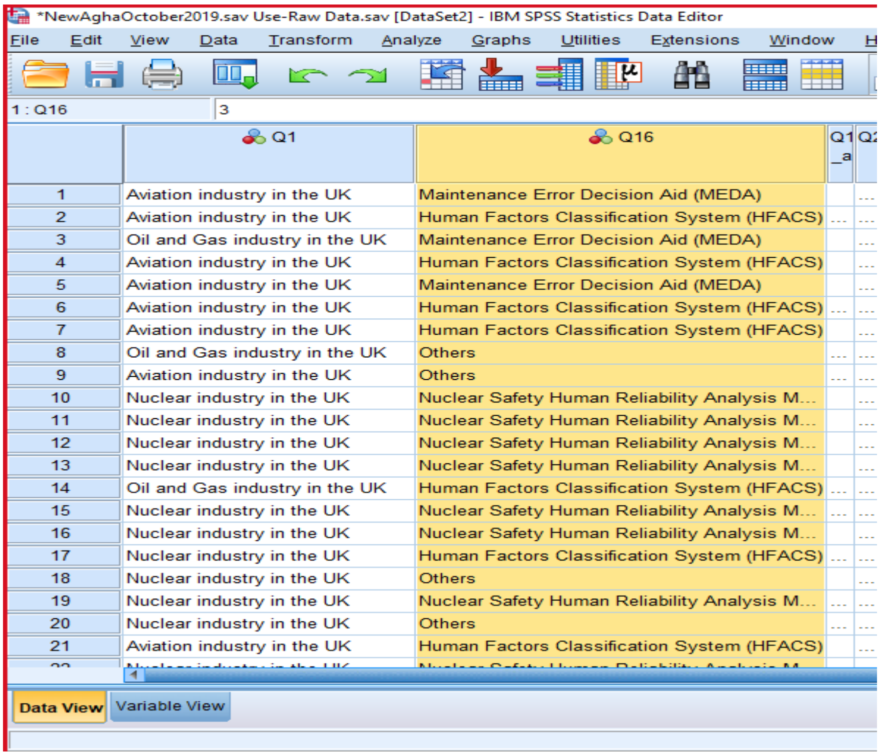
Table 32: Showing human analysis framework preferred by sectors

	Nuclear Safety Reliability Analysis Method (NSRAM)	Human Factors Classification System (HFACS)	Maintenance Error Decision Aid (MEDA)	Others	Total
Count	59	22	0	43	124
Nuclear [%]	**48**	18	0	35	100
Count	0	35	2	22	59
Aviation [%]	0	**59**	3	37	100
Count [%]	5	28	2	14	49
Oil & Gas [%]	10	**57**	4	29	100
Count	64	85	4	79	232
Total [%]	28	37	2	34	100

Sample of columns data used for Chi-square contingency tables

This snippet of the data (Table 33) file shows the industry sector indicated in the column headed Q1 (for Question 1) and another categorical response for Question 16 (in Q16). These have been compared using a chi-square test.

Table 33: Shows sample of column data used for Chi-square contingency tables



	Q1	Q16	Q1_a	Q2
1	Aviation industry in the UK	Maintenance Error Decision Aid (MEDA)		...
2	Aviation industry in the UK	Human Factors Classification System (HFACS)	...	...
3	Oil and Gas industry in the UK	Maintenance Error Decision Aid (MEDA)		...
4	Aviation industry in the UK	Human Factors Classification System (HFACS)		...
5	Aviation industry in the UK	Maintenance Error Decision Aid (MEDA)		...
6	Aviation industry in the UK	Human Factors Classification System (HFACS)	...	...
7	Aviation industry in the UK	Human Factors Classification System (HFACS)		...
8	Oil and Gas industry in the UK	Others	...	...
9	Aviation industry in the UK	Others	...	...
10	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...		...
11	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...		...
12	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...		...
13	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...		...
14	Oil and Gas industry in the UK	Human Factors Classification System (HFACS)	...	...
15	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...	...	...
16	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...		...
17	Nuclear industry in the UK	Human Factors Classification System (HFACS)	...	...
18	Nuclear industry in the UK	Others		...
19	Nuclear industry in the UK	Nuclear Safety Human Reliability Analysis M...	...	...
20	Nuclear industry in the UK	Others	...	...
21	Aviation industry in the UK	Human Factors Classification System (HFACS)		...

Q17: What additional measures do you think should be put in place to reduce accidents in your industry?

Respondents were asked to give more information that could assist in managing safely in their sectors.

Some of the responses are tabulated below:

Table 34: Sectors response (comments) from online questionnaire

Nuclear	Aviation	Oil & Gas
The sector should keep learning from ONR and WANO. Better integration of learning for experience with risk assessment processes.	Creation of security awareness at all levels of the organisation.	Some performance practiced offshore in the UK sector in 1984/5 were inadequate.
A proper review and learning session should be put in place. Better cross organisation/company interaction on learning from experience.		Safety drills, training and retraining of staff on safety aspects
Additional training in human factors above the bare minimum requirement.	In-depth training along the career-path.	A culture where everyone feels they can act without reproach is vital.
Adherence to IAEA safety standards and enhanced ONR regulations.	Training in the form of organisational dialogues about the factors that can improve or distract from good safety culture.	
A culture of zero accidents as a goal should be implemented and monitored. The need to have an assertive attitude in everything.	Training and knowledge-sharing.	A move away from regulatory testing and towards competency-based training and assessment. The testing required by regulation is out-dated and have not evolved with technology.

Applying formal training into practice through workshops and more 'hands-on' experience. Behavioural assessment and learning.	Improving laws and regulations guiding safety in aviation.	Address the working environment of 'over stretch' - doing more with less. Short term it is fine.
Better cross organisation/ company interaction on learning from experience.	Proper safety awareness, transparency in reporting accidents and near misses as well as putting adequate measures in place to avoid accident re-occurrence.	Bow Tie process for managing risk.
Better fatigue management systems.	Constant review of near misses. Enforcement and compliance of safety rules by staffs.	Change management culture. Don't promote selfish ambitious people, but caring, team workers.
Better induction and training for new entrants into nuclear site construction.	Staff should receive adequate training to manage their work effectively.	Clear focus on safety governance from management level down.
Better integration of learning for experience with risk assessment processes. Constant education, training, using the right tool for the job, drills and up-to-date re-certifications.	Workers in the aviation sector (pilots) are trained in crew resource management before they start flying. Therefore, is a common feature in aviation.	Constant education, training, using the right tool for the job, drills and up-to-date re-certifications.
Corrective action programme, routine performance monitoring, identification of gaps and programme of continuous improvement of all key processes and celebrating success.	Training staff on non-technical skills and organisational learning is important.	IOSH Training and certification.
Training session especially for fresh graduates employed in the nuclear industry.	Training is important in aviation and should be extend to other sectors.	Continuous learning and improvement. Implementation of true just culture.
Shorter working hours. Make sure that senior staff do not intimidate staff into performing unsafe work, taking time to do jobs safely.	Workers should be trained regularly to reduce human in organisations	Correct returns targeted at prioritising risk factors
Innovation and implementation of new technologies could reduce the incident of accidents due to ageing infrastructure.	Safety culture, education, training and retraining.	Replacing human with robots, would reduce number of accidents.
Innovation that removes the human element. Allow the engineering, physics and machinery to control the system, rather than relying on human to make active decision.	Management need a greater understanding of the risks on commercial operating pressures place on the safe operation of aircraft.	Limitation of excessive subcontractors.
Enhance safety culture.	More automation.	Listen to the operators, people with experience rather than jumping to

Change management culture. Don't promote selfish ambitious people, but caring, team workers.		conclusions and knee jerk reactions in the name of safety.
Formal training on nuclear safety culture and risk management, backed by nuclear knowledge management.	Good communication with all staff; effective fatigue management.	Development and retention of experience at senior supervisory levels.
Increase the understanding how a new safety measure can impact existing safety measures. Learn more from other industries.	Better fatigue management systems.	Workers should undergo trainings to be able to operate machines and work effectively.
Managers in the fields of safety should have technical backgrounds to better understand accidents.	Better safety culture and training	We have not had any major exploration in our company; however, training and practice is vital.
More training and better leadership. Safety leadership training for senior managers; cross-industry learning; ensuring time is made available.	Developing evidence and competency-based training.	Cross industry learning. Effective reporting and communications. Effective training which is not determined solely by budgets.
Lessons learn globally in form of videos should be shared.	Training, learning from experience, peer review, detailed hazard identification and risk assessment.	Review of Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) to include near misses-although through anonymous recording.
Executive and leader observation and coaching in the workplace. More training and reviews of past incidents no matter what industry it happened.	Considered risk assessment rather than by note or checklist. Effective LFE addressing root causes at all event levels. Periodic safety reviews and don't assume that everything is okay.	The biggest gains would be from culture change leading to a thorough awareness of Human Performance (HuP) tools and habitual application.
Close supervision of employees and frequent internal and external safety risk assessment.		Stronger leadership.
Training, more consideration of human factors. Reduce workload; increase enough funding for safety and improve safety culture.	Less reliance on "off the shelf" safety management systems and more promoting safety culture.	Education that is practical, relevant and engages those at the coal face. Not some college professor full of buzz words and who has no actual experience and just spouts theory.
Training, motivation for best practices and staff inclusion in policy formulation. Cross industry safety methodology forum/framework.		

4.4.1 Result of Kruskal Wallis test and Mean Scores

A summary of Kruskal Wallis (KW) tests (Table 35) of the ordinal responses collected from the questionnaire is presented in this section. The table contains mean scores rather than mean ranks of each ordinal scale. Mean values are given for each industry sector and H is the Kruskal Wallis test statistic. P is the probability that the null hypothesis (no difference between industry sectors) is true. Means are given in preference to medians since the latter may not adequately identify where industry sectors differed. When the P-value of the KW test is <0.05 reject the null hypothesis is rejected and it is concluded that the responses differ between industry sectors.

Differences in mean scores indicate the differences between sectors. For example, on the use of NTS, the means are nuclear (1.28), aviation (1.03) and oil and gas (1.53). This scale is scored 1 = formally used, 2 = informally used, 3 = not used at all. Thus, aviation uses NTS most formally, followed by nuclear, then oil and gas.

The test result of Kruskal Wallis is indicated on Table 35.

Table 35: Indicating Kruskal Wallis test and mean scores across the three sectors

		Mean			**Kruskal Wallis**	
	Scale	Nuclear	Aviation	Oil and Gas	H	P
Q2: What position do you hold within your company?	1-n	3.19	3.56	3.86	4.841	0.089
Length of Service	1-n	2.55	2.56	2.35	3.166	0.205
Non-technical Skills	1-3	1.28	1.03	1.53	25.072	<0.001
Isomorphic learning	1-3	1.55	1.47	1.70	4.253	0.119
Organisational learning	1-3	1.27	1.18	1.24	1.239	0.538
Risk characterisation	1-3	1.28	1.09	1.26	7.249	0.027
Non-technical skills	1-10	7.79	8.45	7.42	8.275	0.016
Isomorphic learning	1-10	8.19	8.23	7.60	2.930	0.231
Organisational learning	1-10	8.42	8.25	7.82	3.583	0.167
Risk characterisation	1-10	8.34	8.35	7.98	1.021	0.600

Q6: My organisation incorporates NON-TECHNICAL SKILLS effectively into training, exercises, and safety practices.	1-5	2.09	1.53	2.27	21.359	<0.001
Situation Awareness (knowing your environment)	1-3	1.78	1.07	1.61	36.666	<0.001
Decision Making	1-3	1.80	1.22	1.81	25.694	<0.001
Communications	1-3	1.58	1.14	1.66	20.234	<0.001
Teamwork	1-3	1.64	1.15	1.65	23.810	<0.001
Leadership	1-3	1.59	1.19	1.66	13.764	0.001
Managing Stress	1-3	1.87	1.64	1.96	4.242	0.120
Coping with Fatigue	1-3	2.20	1.44	1.96	32.188	<0.001
Anticipating critical incidents (including near miss events)	1-10	7.55	7.71	7.21	1.421	0.492
Assessing critical incidents (including near miss events)	1-10	8.03	8.09	7.83	0.652	0.722
Preparing for critical incidents (including near miss events)	1-10	7.83	7.84	7.48	1.787	0.409
Responding to critical incidents (including near miss events)	1-10	8.36	7.93	8.23	3.708	0.157
Recovering from critical incidents (including near miss events)	1-10	7.85	7.66	7.60	2.055	0.358
Review and learning from critical incidents (including near miss events)	1-10	7.96	7.92	7.44	2.266	0.322
Q9: Non-technical skills are a strong feature of my organisation’s practice.	1-5	2.09	1.73	2.16	8.132	0.017
Q10: Isomorphic learning is a strong feature of my organisation’s practice.	1-5	2.43	2.15	2.27	5.280	0.071
Q11 Organisational learning is a strong feature of my organisation’s practice.	1-5	2.09	1.80	2.00	3.714	0.156

Q12: Risk deliberation and risk analysis are a strong feature of my organisation’s practice.	1-5	1.86	1.68	1.84	1.432	0.489
Q13: Lessons learned from other high-risk sectors (e.g. aviation, nuclear, oil and gas) can help inform risk-based decisions in my organisation.	1-5	1.60	1.37	1.78	6.624	0.036
Q14: A combined framework, with benchmarking and a toolkit (between aviation, oil and gas, and nuclear) would be useful for cross industry learning on similar underlying risks.	1-5	1.73	1.83	1.73	0.853	0.653
Human factors	1-10	9.28	9.24	8.69	6.469	0.039
Mechanical factors	1-10	6.74	6.81	6.94	0.560	0.756
Environmental factors (working environment)	1-10	7.44	7.81	6.45	12.613	0.002
Acts of God (Natural factor/mystery)	1-10	4.00	4.31	3.57	4.304	0.116

The rational for conducting the Kruskal-Wallis (KW) nonparametric one-way ANOVA tests were used to analyse ordinal responses and test if responses from the three different sectors had any statistically significant difference. Nonparametric statistics, for example the Kruskal Wallis test, are appropriate for data which are ordinal, such as the responses to the online questionnaire.

4.5 Discussion of Results

4.5.1 Introduction

This discussion is based on the results generated and analysed in this research. These are the online questionnaires which were completed by 232 respondents, carried out in parallel with other research (secondary data and interviews).

4.5.2 Discussion of the Main Findings

The research focused on the four pillars (NTS, isomorphic lessons, organisational learning and risk characterisation) and produced information generated between the three sectors. As observed, the nuclear sector generated the highest number of responses from the online survey, followed by the aviation and oil and gas sectors.

Respondents were requested to state the position they occupy within their respective organisations. The question was important to this research since it helped to determine the respondents' status (portfolio) in their various organisations. For instance, greater seniority or longer length of service might imply that respondents' views could be better relied upon. Of the respondents, the nuclear sector had the highest proportion of senior managers, followed by the aviation and the oil and gas sectors. This further indicates that senior managers in the nuclear sector were willing to participate in the online survey, possibly because there were more confident of answering the questions compared to the other sectors.

Respondents indicated the length of service from a choice of sector categories. The proportion of respondents who had worked in their sector for 10 years or more was highest in the aviation sector, followed by the nuclear sector. The oil and gas sector had the highest proportion of respondents with 1-5 years and with 6-9 years of experience. See Figure 16 (Q3).

Crucial to this research is the use of the four pillars, which are NTS, isomorphic lessons, organisational learning and risk characterisation within the working environment to manage safety. Each segment of the questionnaire tests a different set of ideas and knowledge. Therefore, respondents were requested to indicate if they had used any of the four pillars in training and managing safety in the UK, and to suggest the sector that uses them most for effective safety management. The question is expected to draw out possible lessons for the UK nuclear sector. Most importantly, the question addressed research question one. RQ1: To what extent does the nuclear sector use the four pillars in training and managing safety in the UK?

Sectors' knowledge on Figure 17 (Q4a) was tested on the use of NTS within the working environment, either formally, informally or not at all. This is significant since NTS contributes considerably to the management of everyday human error; and poor non-technical performance permits error to compromise the safety of a process. In the aviation sector, the result is consistent with an expert's view during an interview this research conducted, that the use of NTS is made compulsory during flight training exercises. The result in aviation also supports the work of Flin *et al.* (2008) and Thomas (2018), that NTS in aviation cannot be compromised. However, results from the nuclear and oil and gas sectors were different on the informal use of NTS in the workplace. This implies that the oil and gas sector tend to rely on an informal training approach instead of a formal training strategy which should be regarded as more official form of training in organisations.

The differences in the use of NTS in the nuclear sector were further emphasised by a participant during an interview session this research conducted. He remarked that in the nuclear sector, NTS is not termed as such, but described as soft skills. Furthermore, during a focus group discussion conducted in this research, a nuclear expert said that during his 40 years of service in the nuclear industry, he had never heard the terminology NTS. According to him, NTS is mostly used in aviation rather than in the nuclear sector. This means the terminology or lexicon used is different between the three sectors, which invariably may have affected respondents' understanding of the question especially in the nuclear and oil and gas sectors. This, in turn, may have been the reason why the nuclear and the oil and gas sectors had lower numbers of respondents compared to the aviation sector.

The question on Figure 18 (Q4b) tried to identify whether workers had encountered isomorphic lessons in the working environment. Responses were similar between the three sectors, it indicates that all three sectors were not using isomorphic lessons formally in the work environment, which could be the reason the same type of accidents keep reoccurring in some industries, supporting the work of Toft and Reynold (2006). Kruskal Wallis (KW) test confirmed no significant difference (p =

0.119) between sectors on how participants responded to the question. The result also confirms what participants said during the focus group discussion. Participants independently said that isomorphic lesson had not been formally encountered in the working environment. A participant in the aviation sector noted that the industry was not aware of the term isomorphism. This view was also stated across nuclear and oil and gas sectors by some participants. However, the question could have been scored low probably because respondents either did not understand the question, or because the word isomorphism was not understood despite providing a definition of terms for participants taking part in the online survey.

Another research question was on organisational learning on Figure 19 (Q4c). Participants across the three sectors were asked if it was used within the working environment either formally, informally, or not at all. Though the three sectors recorded a high mean level of response signifying that workers had received formal training on organisational learning, however, Kruskal Wallis test confirmed that there was no significant difference ($p = 0.538$) between the three sectors. The result contrast with literature that states that most organisations have not fully utilised their learning abilities (**Trigilio 2006**). In the same vein, organisations struggle to apply practical methods because they lack concrete remedies (**Basten and Haamann 2018**).

The statement from Basten and Haamann (2018) also agrees with information gathered from the interview conducted by this research that organisational learning across the three sectors was not adequately used. For instance, during the interview, a participant from the nuclear sector said there had not been any organised disciplined process of learning, either internally from companies or between companies. (See Appendix 3). Furthermore, during the focus group discussion conducted by this research, a respondent in the oil and gas sector stated that organisational learning is difficult because no organisation would like to publish its mistakes or accident reports for the public to see. This, he said, was a terrible set-back for organisations, since learning is not taking place even across sectors.

Risk characterisation was another research pillar used to gauge whether it had been encountered by workers in the three sectors. Respondents from the three sectors shows they had encountered risk characterisation on a formal basis to manage and assess workloads. However, means responses were highest in the aviation sector, followed by the nuclear sector. Results from this question may not be directly comparable because the three sectors do not perform the same function. As a matter of fact, worker's experience will differ sector-to-sector. How work is performed, and risk characterised or calibrated will also not be the same. A nuclear expert during the focus groups discussion noted that human factor tools such as: Nuclear 'jewelry' (key outcomes), pre and post job review, and independent review were constantly used to ensure tasks were assessed properly.

From a cultural perspective, respondents were asked to assess the ability of NTS, isomorphic lessons, organisational learning and risk characterisation to promote a stronger safety culture within organisations. (See Table 20 – Table 23). Questions on a 10- point scale measured respondents' view. The importance of these questions is that they indicate how organisations place priority on the use of the four pillars to achieve safety culture. The data revealed that the aviation sector had the highest response on a 10-point scale, while the nuclear and oil and gas sectors rated NTS on 8-point scale.

However, the online data did not agree with the experts' view that NTS covers a wide array of skills that are important to maintaining safe performance in the work environment (**Thomas 2018**). Nonetheless, despite the result that respondents from the aviation sector had formally encountered NTS, it could not be said that NTS was used by workers to promote a stronger safety culture. On the other hand, the result also implies that neither nuclear nor oil and gas sectors have formally made use of NTS to promote a stronger safety culture in the work environment.

Isomorphic lessons were also rated on their ability to promote a strong safety culture. Both aviation and the nuclear sectors highly rated the use of isomorphic lessons on a 10-point scale, though the aviation had the highest mean. The oil and gas sector rated isomorphic lesson on a 9-point scale. The result indicated that the three sectors were not using isomorphic lessons and their ability to promote a stronger safety culture in their various organisations. This is the same as in the use of organisational learning, indicating that organisational learning is not used to promote a stronger safety culture. KW test revealed that there was no significant difference ($p > 0.05$) between the three sectors in using isomorphic lessons to promote a stronger safety culture. These findings agree with what participants independently said during focus group discussions that both isomorphic lessons and organisational learning were not fully utilised to manage safety. Participants also said that efforts are being made to train workers on how to use both pillars to manage effectively in the working environment.

Additionally, to promote safety culture using risk characterisation, the result from the three sectors did not demonstrate a high use of risk characterisation and did not corroborate what sector experts said during an interview session conducted in this research to authenticate the online result. Notwithstanding, in the nuclear sector, a safety expert said risk characterisation in the industry was highly evolved. The industry carries out both deterministic and probabilistic safety analysis that is extremely detailed. It looks at accident scenarios including the most remote and ensures that designs and operators are robust.

In the aviation sector, a pilot noted that there are more layers of control put in place, that more risks are controlled but less opportunities to identify what went wrong. In the oil and gas sector, a drill operator said risk is mitigated against using relevant control measures, and if the risk is not As Low as Reasonably Practicable (ALARP), the job would not be carried out. The fact remains that risk is characterised across the three sectors, but individual sectors determine how it is characterised due to the nature of risks and jobs performed in those individual sectors. KW test revealed there was no significant difference ($p = 0.600$) between the three sectors.

This research asked a 5-point (strongly agree, agree, neither agree nor disagree, disagree and strongly disagree) ordinal questions to respondents. The question was to determine whether organisations incorporated NTS effectively into training, exercises and safety practices. The result from across the three sectors revealed that the aviation sector incorporates NTS effectively into training, exercises and safety practices with more responses in the strongly agree category, compared to the nuclear and oil and gas sectors. The result from the aviation sector agrees with the views from industry players that NTS is used in aviation for training purposes (**Thomas 2018**). In confirmation of the result, KW test indicated significant differences ($p < 0.01$) between the three sectors. On strongly agree, the aviation sector had the highest and considered the best, followed by the nuclear sector as the second best and then oil and gas as the third. The result also agrees with the work of Flin *et al*. (2008), that human error cannot be removed, however, efforts can be made to reduce errors by making sure that people receive suitable NTS to cope with the risks and demands of the job.

Throughout the text p=0.05 has been used as a threshold for significance, i.e. $p < 0.05$ is considered statistically significant. This indicates strong evidence against the null hypothesis since there is less than a 5 per cent chance that the null hypothesis is true. When the null hypothesis is rejected, the alternative hypothesis (typically that the three industry sectors differ) is accepted. Where a result is marginal ($0.05<P<0.10$) a comment has normally been provided on the direction of differences.

Table 24, (Q7) summarises responses on the type of NTS training that operators had received in their various organisations. NTS is comprised of seven forms of elements which were all tested. These categories of elements are discussed below.

4.5.3 Categories of NTS

Situation awareness (SA) training

Situation awareness (SA), known as awareness and understanding of the working environment, was highlighted by participants as one of the NTS elements they had received training in. The result suggests that more staff received formal training in the aviation sector on SA to prevent or mitigate accidents while flying, compared to oil and gas and nuclear sectors. The aviation result is supported by literature that crew members are required to have temporal awareness, anticipating future events based on information of both the past and the present. It is important that people monitor their surroundings so that likely problems can be corrected before they get worse (**Flin *et al.* 2008**). However, the way participants in the nuclear and oil and gas sectors responded to this question could have been influenced by nomenclature. The statement reflects the views that some of the participants, especially in the nuclear sector, stated during the focus group discussion and interviews conducted in this research that situation awareness is known as observation, which in the aviation sector is known as SA. As stated above, this question could have been misconstrued by participants in nuclear and oil and gas sectors and which influenced the response they gave.

Decision-making

Decision making is critical in any workplace. Workers in the three sectors were asked in the online survey if they had received training on decision-making in their workplace. The result revealed that formal training of workers on decision-making was more likely in the aviation sector which is believed to be essential in its working environment especially when flying an aircraft. This was followed by nuclear and oil and gas sectors. However, the result from the nuclear sector is in contrast with the view of nuclear experts who believe that operators in the sector are vested with much authority and know the expectation when challenged with unanticipated or undefined conditions, and therefore strive to place the plant in a safe condition (**INPO 2012**). Decision-making could have been high in aviation because any delay responding to challenges could become catastrophic for operators. It is also understandable of the need to take decisions quickly when working with smaller groups, than in larger groups. Hence, it is possible and expected to take decisions faster in the aviation sector, than in the nuclear and oil and gas sectors.

Communication

Communication which means exchanging of information either verbal or non-verbal between workers in a team is another vital element of NTS. Respondents were requested to state if training on communication had been provided in the workplace. The result shows that among the three sectors, communication was highest in the aviation sector on formal strategy, compared to nuclear and oil and gas sectors which recorded lower score. However, the data did not mean that nuclear and oil and gas sectors were not using communication effectively. Given the nature of work in the aviation sector, communication is *sine-qua-non* which could be the reason the sector had the highest mean response (**Thomas 2018**).

However, most of the accidents that have occurred in high-risk industries are always traceable to communication lapses. The data from nuclear and oil and gas sectors is supported by literature on why accidents that have occurred between the two sectors are always catastrophic in nature, since communication was not adequately used to manage safety (**NEI 2017; Cullen 1990**). Nonetheless, regardless of how each sector responded to this crucial element, it did not negate the fact that accident was magnified due to communication lapses (**Hutchinson 2000**). What is paramount is the ability to effectively utilise the knowledge acquired through quality training. This will determine how safe the three sectors will be in both short and long-term operations.

Teamwork

Teamwork involves coordinating activities within a team, support for others and establishing a shared understanding. It is particularly relevant since it reduces error and maintains safety in the work environment. The three sectors responded that they had received training on teamwork in the workplace. The result indicates that the aviation sector received more formal training. This was followed by the nuclear and then the oil and gas sectors which recorded high responses on informal training approaches. The data from the oil and gas sector is supported by literature that teamwork was lacking in the sector which led to three contractors - Haliburton, BP and Transocean making grievous errors which led to the Macondo Well Blowout (**OSC 2011**). However, the result on teamwork could have been less comparable because respondents are from three different sectors, meaning that work patterns and roles of team members could vary according to sectors.

Leadership

Leadership is defined as guiding others. It is also aimed at providing direction and instruction. Leadership helps to understand and consider the roles and needs of other team members. Respondents were asked if training had been provided to workers in the workplace. The result implies that the aviation sector provided training to staff using formal methods, compared to nuclear and oil and gas sectors (in that order) that relied mostly on informal methods. The result from the oil and gas sector supports experts' views from the literature that leadership in the oil and gas sector was not fully utilised, which contributed to accidents such as Piper Alpha and the Macondo Well Blowout (**Flin *et al.* 2008: 142; OSC 2011**). On the other hand, the result is expected to be different across the three sectors because of differences in work operations which will obviously affect leadership patterns and qualities.

Managing stress

Managing stress is the ability to understand if a worker is overstretched with workloads in a work environment. Providing feedback on whether training had been provided across the three sectors, the result suggests that the aviation sector had the highest response, followed by nuclear and oil and gas sectors. However, based on focus group discussion, managing stress is still a challenge facing high-risk industries in the UK; has also been linked to safety outcomes in industries (**Cooper and Clarke 2003**; quoted in **Flin *et al*., 2008**). Among the seven elements tested in this section, KW test revealed there was no significant difference ($p = 0.120$) in managing stress across the three sectors.

Coping with fatigue

Fatigue is synonymous or related to drowsiness, sleepiness and tiredness. Coping with fatigue was the last NTS element on which respondents were asked whether training was provided in the workplace. The result from the online survey suggests that the aviation sector train workers on coping with fatigue using formal approaches, compared to the oil and gas and the nuclear sectors. The result from the nuclear sector agrees with the work of Grishanin (2010) which noted that the nuclear sector is yet to introduce a formal training strategy to train workers on coping with fatigue (**Grishanin 2010**). KW test revealed that there was significant difference ($p < 0.01$) between the sectors. The aviation sector had the highest of respondents, followed by the oil and gas sector and the lowest was the nuclear sector. Responses to the question may have been high in the aviation sector because the sector knows the implication of not having long hours of sleep before flying an aircraft. Accidents in aviation could occur within split seconds and chances of saving the situation are slim, compared to nuclear and oil and gas sectors which could take a longer time to cascade into a serious event.

4.5.4 Continuation on Additional Research Findings

This research used 10-point scale (1=lowest, 10 = highest) to determine how effective the three sectors were in terms of the following: anticipating, assessing, preparing, responding, recovery, reviewing and learning from critical incidents in their organisations. All the three sectors are aware about how incidents or near-miss events can affect managing safety. The result equally showed how effectively each sector uses the six elements in the workplace. Generally, the three sectors responded to the question on a scale of 10 to emphasises the importance of reviewing and learning from critical incidents. The reason could have been to avoid the same type of incident repeating itself and which could eventually escalate to major accidents (**Trim and Caravelli 2008**). Toft and Reynolds (2006) believe that the crucial aspect of accident reviewing (investigation) of events is the feedback stage which helps organisations learn from past mistakes.

The question whether all the four pillars are a strong feature of an organisation's practice as summarised on Figure 22, 23, 24 and 25; (Q9 - Q12) is different from what has been asked and discussed earlier. While previous research had focused on NTS as strong skills in the aviation sector, in contrast, this result demonstrates that none of the three sectors has made NTS a strong feature of its organisation's practice. However, NTS is considered to be widely used to manage safety in the aviation sector (**Flin *et al.* 2008**).

On whether isomorphic lesson is a strong feature of the three sectors' practice, this result confirms what participants across the three sectors independently remarked during the focus group discussion conducted in this research. They separately said that isomorphic lesson was not a strong feature of their organisation's practice, something each of the sectors said they had started to investigate. The result is also not surprising since participants stated that isomorphic lessons had never been used in various organisations. The result agrees with KW test which revealed that there was no significant difference (p = 0.071) between the three sectors.

Further to examining the use of the four pillars and their ability to manage safety, the three sectors were asked if organisational learning was a strong feature of their organisation's practice. The data suggests that organisational learning is not practiced across the three sectors as it ought to be. This is further supported by a respondent's view in the nuclear sector during an interview session conducted by this research. He noted that organisational learning will evolve over time, as the sector continues to learn how to make the industry as safe as possible. In the aviation sector, a pilot said there is not necessarily as good a spirit of learning as one would like to think. In the oil and gas sector, a participant at an interview conducted in this research said learning exists in the oil and gas sector. According to the participant, the sector is always learning and has different learning strategies.

The last pillar that was examined was whether risk deliberation and analysis are a strong feature of an organisation's practice. The result showed that risk deliberation and analysis are not a strong feature of organisational practice across the three sectors. However, during a focus group discussion, an expert in the nuclear sector disclosed that risk is carefully assessed as ALARP before tasks are carried out. In the aviation sector, a captain said risk is characterised both formally and informally and threats are identified through error management. In the oil and gas sector, a driller said risk is characterised according to people, assets, environment and community. Despite explanations provided by each sector, it appears the reasons did not explain whether risk characterisation is a strong feature of organisation's practice. Kruskal Wallis test revealed that there was no significant difference ($p = 0.156$) how the sectors responded to the questions.

The research sought to know if lessons learned from other high-risk industries can help inform risk-based decisions in various organisations. The result indicated that all three sectors agreed that learning lessons from other sectors is needed for safety management. This response agrees with what participants said separately during the focus group discussion. The sectors agreed that the combined framework will help high-risk industries manage safely. It will support cross-industry learning, collaboration, and add value to industry performance. Most participants from the aviation sector noted that the concept of producing toolkits will provide a lot of benefits across industries. The oil and gas sector also said producing some toolkits is vital to helping high-risk industries learn lessons from each other.

On Table 31 (Q15), which is on a scale of 1-10, the three sectors were asked to rate the following: Human, mechanical, environmental and natural factors as essential contributions to incidents. The result revealed that each sector identified those factors they believe will contribute to accidents. This recognised that there is need for each sector to devise a means of tackling the identified causes of accident in their domain with the hope of finding solutions, except to natural factors.

Furthermore, this discussion also focused on which human analysis framework will be most suitable for the management of safety in the nuclear industries in the UK. The question was intended for senior managers to respond to. The reason being that senior managers, when compared to junior staff, have a better understanding of analytical tools that are suitable for managing safety. Senior managers can also take crucial decisions if there is a need in the workplace without solely relying on the management. However, the results revealed that each sector tends to align itself with those human analysis frameworks that are relevant and known to them. The nuclear sector believed that Nuclear Safety Reliability Analysis Method (NSRAM) is needed. The aviation and oil and gas sectors believed that Human Factors Classification System (HFACS) will address human factor challenges.

Apart from using ordinal and likert-type questions to elicit respondents' opinions in the questionnaire, the research also used qualitative (statement box) responses. Respondents were provided a space to state if they had additional information or measures to reduce accidents in various organisations.

A respondent from the nuclear sector stated that: "The sector should keep learning from the Office for Nuclear Regulation (ONR) and World Association for Nuclear Operators (WANO). There should be a better integration of learning to build workers experience and further training in human factors above the bare minimum requirement." Another respondent said there should be formal training of staff through workshops and more 'hands-on' experience.

In the aviation sector, a respondent stated that: "There should be in-depth training along career-path, improving laws and regulations on guiding safety in aviation." Another participant said that: "There should be proper safety awareness, transparency in reporting of accidents and near misses. Put adequate measures in place to avoid accident re-occurrence and less reliance on "off the shelf" safety management systems and promoting safety culture. Safety problems would not be managed by attending only to technology or focusing on technical skills of workers."

A respondent from the oil and gas sector stated that: "There should be a move away from regulatory testing to towards competency-based training and assessment. Testing required by regulation is out-dated and has not evolved with technology." Another participant from the sector said: "Management should pay adequate attention to operators and people with experience, rather than jumping to conclusions and 'knee jerk' reactions in the name of safety. There should be a limitation of excessive use of sub-contractors as this should be targeted at reducing accidents."

On the whole analysis, the result outcome which generated 232 responses has addressed some of the pertinent issues that are related to the research questions. For example, the result indicates that the UK nuclear sector is not adequately utilising NTS and its elements, isomorphic lessons, organisational learning or risk characterisation to formally train workers for safety management. Therefore, it is of critical importance that some of these lapses are addressed in future studies, and possibly contextualise the research to the nuclear industry in the UK. Doing so will produce direct findings which will resolve some safety challenges affecting the industry.

4.6 Interview Analysis

4.6.1 Introduction

Another aspect of data gathering for this research was the use of interviews (**Kumar 2011**); which was planned (**Saunders, Lewis, and Thornhill 2009**). The interview targeted five personnel with industry specific health and safety expertise (managers, operators and supervisors) in the nuclear and the oil and gas sectors. While the aviation sector focused on pilots, air traffic controllers, health and safety managers and trainers. Predetermined, identical questions were asked to the interviewees. (See Appendix 4 for interview questions and responses). Some of the interviews were conducted face-to-face and recorded with a midget (tape recorder), while some questions were conducted or administered online.

The purpose of the interview is to determine if the three sectors use NTS, isomorphic lesson, organisational learning and risk characterisation with the hope of reducing accidents and contributing to staff training. Overall, the interview was a helpful tool used to put together a valid and reliable data collection which was used to address the research questions (**Saunders *et al*. 2009**).

4.6.2 The Analysis

Interviews were conducted sector by sector: nuclear, aviation, and oil and gas. A total of six (6) questions were asked to five experts across the three sectors. The recorded interviews were translated and data analysed using content analysis (**Vaismoradi, Turunen, and Bondas 2013**), which is one of the common forms of qualitative research analysis used to filter and sort findings. Content analysis equally helped to describe the features of the document's content by examining what is being said (**Bloor and Wood, 2006; quoted in Viasmoradi *et.al.* 2013**).

4.6.3 Qualitative findings

4.6.4 Nuclear Sector (5 participants)

Interview for the nuclear sector was conducted during the World Nuclear Association Symposium 2018, held in London. Five nuclear experts which cut across safety managers, operators and supervisors and health and safety practitioners were interviewed. The transcribed interviews were coded, which was planned to sieve out unrelated comments. Questions asked and responses received from interviewees were as follows:

Q1: Have you come across the term NTS in managing safely in your sector (nuclear)?

Response:

Five participants were interviewed separately on this question. One expert responded on the use of NTS in managing safely in workplace, that:

> *"NTS is different from country to country. For instance, in Russia, the skills are used during the standardised process of teaching and examining the operational personnel in simulations and in some emergency situations on what to do and how to react."*

Continuing:

> *"Stress management, communication, leadership, situation awareness is not part of it, it is a semi-technical skill. Also, there are new digital method of trainings including the use of virtual reality simulators which is widely used in Russia. The real challenge is training new-comer countries as there is no tradition of operating a nuclear power plant, teaching and examining them."*

On the same question, another participant responded that:

"I think that both the World Association of Nuclear Operators (WANO) and the International Atomic Energy Agency (IAEA) holds huge emphasis on developing the best practices and guidelines for safety culture and they both have excellent details on safety culture.

Q2: Which aspect of NTS element does the nuclear industry provide effective training, education and awareness (TEA) on?

Response:

Not all the managers interviewed were able to provide answer to this question. Though a manager noted that:

"A few of them are used, but not recognised as NTS."

Q3: Is there spirit of learning in nuclear and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?

First Response:

Out of the five experts interviewed on the question above, three provided answers to the question. One of them stated that:

"There are two different levels to the question. Learning is different for project and operational teams. On operational side, the industry has an excellent and well-developed set of systems for operational learning both internally, in terms of lesson learned, reviews and shared lesson learned through the WANO.

"On the project side, I think there has not been any organised disciplined process of learning either internally from companies or between companies and I think this is lacking."

Second respondent explained that:

> "*Is a mixture of both normal and organisational learning strategy. The idea of nuclear safety culture started few years ago. This thing will involve over a period as we learn how to make our industries safer.*

> *"Organisational learning now exists in the nuclear sector. The IAEA reviewed the entire safety culture after the Fukushima accident, what effect it had from design and to learn from that disaster and thereafter issued design extension conditions. They realised that after the accident, the reactors were shut down and three hours later the entire place was flooded and there was no cooling anymore."*

Q4: How is risk characterised in the nuclear sector?

Responses:

The first nuclear expert interviewed on this question stated that:

> *"Risk characterisation in the nuclear industry is highly evolved. The nuclear industry does both deterministic and probabilistic safety analysis that is extremely detailed that look at accident scenarios including the most remote and ensure that the designer operators are robust.*

> *"In the core of nuclear industry, I think risk is well looked out for and we know that there hasn't been any modern nuclear power plant with containment, there hasn't been any escape of radiation from containment even from the world accident because of that kind of safety analyses with risk. But on project risk, there has been substantial lack of risk characterisation and assessment."*

Second response on the same question revealed that:

"Risk characterisation is addressed by looking at risk component of safety related and non-safety. Depending on their performance, we then assess risk. Risk is categorised according to safety rules and the impact they have. So, risk category will be created accordingly and then put safety system in place."

Q5: What are the major factors that causes accident in high-risk industries and any reason for that?

Responses

Five experts interviewed responded to the question, each having a divergent view on causes of accidents in the nuclear sector. They stated that:

> *"Organisational culture, human factor, equipment factor and environmental factor. All the four are all possible causes of accident."*

> *"However, it is important humans are trained properly. There are a lot of automated systems which protects the equipment from human error. So, I believe that the proper 3 plus gen design and the automated system are significant foundation to operate nuclear power plants. Is much better to have trained personnel."*

Another expert stated that:

> *"If you look at the accidents that has attracted public attention, each had their own circumstances. If you read the review on TMI, operators' errors are identified on TMI, Chernobyl. But when you look at Fukushima for example, there are sets of circumstances where there was natural disaster and a design issue on those reactors in Japan."*

The third respondent stated that:

> *"TMI was lack of personnel training on (NTS). On Chernobyl accident, human was responsible. While Fukushima was a natural disaster, but operators still lacked the skills needed to manage the accident."*

Q6: Does the UK legislation influence in any direct or indirect way the requirement for the nuclear industry to develop NTS/CRM capabilities or training in their workforce?

Responses

An interviewee noted that:

> *"There is a common regulation and the IAEA has a common regulation considered as a global standard. Nevertheless, there are countries that have stricter regulatory standard. Also, when building a nuclear power plant in a new location, there is need to consider the local regulatory standard.*

> *"There is need for a global regulatory which is not in place, instead what is obtainable is country by country with different approach. IAEA sets a minimum bar, different countries with different approaches and standards. There is no unified approach."*

Second respondent noted that:

> *"The nuclear sector has technical standards set by the ICPRC. It is adopted by the IAEA which has multiple levels of guidance and some of them is mandatory and some optional. These standards are guided and then imported to international regulatory system. So, each regulator adopt each international standard and they are very detailed and significant."*

Third respondent (manager) noted that:

> *"IAEA sets regulation but every country that has a nuclear reactor will have regulations which are backed by the law of the land to control and regulate safety.*

4.6.5 Interview Discussion in Nuclear

Based on the experts interviewed in the nuclear sector, the use of NTS in managing safely is not regarded as NTS but known as semi-technical skills. Interviewees noted that countries operate differently from each other. Some interviewees stated that both the World Association of Nuclear Operators (WANO) and the International Atomic Energy Agency (IAEA) said developing the best practices and guidelines for safety culture is needed.

Another aspect of the interview was to identify in which aspect of NTS does the nuclear industry provide effective training, education and awareness (TEA). Experts interviewed were not able to provide specific answers to this question. However, the real challenge facing the sector is training newcomer countries on NTS, as there is no tradition of operating a nuclear power plant in terms of teaching and examining the sectors and individuals on the use of NTS in workplace.

NTS is not a common expression or language used in the nuclear sector, as in the aviation sector. Though communication and leadership mean the same thing. During the interview, experts revealed that situation awareness is not known as such in the sector. But it was revealed that the nuclear sector has the spirit of learning as culture. Though experts interviewed believed that learning as it is, is a mixture of both individual and organisational learning strategy. Those interviewed in the sector noted that the idea of nuclear safety culture started few years ago and will evolve over a period to learn how to make the industry safer.

Interviewees stated that risk characterisation in the nuclear sector has evolved. They noted that both deterministic and probabilistic safety analysis are extremely detailed, looks at accident scenarios including the most remote and ensure that the designer operators are robust. More so, risk characterisation is addressed by looking at risk component and those tasks that are non-risky. Depending on their performance, risk is then assessed and categorised in accordance to safety rules and the impact they have.

On accident causation in the nuclear sector, the interview established that there are lots of reasons why accident occur. Those interviewed in the nuclear sector said accidents are caused by organisational culture, human, equipment and environmental factors. Though before the Fukushima disaster, there is 3 plus nuclear design which has a lot of safety systems. The machines operate when there are no personnel driving them and are independent of the action of the personnel during emergency. Though it is important to note that operators are trained properly.

On if the UK legislation influences the industry to develop NTS/CRM capabilities or training in their workforce? Industry experts explained that a common regulation exist and IAEA considered it as a global standard. Nevertheless, there are countries that have stricter regulatory standards. Also, when building a nuclear power plant in a new location, there is need to consider the local regulatory standard. IAEA sets a minimum bar, but different countries have different approaches and standards, because there is no unified approach. Therefore, is obvious that there are no regulations that stipulates nuclear sector to train staff on NTS, which is commonplace in aviation.

Therefore, this research suggests that the following should be incorporated as plans to move the nuclear sector forward and ensure that safety is robustly entrenched. These are:

A. Both WANO and IAEA should inculcate in their training manual NTS elements, just as the aviation sector has made it compulsory for pilots to undergo training on NTS.
B. Both individual and organisational learning culture should be made compulsory in the nuclear sector.

4.6.6 Aviation Sector Interview Analysis

Interviews were conducted via face-to-face, telephone and emails sent online. Transcribed interviews only considered information that addressed what the interview intends to achieve.

The questions asked and responses received were as follows:

Q1: Have you come across the term NTS/CRM in managing safely in your sector?

Response:

Five pilots were interviewed on this question and responses were however similar to each other. The pilots noted that:

> *"I have come across CRM in managing safely in my sector. I believe CRM is beneficial for all technical sectors including the nuclear sector. This is because CRM creates a harmony in a working environment which raises awareness and accountability for all personnel to identify risk and manage workloads. In so doing, one can identify resources and deploy them to the right areas or critical points of work in order to maintain high standards in dangerous work environment."*

> *"NTS is used in commercial aviation all the time and can be applied to any industry."*

Q2: Which aspect of NTS element does the aviation industry provide effective training, education and awareness (TEA) on?

A pilot noted that:

> *"I would say all of them. But if I had to prioritise as a pilot, it would be situational awareness and decision making. Situational awareness is because all parties involved, including the captains, first officer and cabin personnel need to be aware or have at the very least travelled mentally to the destination before the aircraft even gets there.*

> *"Decision Making is because in almost all situation, the result of every flight is not based on flying alone but a sum of decisions made. By clearly identifying decisions that need to be made, and analyse whether it's the right course of action*

and decide again to adjust or carry on. Another key point is that people can get tunneled vision, including the best/skilled pilots. Thus, when making decision it is right for the decision to be clear and concise to all personnel and challenged if it found to be unsatisfactory.

Another pilot:

"TEA actually tries to cover all the elements. Communication, managing stress and fatigue, teamwork and leadership are most important in that order. Quite often leadership and decision making come out top of most people's list."

Third and fourth pilot interviewed said:

"Basically, the aviation industry prides itself in providing constant trainings to pilots, crew members and other ancillary staffs in the industry. For instance, situation awareness, decision making, teamwork, leadership, managing stress and coping with fatigue are common features and areas of the industry. They ensure operators of aircrafts and its crew members are acquainted with those elements.

"It is worth to note that the aviation industry is more on fatigue management, but communication ranking the highest, while decision-making is embedded in communication. Though it is critical to take on-board all available information needed to take a decision."

Q3: Is there spirit of learning in aviation and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?

Pilots interviewed noted that:

"A recent incident is the MAX 8,9 air accident this highlights the risk. This is then sent out as publication to all MAX 8,9 operators (after the investigation). It has become apparent what the issue was. Nonetheless, it will now be included in training and all pilots and operators will train their personnel."

Another pilot noted that:

"There isn't necessarily a good spirit of learning as you would like to think. What seems to have happened now is that the 'rump' of the business, those who do more 'thinking' have sort of caught up and are now applying rules to cement their positions rather than promote progress and effective safe flying."

"There is spirit and aspiration to learn in the industry. The industry embraces skills and there is lesson appetite. Lesson learned from NIMROD plane disaster is an example. In the aviation sector, there is opportunity of proper learning, organisational learning and individual learning that is highly motivated. Lesson learned can be transferred to other sectors because the importance of learning is great."

Q4: How is risk characterised in the aviation sector?

First pilot stated that:

"Risk is characterised as moderate, intermediate and severe because of the drive for high safety standards. There is a strong correlation between safety, cost and public attitude to flying. This will impact on profit but also the general sentiments to air travel. The response is always above the standard of severe in order to maintain public trust, and revenue for operators, manufacturers and airlines. Therefore, nobody wants to jeopardise the trust they have worked hard to develop as far as public relations is concerned."

Second pilot:

"There is an interface between pilots and Approved Training Organisations (ATO) in terms of risk characterisation. Information affects risk control. Though the more layers put in places, the more risk are controlled and less opportunities to identify what went wrong."

Q5: What are the major factors that causes accident in high-risk industries and any reason for that?

All the pilots interviewed stated that:

> *"All of the above factors, particularly human factor."*

Q6: Does the UK legislation influence in any direct or indirect way the requirement for the aviation industry to develop NTS/CRM capabilities or training in their workforce?

Experts noted that:

> ***"****In aviation the Civil Aviation Authority (CAA) make stipulations in regulation for a minimum requirement. However, airline and operators implement higher standards which is then submitted to the CAA for approval before it is implemented."*

4.6.7 Interview Discussion in Aviation

The aviation sector has been a proactive organisation in mitigating accidents, errors and near misses using NTS (**Skybrary 2010**), as some of the pilots interviewed stated they have come across CRM in managing safely in their sector. Remark interviewees made about NTS is that it creates harmony in a working environment, raises awareness and accountability for all personnel to identify risk and successfully manage workloads. In so doing, it is hoped that one can identify resources and deploy them to the right areas or critical points of work to maintain high standards in a dangerous work environment.

NTS tries to cover all the seven elements recognised by literature. However, experts interviewed maintained that situation awareness, communication, managing stress and fatigue, teamwork and leadership are most important elements constantly used. Quite often, leadership and decision making are rated high by some pilots.

Those interviewed in the aviation sector stated that the aviation industry provides effective training in all the elements to staff. Priority is given to situational awareness and decision making. Reason being that captains, first officers and cabin personnel need to be aware of where the flight is travelling to, either it is a potential water environment, high terrain or adverse weather prone areas. It is expected for operators to know this and understand how to manage the aircraft.

On decision-making, interviewees in the aviation sector noted that it is important in almost all situations, as the purpose of every flight is not just based on flying, but the sum of decisions made to fly safely. This clearly identifies decision-making as important as it can be analysed to prove whether the right course of action was taken, or further adjustments were needed. Another key point is that people can get 'tunnelled' vision, including the best skilled pilots. Thus, the sector believes that when taking a decision, it is expected for what is communicated to be clear and concise to all personnel. Personnel should also be polite and assertive to challenge any decision that is believed to be unsatisfactory.

However, the aviation industry prides itself in providing constant training to pilots, crew members and other ancillary staffs in the industry. Training covers all the seven NTS elements. Those are common features and areas operators in the industry must be acquainted with. However, interviewees revealed that the aviation industry is also focusing attention on fatigue management, while communication ranks the highest, as decision-making is also entrenched in communication. It is critical to take on-board all available information needed to take a decision.

Spirit of learning in aviation is another area those interviewed in the sector gave further insight on. Learning could be focused on individual, organisational learning or just normal learning strategy. Surprisingly, some pilots revealed that there isn't necessarily a good spirit of learning as one would like to think. What seems to have happened is that the 'rump' of the business, those who do more 'thinking' are now applying rules to rather than promote progress and effective safe flying. Still, interview respondents believe that lessons the aviation has learned could be applied to other high-risk industries.

The few experts interviewed in the aviation sector remarked that there is spirit and aspiration to learn in the industry, as it embraces skills and have learning appetite. Those interviewed said there is opportunity for proper learning that will cut across both individuals and the entire organisation.

Safety experts that were interviewed in the aviation sector noted that risk characterisation is taken seriously. According to the pilots, risk is characterised as moderate, intermediate and severe because of the drive for high safety standards. They believe there is a strong relationship between safety, cost and public attitude towards flying, as it will impact on profit and general sentiments to air travel in order to maintain public trust, revenue for operators, manufacturers and airlines. Nobody, the pilots said would want to jeopardise the trust they have worked hard to earn as far as public relations is concerned.

Additionally, there is an interface between pilots and Approved Training Organisations (ATO) on risk characterisation as information affects risk control. Though the more layers or barriers put in places, the more risks are controlled and less opportunities to identify what went wrong.

Major factors that causes accident in high-risk industries interviewees identified are human, mechanical, environmental and natural disaster. However, most accidents they believe are contributed to human failures in understanding what to do at any critical time.

On if government legislation of the sector has direct or indirect influence to develop NTS/CRM capabilities or training in their workforce, pilots responded that the CAA make stipulations in regulation for a minimum requirement. However, airline and operators implement higher standards which will be submitted to the CAA for approval before they are implemented.

Those interviewed in the aviation sector showed that NTS are prerequisite skills needed to manage safety in high-risk industries (**Flin *et al*., 2008**). On the other hand, there is need for the aviation sector to strive to be a learning organisation, as accident is reduced when organisations learn both internal and external (**Toft and Reynolds 2006**).

4.6.8 Oil and Gas Sector Interview Analysis

The same sets of questions that were applied to five experts in the nuclear and aviation, were also repeated in the oil and gas sector, and same method of analysis applied. The questions and responses from the oil and gas experts interviewed are as follows:

Q1: Have you come across the term NTS/CRM in managing safely in your sector?

Responses

A respondent noted that:

"If by non-technical you mean the softer skills set, then yes. And it is quite common in the oil and gas sector. Now there are lot of trainings to educate the workforce in the areas of human factors and major accident hazard recognition. I am not familiar with crew resource management, but all installations ensure that appropriate skill sets are available in installations, e.g. fire and emergency teams. These initiatives are transferrable to any industry."

Another respondent stated that:

"Yes. Non-technical skills and soft skills was a part of my annual trainings. I believe the same is applicable to all industries, including the nuclear."

The third expert interviewed said that:

"I have come across the term NTS as a trainer in health and safety, oil and gas environment."

Whereas, respondents four and five remarked that they don't have a suitable answer to give regarding the question.

Q2: Which aspect of NTS element does the oil and gas industry provide effective training, education and awareness (TEA) on?

Responses

An interviewee stated that:

"All of these are covered, and all have equal importance. You should also be aware of the offshore Minimum Industry Safety Training (MIST) course that was introduced to the North Sea in 2009 and is specifically used in the UK Continental Shelf (UKCS) to provide all workers travelling offshore with basic safety awareness in order to reduce the risk of accidents and injury. It is carried out using CBT."

Another expert interviewed said that:

> *"Communication and team-work skills are both interrelated. Improved communication skills helped the sector to openly share observations with peers and clients. Team-work skills improved the quality of our job."*

Other respondents said that:

> *"Virtually in all the elements relating to work operation. Also, there is teamwork and communication improvement in the sector. There is International Well Control Forum (IWCF-SA) certification that drillers must pass. This is to acquaint them on situation awareness (SA) before they become a driller to be able to identify kits.*

> *"There is also a minimum training that is provided to all oil rig workers, which is complete Basic Offshore Safety Induction and Emergency Training (BOSIET). It is a survival course, with a certificate that is valid for four years and approved by the Offshore Petroleum Industry Training Organization."*

Q3: Is there spirit of learning in oil and gas and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?

Responses

A respondent said that:

> *"Learning is either formal or informal, and Offshore Petroleum Industry Training Organisations (OPITO) set the standard, through Step Change in safety or bespoke company training. They organise training particularly in emergency response trainings.*
>
> *"One company adopts a 70/20/10 approach. 70% is on the job training. The problem is ensuring one have a robust programme that maps out how this is achieved and how success is measured. No good telling someone to learn the job if there is no structure.*
>
> *"While 20% is what the individual can do by joining a governing body such as IOSH and attend their meetings. Watch relevant webinars. Join groups/networks in their company and/or outside and keep up with current knowledge/events; and then 10% is formal training. This can be applied across all industries."*

Other two respondents stated respectively that:

> *"In oil and gas, we are always learning. We have different learning strategies. Individual learning is part of our day-to-day work. Organisational learning are planned annually based on the vision of the company. We also focused on training our peers. These are knowledge sharing with a group of colleagues within a discipline which are not having any job-codes or budget. This model can be applied to all other industries."*
>
> *"There is spirit of learning in oil and gas sector. Accident statistics from 1992-2012, especially after the Piper Alpha accident indicates that accident rate has reduced drastically. At that time, offshore and onshore drilling was vertical, now there is directional drilling. However, there is room for improvement. On the other hand, there is the problem of contractor management where 60-80% of worker are contractors in the oil and gas sector. As a result, proper management is lacking."*

Q4: How is risk characterised in the oil and gas sector?

Respondents interviewed noted that:

"Hazards present risks that need to be mitigated against using relevant control measures. If the risk is not ALARP then the job doesn't start. We could get very technical here using terms such as QRA, HAZOP, HAZID, LOPA and others. All relevant to high hazard industries."

"There are golden rules on safety which tried to mitigate risk throughout all the premises. We had office rules (fire drills, safety rules like tripping hazards) and on-site rules (working at height, plants with H2S). Also, we have personal risks (depression, health monitoring). One core issue within oil and gas business is zero LTI throughout any project. Other risk assessments were related to environment which was core to all projects. Clients have had very strict environmental requirements like emissions from valves, sewage treatment, energy efficiency."

"Risk is characterised in the oil and gas sector according to people, assets, environment and community."

Q5: What are the major factors that causes accident in high-risk industries and any reason for that?

Respondents said that:

"Accident is caused by several factors in the oil and gas sector. These include people, workplace, and management (interaction of human factor). However, it will depend from industry to industry and site-to-site. Though accident statistics which has happened overtime shows that human error seems to be the major cause. But the underlying factor is organisational factor, which leads to management failure.

"Human factors are there because we are all bad judges of our own risk and we all make mistakes, while mechanical, environmental and natural factors sometimes and rarely do occur."

Q6: Does the UK legislation influence in any direct or indirect way the requirement for the oil and gas industry to develop NTS/CRM capabilities or training in their workforce?

Respondents interviewed said that:

> *"In a broad sense yes, but never the specifics and legislation is goal setting. Though there is influence. The UK safety case regulation-HASWA 1974, has more than 300 regulations that covers oil and gas."*

4.6.9 Interview Discussion in Oil and Gas

From the interviews conducted, it revealed that the oil and gas sector make use of some of the skills to manage safely, but they are not largely known as NTS. They are rather regarded as soft skills such as communication and teamwork. Those interviewed in the oil and gas sector are of the opinion that there are a lot of educational programmes for the workforce in the areas of human factors. Safety experts said during the interview that they are not too familiar with CRM as it is known in the aviation industry, but in all installations, they are appropriate skill sets that are available. These initiatives the sector believe are transferrable to any industry.

Respondents said the oil and gas sector provides effective training, education and awareness (TEA) and that all the seven elements of NTS have equal importance. However, interviewees could not point out those NTS elements that are connected to the industry. Instead, they noted that there is an offshore Minimum Industry Safety Training (MIST) course that was introduced in the North Sea in 2009. It is specifically used in the UK Continental Shelf (UKCS) to provide all workers travelling offshore with basic safety awareness with the hope of reducing risk of accidents and injury.

Communication and team-work skills are used in the industry, experts said. They said that communication and teamwork are interrelated, as improved communication skills help operators to openly share their observations with colleagues. On team-work skills, the oil and gas experts interviewed said they help to improve the quality of the job done. Oil and gas have introduced International Well Control Forum (IWCF-SA) certification that drillers must pass. This is planned to acquaint staff with situation awareness (SA) and be able to help drillers identify various things that happens within their environment, oil and gas experts said at the interview.

There is also a minimum training course that is provided to all oil rig workers. This is known as complete Basic Offshore Safety Induction and Emergency Training (BOSIET). It is a survival course, with an awarding certificate that is valid for four years and approved by the Offshore Petroleum Industry Training Organisation (OPITO).

Learning in the oil and gas sector is either formal or informal; and OPITO sets the standard through Step Change in Safety or through bespoke company training. They organise training particularly in emergency response. Also, the sector adopts what is described as 70/20/10 approach of learning. The 70% is on the job training. The problem though is ensuring there is a robust programme that maps out how it is achieved and how success is measured. It was also noted that it is not good informing workers to learn the job if there is no structure put in place to support learning.

The 20% is what the individual can do by joining professional bodies such as IOSH and attending meetings, watch relevant webinars, join groups/networks and keep up with current knowledge/events. The remaining 10% is formal training and can be applied across all industries.

However, experts interviewed in the sector said learning is never ending, as there are different learning strategies. Individual learning is part of the day-to-day work, and organisational learning is planned annually based on the vision of the company. The interviewees said the workforce within the sector is also focused on training colleagues, which they believe is knowledge sharing with group or colleagues.

The oil and gas experts interviewed noted that the aftermath of Piper Alpha brought a lot of changes in the sector and increased the spirit of learning. Accident statistics from 1992-2012 in the oil and gas sector indicate that accident rate reduced drastically. An expert interviewed said offshore and onshore drilling has changed from vertical to directional drilling. Though there is problem of contractor management, where 60-80% of workers are contractors which is a challenge the sector had to contend with.

Risk characterisation is another pillar to which those interviewed said attention is given, as hazards present risks that must be mitigated against using relevant control measures. Experts interviewed noted that if risk is not as low as reasonably practicable (ALARP) then the job won’t be done. There are other methods such as quantitative risk assessment (QRA), hazard and operation (HAZOP), hazard identification (HAZID), and layer of protection analysis (LOPA). All are relevant to high-risk industries to managing safely.

From the interview analysis, the oil and gas sector have golden rules on safety which tried to lessen risk throughout all the premises. Representatives from the sector interviewed said there are office rules (fire drills, safety rules like tripping hazards) and on-site rules (working at height). Also, there are personal risks (depression, health monitoring). One core problem within oil and gas business is zero lost time injury (LTI) throughout any project. Other risk assessments were related to environment which was core to all projects. The experts interviewed said clients have had very strict environmental requirements like emissions from valves, sewage treatment, and energy efficiency.

Another aspect of the interview questions was to rate the highest accident causation in the sector. The interviewees believed that accidents are caused by several factors. These include people, workplace, and management (interactions of human factors). However, those interviewed in the sector said that it varies from industry to industry and site-to-site. Accident statistics point to the fact that human error seems to be the major cause of accidents in high-risk industries.

Legislation in the sector is reliant upon the UK safety case regulation, which is the Health and Safety at Work Act 1974 (HASAWA). The act has more than 300 regulations that covers the oil and gas sector in the UK. Legislation in the sector is to ensure workers operate in a safe and organised environment.

The five experts interviewed in the oil and gas sector said the sector operate with relevant skills such as communication and teamwork in workplace activities. However, some accidents that have occurred in the oil and gas proved otherwise. For instance, the Piper Alpha and Macondo well blowout were connected to lapses in NTS. Therefore, there is need for the sector to take the spirit of learning culture seriously and ensure that workers are trained with those prerequisite skills needed to carry out work safely. (See Appendix 2 and 3 for interview questions and responses in table format).

Secondary Data Analysis

4.7 Introduction

Secondary data (**Johnston 2014**) was collected to determine which aspect of human factor led to accidents causation in the nuclear sector from 1998 to 2018. The first set of data was collected from 1998-2010 (**Sovacool 2010**), while complementary data was obtained from 2011-2018 (**Laka n.d**). Information collated from the accidents were coded in Microsoft Excel spreadsheet for analysis.

Five sets of analysis were carried out, namely - HFACS; trend analysis; causal factor analysis, using Microsoft Excel. Pearson's correlation and chi-square test were analysed using SPSS. (See Appendix 6 for Pearson correlation analysis and Chi-square test). The result revealed that most of the accidents that occurred in the nuclear sector were triggered by human error (**Downer 2010; Reason 1990**).

The findings also showed how related factors within a sector triggered accidents if not properly managed, together with technical and organisational factors (**Lees 2012**). Different causes of accidents have proved Heinrich *et al*. (1980) right, as accidents are not expected to be credited to a single reason, or in most cases to a single person (**Heinrich *et al*.1980; cited in Shappell and Wiegmann 2000**).

Skalle *et a*l. (2014) noted that technical errors and organisational factors are causes of accidents in recent times; while Norazahar *et al*. (2014) stated that disasters are somehow caused by more than one causal factor regardless of what is been focused on. Deacon *et al*. (2013) said that human error, which is a major causal factor to accidents is always present; playing important role in causing accidents (**Cai *et al*. 2013**).

4.7.1 HFACS Analyses

On HFACS analysis, it is possible for unsafe supervision on Figure 28 to create the condition for planned inappropriate operation, which equally triggered physical mental limitation. Crew Resource Management, personal readiness, physical environment and technological environment all combined to cause accident. While failed to correct problems increased and caused an effect that triggered negative on physical environment.

Physical environment led to perceptual errors and technological environment led to exceptional error. On the other hand, physical mental limitation, crew resource management and personal readiness triggered errors. CRM and personal readiness caused perceptual errors which eventually led to accidents. HFACS suggests that if staff, especially those at safety ends are not properly trained and supervised, there is the tendency that errors committed as a result of planned inappropriate operations and failure to correct problems is capable to trigger accident in high-risk industries, including nuclear power plant. See Figure 28 on the interconnectedness of HFACS analysis and why accident could readily occur when one of the environments is triggered by unsafe act.

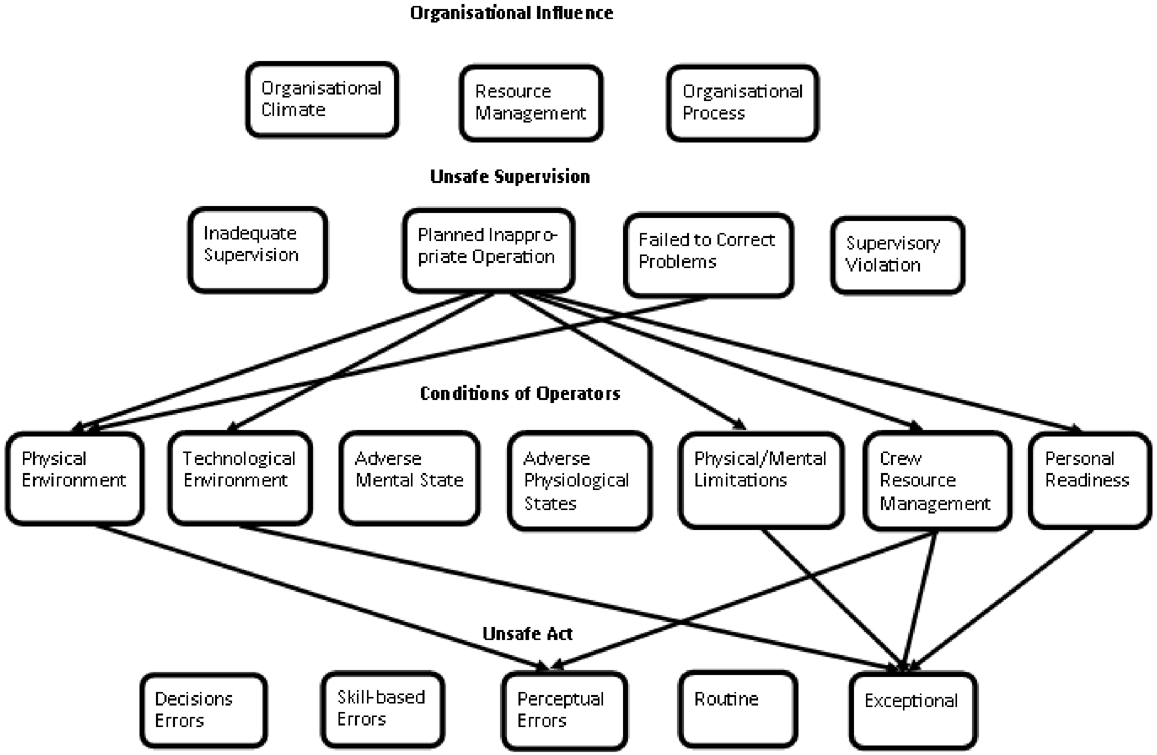


Figure 28: HFACS, adapted from Wiegmann and Shappell, 2003

4.7.2 Causal Factors of Nuclear Accidents

Figure 28 shows HFACS analysis for nuclear accident from 1998 – 2018. It revealed accident causal factor graph.

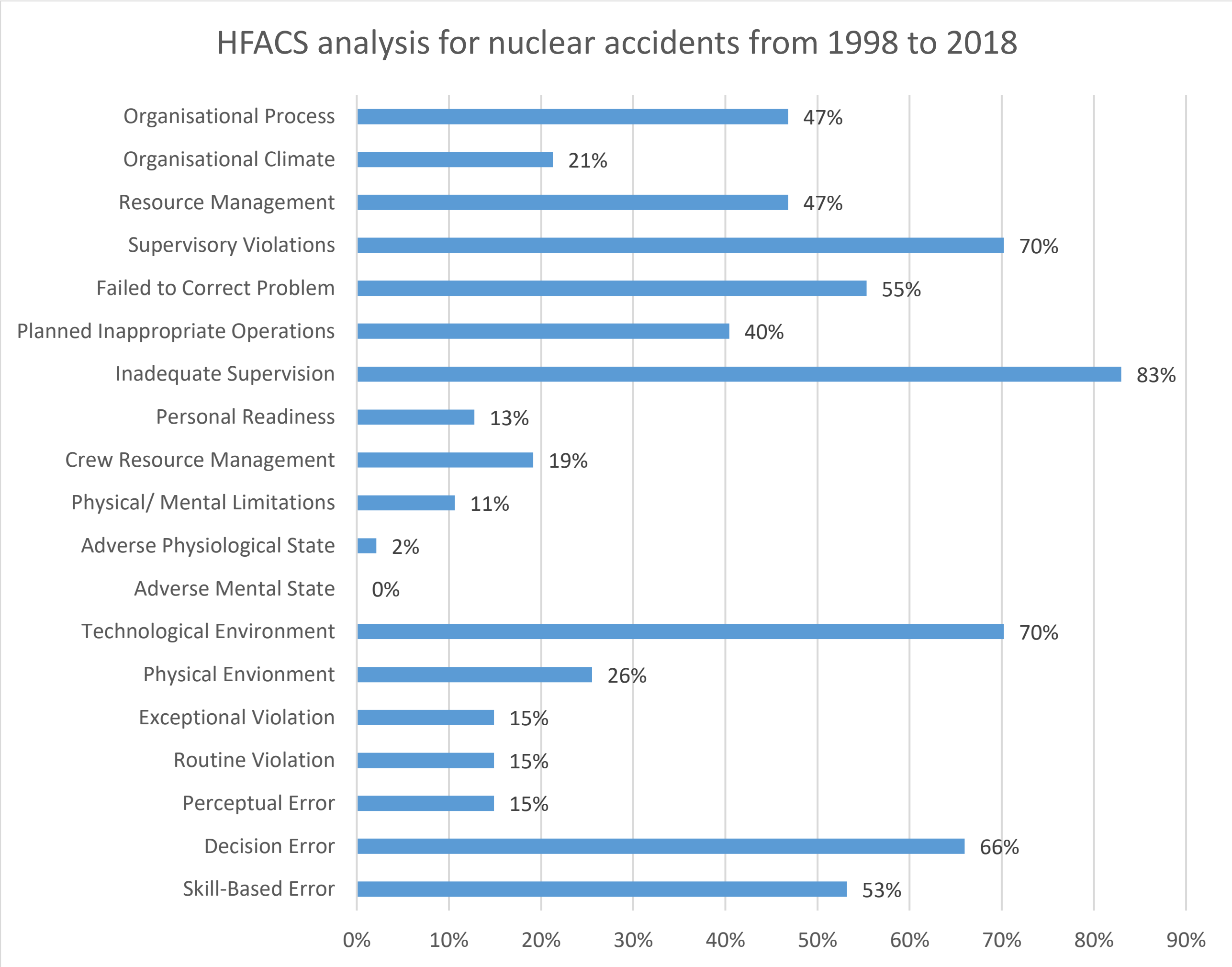


Figure 29: Causal factors of nuclear accidents from 1998 – 2018

The result indicated that inadequate supervision (83%) was the major human causal factor of accidents in the nuclear sector from 1998 to 2018, followed by technological environment and supervisory violations (70%), decision error (66%), failure to correct problems (55%) and skill-based error (53%). This is an indication that most accidents in the nuclear sector were adversely influenced by flaws in non-technical skills such as leadership (supervisory violations), teamwork (skill-based error), situational awareness (failure to correct problems), communication (inadequate supervision) and decision-making (decision error). As a result, there is need to train operators on NTS use to managing safely. Figure 30 indicates trend analysis of nuclear accident.

4.7.3 Trend Analysis

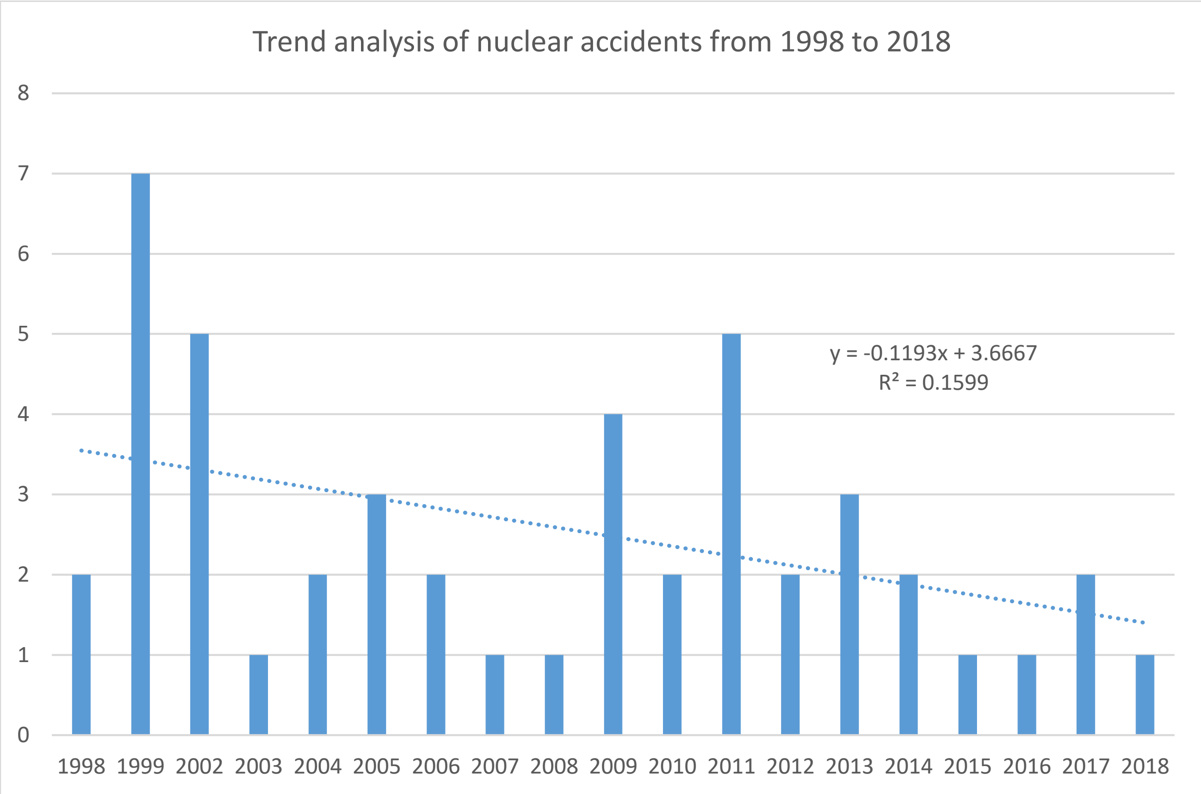


Figure 30: Trend analysis from 1998 - 2018

The trend line in the trend analysis shows that nuclear accidents are reducing on the average compared to previous years. However, in the last 10 years, there has been little improvement in the number of nuclear accidents as the number of nuclear accidents increased from 2 in 2010 to 5 in 2011. The R^2 value denotes the accuracy of the trend line in a value of 1 signifies 100% accuracy in prediction of the trend analysis.

4.8 Impact of Covid-19 on Nuclear, Aviation and Oil and Gas in the UK

4.8.1 Introduction

The emergence of the coronavirus 2019 (Covid-19) pandemic in the UK in February 2020 (**Holmes 2020**) proved an opportunity for additional research on: “The Impact of Covid-19 on Nuclear, Aviation and Oil and Gas Safety in the UK.” Because the dynamics of risks may have changed in most UK industries, there is urgent need to find which aspect of government proposed changes (policy) would be affected mostly on the four pillars (NTS, isomorphic lessons, organisational learning and risk characterisation) of this research across the three sectors.

For instance, under the current circumstances managing stress (under the NTS category) may have changed. Additionally, other pillars such as risk characterisation in the work environment arising from coronavirus may have altered communications and decision-making dynamics around risk, affecting workers performance during the post covid-19 period.

This preliminary result presented a survey of 53 respondents and offers some cursory data on how Covid-19 may have affected the researched areas. Therefore, it is recognised that further research is required on Covid-19 if precision and a fuller understanding of the coronavirus impacts are to be fully understood and properly gauged. It will be interesting to see what level of organisational learning will arise from the coronavirus, and the nature of “Covid-safe” conditions that will emerge in each industry setting. There may be some cross-industry isomorphism opportunities behind each sectors response in the workforce context spanning NTS, risk characterisation, and organisational learning.

4.8.2 Covid-19 Result Analysis

This result analysis took a cue from what was already established in the main research. SPSS was used as analytical tool to determine to what extent Covid-19 will have on organisations in the use of NTS, organisational learning, isomorphic lessons and risk characterisation; and how new rules will affect workers environment in the UK to manage safety.

The online survey produced the following results:

Q1: Currently work in the following industry

Details of how each responded is indicated on Figure 31.

Respondents were nuclear (n=24, 46%); aviation (n=17, 33%); and oil and gas (n=12, 23%).

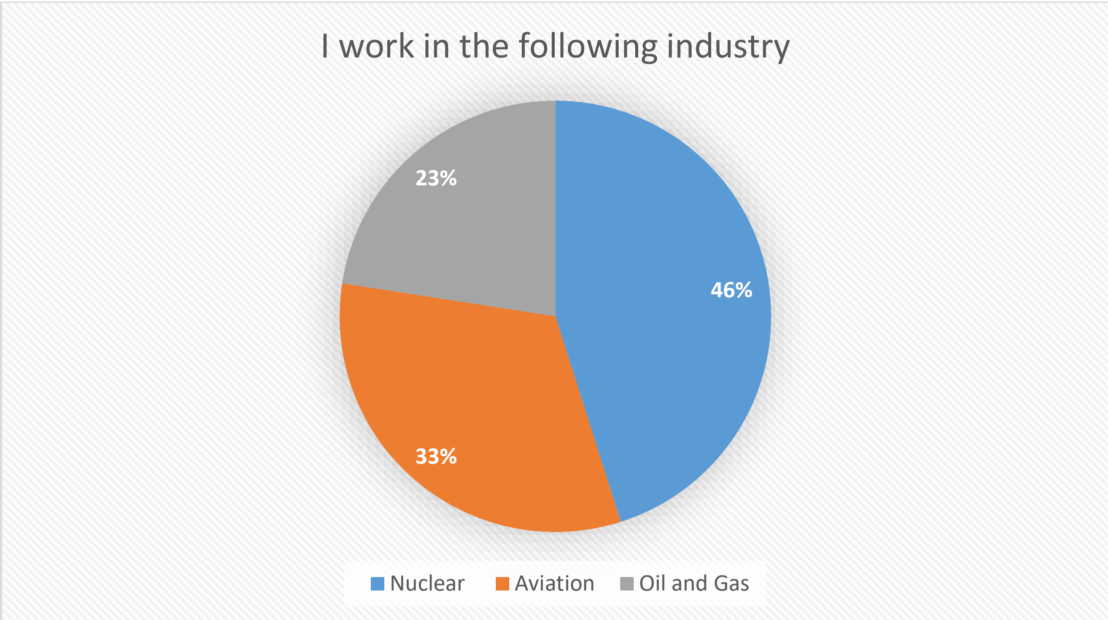


Figure 31: Overall response according to sectors

Q2: What position do you hold within your company?

Table 36 is a crosstab of Q1 and Q2, which illustrates how each sector responded.

Table 36: Position respondents hold in various sectors

		Senior Manager	Manager	Supervisor	Operator	Technical	Non-technical	Others (pilots/captain/cabin crew)	Total
Nuclear	**Count**	8	**2**	2	0	**8**	2	2	24
	[%] of Total	**33**	8	8	0	**33**	8	8	100
Aviation	**Count**	0	0	2	1	1	0	13	17
	[%] of Total	0	0	12	6	6	0	**77**	100
Oil & Gas	**Count**	2	4	**3**	1	1	0	0	12
	[%] of Total	17	**33**	**25**	25	25	0	0	100
Total	**Count**	11	7	7	2	12	3	26	57
	[%] of Total	19	12	12	6	21	5	15	100

Q3: Total years of service

Detail of how each sector responded is indicated in Figure 32 on the bar chart below.

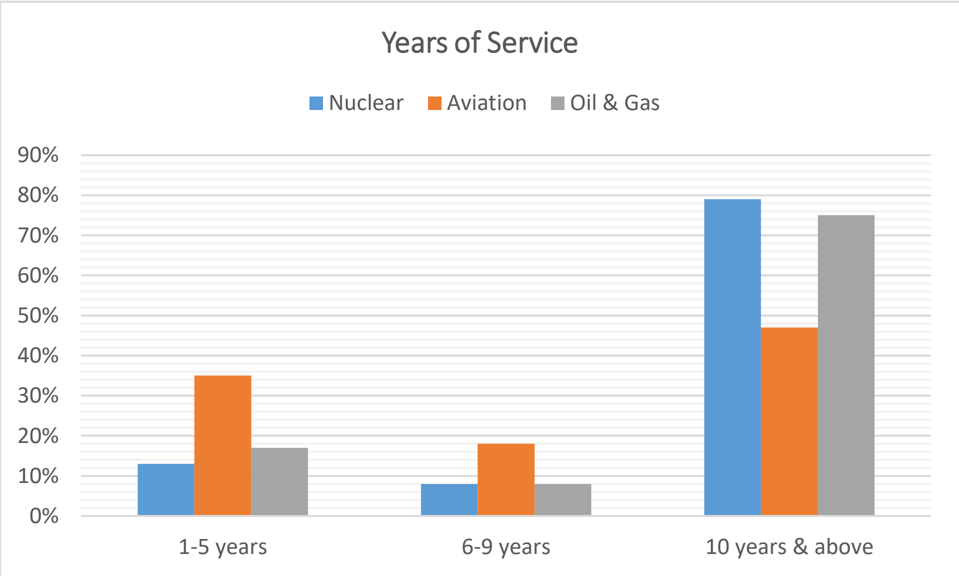


Figure 32: Years of service according to sectors

Q4: Has the impact of post Covid-19 CHANGED the following NTS in your work environment either positive or negative?

Detail of how each sector responded is indicated on Table 37 – 43.

A. Situation Awareness

Table 37: Indicating impact of Covid-19 on situation awareness

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**29%**	**38%**	21.0%	8%	4%
Aviation	**18%**	**59%**	6%	6%	6%
Oil and gas	**50%**	17%	25%	0%	8%

B. Decision-making

Table 38: Indicating impact of Covid-19 on decision-making

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**9%**	**39%**	26%	13%	13%
Aviation	**12%**	**35%**	6%	24%	12%
Oil and gas	**25%**	**25%**	33%	17%	0%

C. Communication

Table 39: Showing impact of Covid-19 on communication

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**25%**	**33%**	25%	13%	4%
Aviation	**35%**	**29%**	6%	24%	0%
Oil and gas	**42%**	**8%**	25%	17%	8%

D. Teamwork

Table 40: Indicating impact of Covid-19 on teamwork

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**13%**	**50%**	13%	21%	4%
Aviation	**29%**	**35%**	6%	24%	0%
Oil and gas	**42%**	**25%**	17%	17%	0%

E. Leadership

Table 41: Showing impact of Covid-19 on leadership

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	8%	**38%**	42%	8%	4%
Aviation	**25%**	**31%**	19%	13%	8%
Oil and gas	**33%**	**8%**	42%	8%	8%

F. Managing stress

Table 42: Indicating impact of Covid-19 on managing stress

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**25%**	**38%**	29%	4%	4%
Aviation	**24%**	**59%**	6%	12%	0%
Oil and gas	33%	**25%**	33%	8%	0%

G. Coping with fatigue

Table 43: Showing impact of Covid-19 on coping with fatigue

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	**17%**	**49%**	29%	8%	0%
Aviation	**18%**	**35%**	29%	12%	6%
Oil and gas	**42%**	**8%**	33%	17%	0%

Q4a: Respondents comment on impact of post Covid-19 on NTS elements

Table 44: Comments on impact of Covid-19 on NTS elements

Nuclear	Aviation	Oil & Gas
Remote operation means less social interaction which is a way of seeking opinions and forming coalitions.	Changed our communication methods the way we operate because we must adopt mitigations for COVID-19.	How staff will work after post Covid-19 will change drastically because of social distancing and work pattern.
More work than before. More video myths less thinking time. More bids and strategy planning.	Most communication are done online, and it can't be a replacement for dealing with people face to face. A of lot communication isn't verbal alone. And at times team cohesion is affected.	I saw the changes in managing stress and fatigue prior to all the jobs being suspended and I think this will carry through however the others are too early to say.
Communication is more cumbersome especially working remotely without keeping situational awareness with site presence.	Lack of operational exposure. However, there is no fatigue element because I am not working.	Increased awareness on interactions (i.e. critical review of meeting schedules).
We are good at communicating and this has stayed the same and lucky to be able to work from home with little change to the business we work in.	As a professional, it is important to not allow external events impact operational concerns like decision making or teamwork, especially where safety is also concerned. However, with more personal NTS like stress and fatigue, the worries that are associated with the COVID-19 pandemic, do have a small impact.	Basically, no work available since Covid 19.
Communication have generally improved due to widespread audio and video conferencing. Biggest issue is isolation that has impacted situational awareness negatively.	Communication through PPE, differing work cycles pre and post flight. Fatigue unable to comment, yet to operate.	I work from home. I've stopped travelling. We have regular tele-conferences. I reach out to customers through IM emails, phone, tele conference.
My environment at work has remained unchanged as social distancing is something that can be easily incorporated. Changes to shift patterns and family circumstances (school closure) means fatigue is certainly factoring in the operational environment.	Managing a crew with generally higher anxiety levels. Managing multiple new procedures which change frequently. Lack of flying currently makes doing the normal job more difficult/stressful.	A lot of operational procedures have changed due to social distancing measures.
Focus on protection from COVID 19 whilst maintaining the ability to deliver projects.	So long out of role means ability to instinctively build SA has been eroded - more of my concentration will be taken reacquainting with rusty manual skills/SOP's.	Leadership and Teamwork are an awesome combination.
Awareness of restrictions on workforce is heightened and encouraged to come to the forefront. A reduction in meetings and more use of technology has freed time for personnel, team communication is more frequent and to the point.	Communication amongst us has increased dramatically. But from the company, it's reduced considerably.	Everything has changed in the work environment. Not having in person meetings makes communication more difficult. Learning to handle a different type of stress as well as listening to offshore workers who are using situational awareness and feel fearful of causing a major accident has added to stress.

Different ways of working have impacted on business have to go through a new learning curve to adopt and adapt to a different approach.	Aviation is hard hit. Talks about redundancies all over the industry. This increase stress slightly and thus impacts the stress management. Stress has an influence on fatigue and coping with fatigue.	Working from home has meant a reduction in teamwork and communication. Not having the office interaction means team meetings and phone calls are sporadic by comparison. Covid-19 has however made everybody far more environmental aware.
With all my co-workers working from home the balance of the company and the way in which the company communicates has changed in a positive way. I'm unable to undertake surveys in person and have resorted to using video conferencing to address specific risks.	Given the effect social distancing measures will have going forward, I believe it will create barriers in communicating with colleagues and passengers. I feel there will be more pressure on performance, whilst working increased hours and worse working conditions particularly to do with easyJet's attempts at exploiting our fatigue protections. Nevertheless, decision making specifically within the flight deck should not be impaired, although it may be if you acknowledge the effects of fatigue.	Work continues, under careful mitigation. Rotations are longer due to travel limitations. Stress is of course higher due to greater hazards. This has led to greater teamwork and leadership.
People are more aware of what is going on around them, especially movements of others. Communication and teamwork are hampered by the lack of face to face activity.	Due to new rules implementation fatigue factors are very high.	
Remote working lacks the huge amount of non-verbal communication so everything else must be enhanced.	Yes, there are new challenges and procedures, but all these skills were already entirely necessary and well developed to deal with the tactical and strategic challenges of the job. Yes, they are still particularly relevant, but I don't believe the current crisis has increased the use of these skills. They're now just being applied to an additional set of operational issues.	
There has been no change. Awareness of hazardous environments has always been present.	Covid 19 restrictions will impact teamwork and communication due to PPE and social distancing requirements. Day will be longer due to increased boarding times or cleaning requirements on turnaround.	

Q5: Using a scale of 1 – 10 (1 = lowest, 10 = highest) rate the following changes to your working environment. Has Covid-19 had any detrimental impact on NTS to the following degree:

Details shows how sectors responded to changes in working environment on Table 45 – 51.

Social distancing (2 meters apart)

Table 45: Indicating responses on social distancing

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	2	1	0	1	2	1	5	2	0	7	3
[%]	8	4	0	4	8	4	21	8	0	29	13
Aviation	1	0	1	0	2	1	0	4	1	4	3
[%]	6	0	6	0	13	6	0	24	6	24	17
Oil & Gas	0	1	3	1	0	0	0	0	1	4	1
[%]	0	9	27	9	0	0	0	0	9	36	9

Reconfigured workplace(s)

Table 46: Indicating responses on reconfigured workplace(s)

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	1	0	3	2	3	1	4	1	1	5	3
[%]	4	0	13	8	13	4	17	**4**	4	**21**	13
Aviation	1	1	1	0	1	1	1	2	2	3	4
[%]	6	6	6	0	6	6	6	12	12	18	**24**
Oil & Gas	2	1	2	1	0	1	0	0	1	3	1
[%]	18	9	18	9	0	9	0	**0**	9	**75**	25

Disinfection protocols

Table 47: Indicating responses on disinfection protocols

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	2	2	3	3	1	0	2	3	2	2	4
[%]	8	8	13	13	4	0	8	13	8	8	17
Aviation	0	0	0	0	0	1	0	4	0	10	2
[%]	0	0	0	0	0	6	0	24	0	**59**	12
Oil & Gas	0	0	0	0	1	0	0	2	2	5	1
[%]	0	0	0	0	9	0	0	18	18	46	9

Remote working

Table 48: Indicating responses on remote working

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	3	0	1	2	1	1	2	0	2	12	0
[%]	13	0	4	8	4	4	8	**0**	8	**50**	0
Aviation	3	1	0	0	0	0	0	0	0	5	8
[%]	18	6	0	0	0	0	0	0	6	29	**47**
Oil & Gas	2	0	0	0	1	0	1	0	3	5	0
[%]	17	0	0	0	8	0	8	0	25	**42**	0

Personal Protective Equipment (PPE)

Table 49: Indicating responses on personal protective equipment

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	2	7	0	1	2	1	1	3	1	1	5
[%]	8	29	0	4	8	4	4	13	4	4	**21**
Aviation	0	2	0	0	1	0	1	0	5	7	1
[%]	0	12	0	0	6	0	6	0	29	**41**	6
Oil & Gas	1	0	1	0	1	0	1	0	1	4	2
[%]	9	0	9	0	9	0	9	0	9	**36**	18

Changes in shift patterns

Table 50: Indicating responses on changes in shift patterns

Count (Rating)											
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	4	3	2	1	0	0	1	3	1	4	5
[%]	17	13	8	4	0	0	4	13	4	17	**21**
Aviation	1	0	1	0	1	2	0	3	1	5	3
[%]	6	0	6	0	6	12	0	18	6	**29**	18
Oil & Gas	1	1	1	0	0	0	0	0	0	5	2
[%]	10	10	10	0	0	0	0	0	0	**50**	20

Travel to and from work

Table 51: Indicating responses on to and from work

	Count (Rating)										
Scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Nuclear	5	1	1	0	0	2	3	1	1	7	3
[%]	21	4	4	0	0	8	13	4	4	**29**	13
Aviation	4	2	4	0	1	0	1	0	0	4	1
[%]	24	13	24	0	6	0	6	0	0	**24**	6
Oil & Gas	1	0	0	0	1	0	1	0	3	4	1
[%]	9	0	0	0	9	0	9	0	27	**36**	9

Q5a: Respondents comment on how Covid-19 will impact on the working environment

Table 52: Respondents comment on possible effect post Covid-19 on work environment

Nuclear	Aviation	Oil & Gas
Remote working impacts the socialisation of ideas, concepts and arguments potentially limiting the broader input required to make fully informed decisions.	Social Distancing not always possible such as on the Flight Deck or Flight Simulator.	Don't think most of this will affect offshore work due to the current layout of rigs. Maybe will affect design of new installations. Travel to /from work may be impacted short term and I do think cleaning protocols will carry lessons from this forward.
Already working from home as does my team. Only effect is more isolation.	It is not natural for people to social distance. Measures had to be put in place to make sure social distance is adhered to but also as a business they had to mitigate risk factors by forcing people to work from home and for us who couldn't, cleaning and disinfecting protocols came in.	Operations are not as hands-on as they used to be before the coronavirus.
Remote working without visit and interacting with site.	Social distancing and maintenance of robust cleaning protocols in the flight deck are very difficult. Work patterns are impossible to gauge until we go back to work.	For my work I simply must make decisions on my own and then hope it is approved. Sometimes I do not know if the work I hand in is being properly reviewed.
Working from home so kept social distancing.	Having been furloughed, it is hard to accurately gauge some of these measures, however other changes are much more noticeable like different working patterns (I.e. no work) as well as increased cleaning and safety supplies onboard aircraft.	Working from Home
Lack of travel has been very beneficial in terms of productivity. Overall fatigue has been reduced even working more hours.	It has taken time to introduce training protocols in simulators.	Offshore vessels already built compact for minimum staffing levels, distancing is impossible, so emphasis is on keeping infection off vessel and a response for when it occurs onboard. Travel to and from port is the great challenge. Onshore support, they are mostly WFH.

My workplace has placed a mandatory requirement to wear face masks and light eye protection when working within 2m of another person. However, clear guidance, training and support has not been appropriately provided for employees to ensure compliance. PPE needs to be readily provided (with masks that come in a variety of sizes).	Being In aviation, it's hard to implement social distancing within an aircraft. Being on the flight deck we get our own supply of air therefore PPE isn't considered essential for us.	The inherent uncertainty is something that can prompt negative responses.
Roll out of technology for remote working has been slow, this has affected the ability to work constructively away from the workplace especially during shifts offsite.	Covid has an influence on some parts of the job although no direct influence on the skills itself. For example, PPE must be worn in some occasions and thus has an influence on the job but does not impact the NTS.	
Covid-19 has introduced significant change to ways of working and hence the high scores across the board. PPE has only been impacted by the need to wear a protective mask, where social distancing can't be achieved. Guidance is subject to change to reflect the changing position and therefore can be subject to a level of interpretation.	It is impossible to change the way in which pilots work, or seat configurations within an aircraft. Staff bus routes between the car park and the airport will be challenging if they enforce social distancing as they were often full. Disinfection and increased hygiene methods were needed a long time ago.	
The main disruption to my working environment has been travel to the office in London and travel to sites to undertake surveys.	To adhere to new guidance all the above need to be considered.	
My work requires me to work face to face with clients, often in a classroom environment, so significant impact in areas indicated	Initial guidance was rather muddled. It's taken time to settle down into something workable and sensible.	
Things are changing.		
Already setup for home working so just the additional personal behaviours that have now changed to reflect the constraints and how others are working.		
Working remotely is not a problem if there is proper communication.		

Q6: Has the impact of Covid-19 CHANGED the following in your operational environment

Details on the impact of Covid-19 on the four pillars is shown on Table 53 – 56.

Non-technical Skills

Table 53: Changes on NTS on post Covid-19

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	0%	**33%**	29%	29%	8%
Aviation	**13%**	**47%**	29%	12%	0%
Oil and gas	**33%**	**25%**	25%	17%	0%

Isomorphic lessons

Table 54: Impact of post Covid-19 on isomorphic lessons

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	4%	**36%**	33%	17%	8%
Aviation	13%	19%	**50%**	12%	6%
Oil and gas	**27%**	18%	**36%**	18%	0%

Organisational learning

Table 55: Impact of post Covid-19 on organisational learning

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	17%	**42%**	17%	17%	8%
Aviation	24%	**41%**	29%	6%	0%
Oil and gas	**33%**	17%	33%	17%	0%

Risk characterisation

Table 56: Impact of post Covid-19 on risk characterisation

Industry	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Nuclear	17%	**38%**	29%	8%	8%
Aviation	18%	**41%**	35%	6%	0%
Oil and gas	**33%**	25%	33%	8%	0%

Q6a: Respondents comment on Covid-19 impact in operational environment

Table 57: Respondents comment on post Covid-19

Nuclear	Aviation	Oil & Gas
Loss is function of time, but it is likely that extension of remote work for long period of time will lead to some loss in skills and disconnect from operational environment although it is not the case at present.	Changed the way we operate. And as a company as a whole changed our methods of communication and protocol.	I do not think much will change once we are out of this pandemic
Learning has gone online for some sessions, but some sessions have been put on hold until face to face sessions can resume.	The two greatest is organisational learning. A lot is having to change to observe guidelines and organisations are learning but now most have you factor pandemics and public health emergencies in huge ways. But some roles just can't change.	It feels like we entered a strange environment in early March where one day merges with the next. There is no time off. And the risk is different, and we do not even know which ones are most important
COVID has impacted on risk compliance with social distancing - e.g. fewer trips to site to maintain equipment.	Organisational learning would have definitely changed because of this pandemic. Greater flexibility and quicker responses to erroneous events will certainly be positives to come out of this. Not too sure what is meant by an isomorphic lesson, however.	Only able to provide advice or information when requested as opposed to the organic process within the office environment.
COVID19 has impacted all areas because it has taken away the direct social interface i.e. face to face contact, which is so important in achieving these. Risk characterisation now has to incorporate the additional facet of COVID19.	My working environment is the flightdeck and the cabin. Besides lack of flights and passengers we have had some additional rules and protocols to adhere too. Overall Covid has not really had any other impact on the job and my work environment. The flightdeck is exactly the same and we do our job in exactly the same way.	All the above are common components of my role/industry which is why this is only an Agree not a Strongly Agree.
All changes described above have been positive changes i.e. things have got better. Risk characterisation of the facilities I visit has reduced as I'm only able to undertake partial surveys using video conferencing to receive specific updates on specific risks that have previously been identified.	No doubt there has been changes to our operational environment. New way of working is a must.	In my opinion existing behavioural characteristics and patterns are exaggerated.
It is still not clear how long things will be going on.	Again, Covid has been a unique and new problem. The processes to make decisions about it have, however, already been well established and have not changed. It's just a different problem, not a different framework for dealing with the problem.	
	NTS change as a result of changed social interaction norms. All airlines re-evaluating risk, responding and learning from others as it's a new threat.	

Q7: Additional measures respondents think should be put in place at work to protect staff environment

Table 58: Additional measures to protect staff environment

Nuclear	Aviation	Oil & Gas
None - the current social distancing is sufficient.	We have put in place many measures and mitigations against COVID-19. Social distancing, face covering, online communication, use of sanitizer and higher frequency of cleaning.	Organisations should operate as it suits them in this post covid-19 era.
No more offices. They are an unnecessary expense. Less travel.	If infection remains a threat and until there is a vaccine, then masks and the use of hand sanitizer for passengers and cabin crew. Sanitising wipe down of flight deck controls before flight.	Improve the medical facilities and protocols for dealing with this type of issue in future, and the protocols for transporting contaminated staff to an onshore hospital.
Testing and tracing should be used to enable some punctual interaction between remote worker and sites.	As this pandemic is changing and developing final summations will be difficult. As a business we need to find a way to be less reliant on the conventional way of working.	Review open plan office spaces. Promote remote working. Improve the efficiency of remote working by adapting existing technologies.
We have a team working on this and we are ensuring 2-meter rules and keeping people safe. We have a staged return once the lock down is lifted.	Good quality and adequate PPE. SOP changes to ensure that our exposure to passengers and airline ground staff is minimised and any risks mitigated.	Face masks, hand cleaning.
Biggest issue is slow internet which is detrimental to homeworking. This is especially true when multi-tasking. This is leading to frustration that we will be unable to work.	If PPE is mandatory in public where social distancing cannot be achieved (on aircraft or in airports, for example), then this should be provided to employees by the employer/government.	Face masks, washing of hands regularly, social distancing, proper nutrition and refresher training.
Prevention needs greater focus, meaning test kits readily available for the workforce for routine and random checks. Continued efforts to reduce numbers going into work.	Quarantine has not been addressed properly for transport workers, especially post global operations.	Healthy attitude, health and wellbeing. Everyone focused.
Focus on the soft skills for staff to create a learning organisation.	Clear explanation of protective protocols being used and likely levels of risk.	Testing every single worker!
Remote working whenever possible.	None - most are inhibiting and impractical.	My company has put in place rigid protocols with regards to Covid when we return to work. I feel people who can work from home should continue to do so until the virus is under control.
IT access given to all personnel to work effectively offsite. Offsite work encouraged as a first choice. More social distancing measures introduced within the offices to prevent the need for shifts.	Temperature checks at all airports should be mandatory.	Testing while in isolation, negative results received before joining vessel. Avoid overly long rotations. Much more local crew - less seafarers from SE Asia, less Europeans in America.

We follow government and organisational guidance which are proportionate to the COVID19 impact, at any given point in time.	Proper ventilation, opening doors on turn around. Wearing masks in places with insufficient ventilation. Get rid of the 1,5-metre distancing. Educate passengers more about Covid and how it spreads.	I'm working from home.
A reduction of nuclear safety related activities should be tolerated for minimum time, the risk presented by the facility must remain tolerable with maximum achievable defence in depth.	The front toilet should be reserved for Pilots and cabin crew only. We shouldn't be at the risk of hundreds of passengers.	Monitoring of controls. This is a long-term issue and will be difficult to maintain good practice.
Other than hand washing facilities, and cleaning of frequent contact points, nothing. The whole situation is over exaggerated.	Full on protective suits when in contact with passengers.	
We need to build trust back into the work force to enable them to want to return to offices and be confident they are safe. This will require a lot of effort and cultural change.	Guidance should include social distancing of at least one metre. No more than 3 in the lift at a time. Wearing of mask if within one metre of another colleague. Frequent sanitising of work tops.	
The biggest difference is to hot desking and associated hygiene issues.	Primarily, testing for all crew. PPE, social distancing measures where possible, amended working hours and rest facilities.	
None. Externally I work in other people's environment remotely I work self at home.	I don't think that more additional measures are necessary.	
To be honest, where I work has been impressive. Signage, PPE and sanitisation is perfect. The change rooms are one-way systems, with areas designated to get ready 2m apart.	Airport terminal congestion likely the largest threat area to staff and passengers for ongoing transmission.	
None further at this time, though full return to office work might require use of body temperature measures prior to being allowed to enter the work environment.		

4.8.3 Discussion on the Impact of Covid-19

4.8.4 Introduction

This second section of discussion is focused on whether Covid-19 has impacted on the four pillars (NTS, isomorphic lessons, organisational learning and risk characterisation) either negatively or positively across the three sectors in the working environment. The survey also examined how government rules on social distancing, reconfigured workplaces, disinfection protocols, remote working, use of personal protective equipment (PPE), changes in shift pattern, travel to and from work will affect workers performance and safety management across the three sectors.

4.8.5 Discussion

Respondents first identified the sector they work for during the survey. The nuclear sector had the highest number of responses, followed by the aviation and the oil and gas sectors. In terms of the level of experience from each sector, the data shows that nuclear had more on senior manager and technical staff, the aviation had more on pilots, captains and cabin crew and the oil and gas had more on manager and supervisor respectively.

Finally, on demography between sectors, respondents stated the number of years spent in service. From 1 – 5 and 6 - 9 years of service, the aviation sector had the more, followed by the oil and gas on 1 – 5 years of service. But the oil and gas and nuclear sectors had the same number of respondents in year 6 – 9. From 10 years and above, the nuclear and oil and gas had more, followed by the aviation sector. It is also interesting as it shows that the longer participants have worked in their sectors, the better the understanding of questions.

Respondents were requested to determine the impact Covid-19 would have on the elements of NTS in operational environment in 37 - 43 (Q4). On situation awareness, participants across the three sectors recorded more response on ‘strongly agreed’ that Covid-19 will have serious effect on work activities. This shows that management will focus more on the health and safety of workers based on the cognitive effect the pandemic had created on people’s consciousness or perception, with minimal focus on situation awareness in workplace. However, it is believed that the aviation sector cannot substitute situation awareness for something else even if there had not been Covid-19, as situation awareness has no alternative on flight operations.

Another NTS element that participants responded to is decision-making. The result suggests that decision-making in the work environment would be impacted by Covid-19 especially in the oil and gas sectors on strongly agree, compared to aviation and the nuclear sectors that recorded more respondents on ‘agree’. However, because participants never envisaged that there will be Covid-19, therefore, they lacked understanding about the entire requirements and challenges it would cause in the workplace. Also, government view or policy was unclear on guidance, leading to possible confusion regarding workplace safe conditions.

More so, decision-making is not expected to be easy in the work environment because there are so many factors to consider that should not be detrimental to workers safety and affect work progress. For instance, it would be difficult to ask workers to work in large groups as that would go against the ‘rule of six’ stipulated by the government. On the other hand, some of the managers may not be on hand to take decisions either remotely or in work environment. However, an expert from the aviation sector during the survey said that decision making specifically within the flight deck should not be impaired, although it could happen if one acknowledges the effect of fatigue.

Communication was another NTS element respondent’s provided information on. The data revealed that communication would be negatively affected across the three sectors because of Covid-19. Respondents’ views were supported by comments provided during the online survey. For instance, a respondent from the oil and gas sector ‘strongly agreed’ that Covid-19 would adversely affect communication as most work (exploration and drilling) are executed in remote places or offshore. This he said could lead to delayed feedback when staff rely on emails instead on face-to-face discussion. A respondent in the aviation sector also said Covid-19 has changed the way the sector operates on communication and protocol, as a lot of communication in the sector is not only verbal and would have effect on team cohesion. A respondent from the nuclear sector noted that communication has generally improved due to widespread use of audio and video conferencing.

Lack of digital communication platforms could have hindered the degree to which respondents perceived adequate communication. With time, this possible communication gap is likely to have been addressed, which means remote workers are likely to be better informed. This could have skewed the data in the early stage of the survey collection.

The result also revealed that teamwork, which is crucial to carrying out roles collaboratively and effectively, would be impacted by Covid-19 across the three sectors in the work environment. The result is in line with what participants separately said during the online survey that: “Covid-19 has impacted on all areas of work because it has taken away the direct social interface such as face to face contacts which is so important in achieving work objectives.” Likewise, an oil and gas expert remarked that because of social distancing and the fear of spreading the disease, teamwork would be drastically affected. However, it is viewed that staff would find it difficult to integrate, creating an adverse effect on productivity. Invariably, safety can be compromised due to the impact of Covid-19 on teamwork.

Additionally, leadership was another NTS element the result indicates would be affected across the three sectors in the work environment. Because lack of management supervision arising from Covid-19 will have impact on workers, though that depends on the nature of job they do. This statement is supported by an expert view in the oil and gas sector as he noted that he takes decisions on his own and then hope it is approved. Another concern was he doubts if the work he executed is properly reviewed by his boss. But another respondent in the nuclear sector feels the impact of Covid-19 on leadership would be minimal in the sector.

Managing stress is essential to this survey as it directly affects workers health and performance. Despite responses provided by each sector, the result implies that managing stress will be adversely affected by Covid-19 in the work environment as it has the propensity to increase working hours and task on mental ability of workers. Mistakes committed by workers will be high due to lack of supervision because of social distancing. High level of redundancy which has increased across the three sectors since the outbreak of Covid-19 has increased workload. From a respondent point of view provided on a statement box during the survey, said stress has led to errors, while absenteeism of workers is high due to stress related cases.

The last NTS element respondents were asked to provide information on whether Covid-19 will have impact on coping with fatigue in workplace environment. The result agrees with an expert view in aviation that due to new rules introduced because of Covid-19, fatigue factors will be higher because of excessive workload. With staff trying to manage themselves against possible contracting of Covid-19 and managing their workload, there is the tendency these challenges could cause further anxiety and workers performance.

This research also used a 10-point scale (1 = lowest, 10 = highest) to rate the changes recorded in working environment due to Covid-19 will have any impact on NTS as it relates to new government policy on social distancing, reconfigured workplace, disinfection protocols, remote working, use of PPE, changes to shift pattern and travel to and from work.

Social distancing has been identified by this research to influence teamwork. The result demonstrates that all the sectors will be affected by the effect of social distancing in the workplace safety management. The result is supported by a respondent from the nuclear sector that social distancing will impact on socialisation of ideas and concepts which will potentially limit the broader input required to make fully informed decisions.

However, another participant from the aviation sector said social distancing will not be possible on the Flight Deck or Flight Simulator. Though it could be practicable for cleaners to distance themselves during working hours. In the oil and gas sector, an operator said: “Offshore vessels are already built for fewer staff; therefore, distancing is impossible.” Nevertheless, if social distancing is practiced in some organisations, the tendency is that workers error will increase. It will also delimit proper supervision of workers especially in nuclear and oil and gas sectors as safety could be possibly compromised.

On reconfigured workplace, the result indicates that Covid-19 will have a negative effect on working environment. However, statement from a pilot provided during the survey gave a contrary view that it is impossible to change the way in which pilots work, or seat re-configurations within an aircraft. He further said that because Covid-19 was not anticipated, some high risk-industries will grapple to cope with reconfigured workplace which will have an overall negative effect in workplace.

More so, the result revealed that disinfection protocol will have more effect in the aviation and the oil and gas sectors, and low effect in the nuclear sector. The possible reason why disinfection protocol could be high in aviation is the fact that windows in airplanes are closed during trips. Therefore, there is need to disinfect airplanes effectively. This view is supported by a pilot during the survey that noted disinfection and increased hygiene methods was needed a long time ago.

With the adoption of remote working as another challenge, workers responded that Covid-19 will affect the three sectors. The data revealed that the oil and gas and the nuclear will be affected on remote working. But respondents from the aviation sector believe that remote working will be ineffective. However, a nuclear operator said during the survey that roll out of technology for remote working had been slow and had affected the ability to work constructively away from the workplace especially during shifts offsite. On the contrary, another participant noted that working remotely is not a problem if there would be proper communication. But another participant in the nuclear sector said it is likely that extension of remote work for long period of time could lead to some loss in skills and disconnect from operational environment, which is not the case at present, the participant said.

The use of Personal Protective Equipment (PPE) and the impact it will have on the three sectors in working environment was considered. The result suggests that all the three sectors will be impacted by PPE. However, the effect is expected to vary across the three sectors due to the nature of work been carried out in those sectors. A pilot stated during the survey that: “We get our own air in the flight deck; therefore, PPE is not considered essential for us.” While a respondent from the nuclear sector remarked that PPE has only been impacted by the need to wear a protective mask, where social distancing cannot be achieved. Nonetheless, even before Covid-19, the three sectors already had a PPE that suits their workplace activities.

‘Changes in shift pattern’ was examined to assess whether there will be an effect due to Covid-19 in the work environment. The result implies that Covid-19 will have effect on the three sectors on changes in shift pattern. But the nuclear sector did not believe that changes in shift pattern will have serious effect on how work is carried out. Now, changes in shift pattern is already affecting how the aviation sector is operating, a participant said during a focus group discussion.

On how travel ‘to and from’ work will affect work environment, the result demonstrated that it would have an impact on the three sectors, especially on oil and gas and nuclear sectors. Another plausible reason was because pilots and crew members in the aviation sector are always on both short and long-haul flight. Because flight trips must be completed, provision to travel to and from work should be provided.

A participant from the nuclear sector said lack of travel has been very beneficial in terms of productivity, reduced fatigue, but working more hours. Whereas, a participant from the oil and gas sector said travel to and from port is a great challenge during Covid-19.

Lastly, respondents were requested to state whether Covid-19 has changed and impacted on NTS, isomorphic lesson, organisational learning and risk characterisation in the work environment. The result stated that across the three sectors, the oil and gas sector and the aviation sectors ‘strongly agree’ that NTS would be impacted due to Covid-19. However, the nuclear sector had more response on ‘agree’ that NTS will be impacted because of Covid-19. The result implies that the effect of Covid-19 across the three sectors will vary. Participants pointed out that managing stress and coping with fatigue due to staff redundancy will be unbearable in some sectors. Nevertheless, other elements of NTS such as teamwork will be largely affected.

The next pillar the three sectors responded to was isomorphic lesson. The result implies that isomorphic lesson in the three sectors will change because of post Covid-19 in operational environment. Organisations will be contending with a lot of other challenges such as managing personnel (keeping safe) and financial resources. But on the effect Covid-19 will have on organisational learning in the work environment, the result implies that in the three sectors, organisational learning will change. A participant from the aviation sector remarked that: “A lot have to change to observe guidelines and organisations will change because some sectors will be learning new ways of doing things.” In the oil and gas sector, an expert stated during the survey that much will change once the pandemic is over but was not specific on what would change. Conversely, a respondent from the nuclear sector said Covid-19 has impacted all areas as it has taken away the direct social interface of face-to-face contact, which is so important in achieving organisational learning.

Risk characterisation was the last category on which respondents’ views were sought. The data from the three sectors implies that risk characterisation will change in the work environment, as less attention will be focused on how risk is managed due to workload, pressure and staff redundancy. Also, it is the conclusion of this research that there will be lapses in communication, leadership and decision-making, which consistently will affect how risk is characterised.

The analysis suggests that NTS and its elements; government rules on social distancing, reconfigured workplace, disinfection protocols, remote working, use of PPE, changes in shift pattern and travel to and from work will change due to Covid-19. Also, NTS, isomorphic lesson, organisation learning, and risk characterisation would not be left as it expected that there will be negatively impacted. Therefore, there is need for the three sectors to ensure safety is not compromised in the workplace because of the new rules or guidelines put in place because of Covid-19. Workers should be retrained to understand the dynamics of these new challenges.

4.9 Focus Groups Discussion

4.9.1 Introduction

The Focus groups discussion carried out in this research specifically tested the validity of the outcome of the online results (232 respondents) gathered across the three sectors. The results presented focused on sectors response on NTS, isomorphic lessons, organisational learning and risk characterisation. Groups were selected based on experience and were interviewed in a relatively unstructured way after each presentation (**Bryman 2012: 500**). Participants from each group assessed the result and then gave objective views of how each sector responded to the online questionnaire.

The second presentation was the conceptual framework. It comprised a six-point toolkit designed to aid cross industry (isomorphic) learning and to support practical safety solutions across the three sectors. Discussions were held via virtual meeting (Microsoft Team Meetings). It held twice a day and was conducted for two days (14th and 28th of July 2020). Each focus group comprised three experts drawn from the three sectors, as these possibilities mean that the group was helpful to elicit a wide variety of diverse views in relation to issues discussed. Thereafter, participants were emailed five sets of questions to answer and forward back to the researcher. (See appendix 11 on questions emailed to participants).

4.9.2 Sector's Response

Participants across the three sectors responded to the questions asked after each presentation. They brought to the fore issues that were in relation to the topics which they deemed significant in shaping ideas.

4.9.3 Nuclear Sector

4.9.4 Comments on Online Result Presentation

Some of the participants drawn from the nuclear safety experts revealed that they have never heard the term Non-Technical Skills (NTS) and some of the pillars like isomorphic lessons within their work domain, which means terminology could be different but same in meaning across industries.

A participant noted that:

> *"Since my years in the nuclear industry, I have not heard the terminology NTS. NTS is high in aviation and lower in nuclear, which means terminology used is different. Instead, in nuclear, we talk about excellence human performance. They are both derivative of human factor. Lexicons and language may be different in/ across sectors. And lexicon is invaluable because we are separated by that. "I have worked in the USA and we are separated from common language. How control room operate typically are different from other sectors."*

The view stated above agrees with what this research earlier gathered during interviews held with some nuclear experts. They believe that NTS is not labelled as such in the nuclear sector but could be known as soft skills.

On other pillars such as isomorphic lessons, organisational learning and risk characterisation, participants from the nuclear sector said the sector is a learning organisation and risk is carefully assessed as "ALARP" (As Low as Reasonably Practicable) before tasks are carried out. Whereas, on isomorphic lessons, it is something the industry must work on to avoid near-miss accidents.

On all the seven elements of NTS, participants in the nuclear sector agreed that virtually all the elements are used in the sector in managing workplace safety but managing stress and coping with fatigue is still lacking. A participant stated that:

> *"Situation awareness is common in nuclear. We train workers in simple tools and rule base, decision making in terms of individual capability, use three-way communication plan, teamwork and there is also a huge jump in leadership in the last couple of years on how to get results. Though managing stress and coping with fatigue is less in nuclear. But we use Key Performance Indicator (KPI) to monitor workers performance,"* one of the participants said.

Participants believed if organisations can learn from each other, perhaps accidents will reduce across industries. On risk characterisation, human factor tools such as: Nuclear 'jewelry' (key outcomes), pre and post job review and independent review were constantly used to ensure tasks were assessed properly.

> *"There is simple human form analysis to manage safely. Safety staff were formally trained in emergency management both on-site and off-site events and control centers. We were observed by the regulator who then provides feedback," the nuclear participant added.*

However, another participant said that questions were asked to workers from different career background; therefore, it is expected that different responses will be received.

> *"There is possibility some of the respondents are engineers, safety practitioners and or operators. This are subject to industry scrutiny as supply chain is different.*
>
> *When I worked for Sellafield, training was brilliant, but in supply chain, the case was not the same. When you look at the career pattern, engineers go to Sellafield and get fantastic training, whereas, the case is not the same for others. You may get different feedback from different sectors because the supply chains serve many industries.*
>
> *Regulators learning from each other will be different, especially aviation which operates differently. The absolute tragedy that is far reaching is because if there is accident in aviation, it does not stop people entering planes. But in nuclear, it is not the same. Reeling that learning has to be set into contextualization," a participant said.*

4.9.5 Comments on Conceptual Framework Presentation

Participants in the nuclear sector were unanimous in agreeing that the conceptual framework will help high-risk industries manage safely. It will support cross-industry learning, collaboration and add value to industry performance. Error precursors (fatigue and stress), flaws and poor technical defenses, organisational witnesses which comes from organisational cultures and attitudes are triggering events to accidents. While checklists are developed to investigate full blown root cause analysis to determine error precursors. However, how participants reacted on each of the toolkits is presented on Table 59.

4.9.6 Aviation Sector

4.9.7 Comments on Online Result Presentation

Safety participants from the aviation sector noted that NTS are used in the sector. One participant stated that:

"NTS is identified in aviation. It forms an early indicator in pilot training and used regularly, and I am not surprised about the result. We do not take information in, but we give it out to other industries. But it is a good example for the aviation sector to learn inwardly and, also from other sectors."

On the remaining three pillars used in this research, representatives from the aviation sector said isomorphic lessons are relatively common as they do learn from other organisations on other skill sets. However, they equally agreed that organisational learning is very relevant.

"The whole organisation has changed a lot and organisations are working to learning skills which is more generic skills. Every year standard of operating procedures has become common in aviation. We have made a definite progress on operating procedures," the participants said.

On risk characterisation in the industry, the participants from the sector stated that:

"Risk is characterised both formally and informally. We identify threats through error management which emanated from CRM. Our procedures are to consider what could possibly go wrong and which is somehow difficult to know.

Also, a participant from the sector responded that risk characterisation relates to high number of planes, which is carried out using software by pick and choose method. "There should be a just culture to encourage quality report from flight crew and show a good analytical prowess. In flight operations crews, there is need for good quality risk characterisation," a participant noted.

On all the seven elements of NTS, aviation participants unequivocally stated that the sector is trained in all of them.

"We are formally trained virtually in all of those elements and are covered in training exercise," participants noted. But on managing stress and coping with fatigue, aviation participants explained that, "Managing stress and fatigue are low and those are two areas we have to improve. Besides, there is

no formal method of training staff on managing stress as it seems to be difficult. It is not a defined skill, though we have initiatives such as peer support."

4.9.8 Comments on Conceptual Framework Presentation

The aviation sector commented on the toolkits as an addendum of the conceptual framework which also forms the interface of the research. However, aviation participants on the focus groups discussion noted that the concept of producing toolkits has a lot of validity.

See Table 59 on how the aviation sector responded on the toolkits

4.10 Oil & Gas Sector

4.10.1 Comments on Online Result Presentation

Participants from the oil and gas sectors noted that the online result analysis differs in percentage because experience differs across the three sectors. Participants from the sector noted that because respondents have different background, experience from those sectors will certainly differ especially on NTS and its elements.

Participants said that:

"There is difference in standard and expectations. Some of the outcome of the results are expected, while some are not. Other than that, the result presented is a true picture of what is obtained in the oil and gas industry on NTS and use of other pillars to manage safely."

The participants also noted that safety culture in oil and gas must change.

"Some people are compliant to safety culture, while others are not. I work closely to some staff and safety performance is something we must focus on. Safety practices are not the same due to differences in topography, resulting to differences in standard."

On which is the NTS seven elements, participants were asked which of those elements they have been trained in or used in staff training in the UK. Participants responded that:

“There is a lot of focus on teamwork and communication in oil and gas for the whole team. Decision-making is more of management tool and making people more aware and we do hold a lot of team meetings. Leadership is not only on the position occupied in the team, but it entails encouraging other people.

“Managing stress and coping with fatigue is not something that is used often in the industry. We only train new staff on communication. I don’t think there is enough going on especially on offshore.”

4.10.2 Comments on Conceptual framework Presentation

Participants from the oil and gas sector said that the concept of producing some toolkit is vital to helping high-risk industries learn lessons from each other. For instance, on-site evacuation after an incident notification and escalation procedures are worth learning from. However, they identified that the greatest challenging would be how to achieve those six toolkits as information is difficult to come by, and there is no structure and culture of getting and sharing information in oil and gas mostly from developing countries. Most industries are not keen to giving out information to the public except on major accidents. How participants from the oil and gas responded on the toolkits is shown on Table 59.

4.11 Toolkits as Research Contributions

The six-pronged toolkits have been discussed in this research in the conceptual framework to focus groups discussion. The toolkits consist of six areas, which are: Lexicon (showing variation in terminology from different sectors); Benchmarking data; Accidents/Incidents examples which focused on lapses on the four domains to manage safely; Training logs; List of publications across the three sectors and Archiving of incidents. However, only four of the toolkits was produced as examples. See Appendix 13 for each of the toolkits produced.

Table 59: Participants view on toolkits

Toolkits	Nuclear Sector	Aviation Sector	Oil & Gas Sector	Observations
1. Lexicons	"Lexicon is invaluable. We are separated by common language in these sectors and to be able to put some form of translation mechanism in place will be very helpful. "Lexicon of language has been a barrier to learning between the three sectors as there are unique markers that represent something different. Therefore, language is important as it will track difference in meaning," all the participant said.	"This has led to some challenges and difficulties communicating to colleagues from different countries." Another participant noted that: "Because aviation operates globally, there is need to communicate using a common language that mean the same thing, as it is imperative because of shuttle differences."	Agreed with what other sectors said.	The Lexicon could be used in all training materials in point 4 (Training logs) to facilitate a common sector language. However, lexicon will not be a panacea that will create success in some of the sectors, especially the nuclear sector. Therefore, the onus is on the sectors to ensure that parlance does not become a barrier to safety management. Also, regulators between the three sectors can make it mandatory that NTS should have the same meaning irrespective of sectors.
2. Benchmarking Data	Participant in the nuclear sector noted that: "Benchmarking data is good because it will create the willingness to adapt, understand and learn key data sects. Data should be well documented for reference purposes and will be valuable."	"It is something that will be helpful to compare metrics and the difference in industries management. There is need to benchmark organisations on stress management and coping with fatigue and see what others have done," participants explained.	Participants noted that: "Data gathering is very difficult as most organisations do not easily give out information."	Benchmarking of data stimulates other organisations to see the gap they need to fill to achieve safety purposes and explore some of the human factors in Point 4 (Accident/Incident). For example, benchmarking data could include data and processes tied to the storage of hydrocarbons in OGM and the storage of Jet fuels in aviation and chemicals in aviation and nuclear. In addition to this, the process of handling fuels might be useful in curtailing fire disaster in organisations.

3. Accident/Incidents	"Exploring some of the human factors that triggered either accidents or incidents, or due to design error is worth investigating. When smaller incidents are controlled, the likelihood of bigger accident occurring will be reduced. Accident/incidents investigation will also compare triggering effects that led to those accident and which are designed to draw out lessons," participants said.	"In the aviation, we look at what went right and not what went wrong. So, the three accidents and incidents will give a clue on how they are managed," aviation participants said.	Participants from the oil and gas sector said: "The concept of producing some toolkit is vital to helping high-risk industries learn lessons from each other." Understanding causes of accidents/incidents are vital to managing future occurrences successfully.	Understanding of accidents/incidents is expected to contribute and help organisations fine-tune its trainings logs in Point 4. • The purpose of having three minor incidents and three major accidents would allow for assessing the potential escalatory risks, however these are all "accident" based events, and not malicious, criminal or terrorist scenarios meaning an incomplete comprehension of the wider risk potentials could skew learning to some degree. Example Germanwings co-pilot suicide was a deliberate accident caused by human. For instance, the Tenerife airport disaster of two Boeing 747 aircraft which collided on the runway at Los Rodeos airport on the island of Tenerife.
4. Training Logs	A participant noted that: "In nuclear we have a model cite license. The 36 conditions on regulations are identical and UK nuclear has a goal setting regime. Training is an element within that and shall appoint Duly Authorised Person (DAP) for training and Suitably Qualified and Experienced Person	Training is very valuable especially in the advocation of safety culture and sharing of information to learn from previous incidents," participants said.	"Some sectors will be reluctant to share any information they have because most of them do not have training budgets, and if at all, budgets are low or slashed," participants from the sector stated.	The importance of sharing training logs will help organisations share relevant information and build up a robust safety contents geared towards achieving managing safely and understanding of common language in Point 1.

	(SQEP) to perform. They have their training defined and records kept." "NTS training is not as rigorous in the nuclear sector which should be looked at. If the aviation is good at that, then the nuclear sector should also perform in that too, while a reflection log approaches to get the value of learning can emanate from that." "Learning has to do with a lot of things. Organisations need to put their heads down and learn, but sometimes there are resistance in the industries."		"High-risk industries are sacrificing learning for blame, leading to workers been penalised because there is no just culture. There is no incident reporting in most sectors and that makes it difficult for organisations to learn and no field report except on major accidents.	However, the plausible challenges highlighted could be e.g. • regulatory specific requirements unique to each industry. • Unique terminologies and process systems such as Failure Mode and Effect Analysis (FMEA), Air Safety Case Reporting etc • KPI's for training etc • Willingness to share training logs for competitive reasons and Intellectual property reasons. For recommendations – note that only regulators could share as gatekeepers of this sensitive information between themselves and draw up lessons for industry.
5. List of Publications	"Peer reviewed publication across the three sectors is expected to add value in industry learning. It is also a directory of key publications which allows people to explore other systems and make their own cognitive understanding and learn from it," a participant said.	Is to allow the cross-sectors see some publications of interest on the critical four areas of the research. It will provide opportunity for further learning across sectors, this, participants said.	No comment.	Industry learning will be highly facilitated if sectors have access to directory of key publications which allows people to explore other systems (Point 4) and make their own cognitive understanding and learn from it. • Too many publications might be problematic and overkill. • Documents might be out of date in future or have amendments that need reviewing for the latest guidance (date currency of

				publications list) requiring frequent updates to list Recommendation – There would be benefit in developing a companion list of key legislative and regulatory requirements for each sector (in a condensed summary). This also would need to be considered in Benchmarking activities (see point 2).
6 Archiving of incidents	"Some people are not willing to share information because of competition. Any event in nuclear would have had a tremendous effect on everyone; and the biggest barrier to learning is an emotional one and how it affects individual is a real challenge. Therefore, there is hostile resistance to sharing information, something more emotional, biggest barrier to learning and there is some form of emotional bond to an event," a participant noted.	"Where poor learning does not match across sectors, will be a challenge in another sector. That is, where an organisation is trying to solve a problem but ends up creating another problem will be a great challenge," the participants explained.	Participants from the sector remarked that: "There is no structure and culture of getting and sharing information in oil and gas mostly from developing countries."	Archiving of incidents will serve as a reference point to error correction (point 4) across sectors. It will also serve as 'knowledge reserve' for sectors to draw from when needed. • Challenged with hermeneutics or interpretation during extrapolation processes leading to misaligned understanding.

4.12 Validation of the Online Results and Toolkits

Participants across the three sectors validated the online result and the toolkits designed to help the three sectors improve on safety cases. Almost all the participants admitted that the online result which focused on NTS, isomorphic lessons, organisational learning and risk characterisation are true representation of activities in their various sectors. For instance, participants in the aviation sector noted that the use of NTS and its elements are common practice in the sector, while the use of isomorphic lessons and organisational learning to manage safely are not common features of the sector.

In the nuclear and oil and gas sectors, participants stated that NTS are not known as Non-technical Skills but referred to as soft skills. On isomorphic lessons and organisational learning, both sectors said that it is not a common feature of the organisations. However, participants from both sectors admitted that learning from past accidents will reduce future occurrences.

Though, one of the participants from the nuclear sector who did not accept the result on risk characterisation maintained that:

> *"In all the four operations that exists in nuclear, we quantify risk, even though it varies. It is centered on identification of hazards and operability issues. Deterministic and probabilistic analysis are involved, scrutinized and discussed ranging from projects, individuals and industry meetings. I am surprised the result was 77%, as it supposed to be higher than that."*

Though the participant warned that there are benefits to be derived in the toolkits, but the research should be cautious.

> *"There should be better understanding of the toolkits according to cultural makings. Also, culture is embedded on what the organisation is set to achieve. If an organisation is commercial focused, culture is not usually considered," participants suggested.*

4.13 Justifications of the Results and Toolkits

The toolkits produced from this thesis are contributions to knowledge across the three sectors investigated. It was equally designed and intended to improve learning, share ideas on safety and training exercises across the three regulators. The result and the toolkits went through rigorous scrutiny from participants during the focus group discussion. There is also merit in the toolkits having followed the processes in level 3 in the conceptual framework and has been tested by experts across the three sectors.

Participants admitted that the toolkits might not solve most of the safety challenges facing the three sectors, especially the nuclear sector. However, will give a direction on how organisations could look at those six areas and remodel their safety plans to suit organisations safety needs. For instance, one of the participants from the nuclear sector noted that having a common language may not be the panacea that will create success in these sectors. On the other hand, another participant from the aviation sector said because the toolkits have gone through many layers of analysis, it will have far reaching benefits if practiced by organisations.

CHAPTER 5
5.1 CONCLUSION

5.2 Research Conclusion

This research has a wide-ranging objective. They are categorised as follows: (i) To critically evaluate and benchmark non-technical skills and their values in achieving workplace safety in the UK nuclear power industries. (ii) To investigate the extent to which isomorphic lessons, organisational learning and risk characterisations derived from approaches used in safety-critical industries such as aviation and oil and gas informed and/or added value to the resilience practices undertaken in nuclear industry. (iii) To design and create a holistic framework (with key processes, principles, terms, and toolkits) to support isomorphic lesson opportunities, optimise and benchmark NTS capabilities, risk characterisations, and organisation learning in the nuclear industry within the UK.

Key findings relevant to addressing the research questions and gaps were highlighted in this research. The most crucial question was: To what extent does the nuclear sector use non-technical skills, isomorphic lessons, organisational learning and risk characterisation in training and managing safety across the three sectors in the UK?

The three main research objectives are explained as follows:

5.2.1 To critically evaluate and benchmark Non-Technical Skills and their values in achieving workplace safety.

The analysis revealed that potential gaps exist in the use of the four mentioned areas or pillars to manage workplace safety for the nuclear sector. Of all the industry specific data collected, the results show that the nuclear sector has not fully familiarised itself at promoting all the elements of NTS in the workplace environment. In addition, it is hard to find evidence of any other comparable system used in the nuclear sector that would suffice. It is further believed that the nuclear sector has different understanding for NTS, which could have affected the outcome of the result.

However, the results showed how feed-forward thinking and proactive organisations such as the aviation sector mitigated accidents, errors and near misses using non-technical skills to manage the industry effectively. As a result, it is pertinent to state that the nuclear and the oil gas sectors should learn lessons from the aviation sector in the use of NTS to manage safety; as the aviation sector has demonstrated wide use of NTS and its entire elements to promote strong safety culture.

5.2.2 The investigate the extent to which isomorphic lessons, organisational learning and risk characterisation informed and/or added value to the resilience practices undertaken in nuclear industry.

From what was observed on the result, the three sectors lacked comprehensive understanding of isomorphic learning. This was anticipated by the researcher and hence definitions were provided in the questionnaire to assist participants. Even with this provision of support in place, it was noted that no respondent could offer substantive comprehension of how isomorphism works in practice. Further observation of respondents' lack of understanding was further revealed during the focus group discussion conducted in this research. This could be the result of an inability to grasp academic and theoretical concepts.

Another limitation of this research is how the three sectors responded on organisational learning. Even though the question could have been largely understood by participants, the result revealed that the three sectors are not comprehensively using organisational learning as strong features to promote safety environment. However, the result could have shown the aviation sector had high respondent in organisational learning, that did not in any way indicate that the sector uses organisational learning better than other sectors in safety management.

Therefore, the aviation sector is also still a learning organisation as accidents can occur any time. On the other hand, the nuclear sector can further learn from mistakes made in the oil and gas sector especially on communication, organisational learning and risk characterisation. These were errors identified to have caused some avoidable accidents in the sector such as Piper Alpha and the Macondo Well Blowout.

On risk characterisation, though the three sectors responded that risk is characterised, but more needs to be done, as the result imply that no sector is better than the other in using the pillar for safety management. Therefore, it is imperative for the three sectors to adequately characterise risk and make it a common feature of organisational practice.

Since the nuclear sector identified human factor as a primary cause of accident in one of the questions asked respondents, the onus is on the nuclear sector to look inward and step up strategies to improve human training. The result from NTS elements validates literature findings that emotional stress, mental workload, or physical breakdown (coping with fatigue) contributes to error if not properly managed (**Flin *et al.* 2008**).

Provision of formal training strategies is essential to the development of knowledge, attitudes and skills of workers. This statement further reinforced information participants independently provided during the online survey. They said formal training of workers on safety culture, risk management backed by nuclear management will impact positively on the entire safety practices in the sector. However, the research does not conclude that the nuclear sector has no knowledge of (NTS) safety management. As a matter of fact, respondents in the nuclear sector suggested that the use of NTS should be made compulsory to new entrants in the industry, which is applicable in the aviation sector.

Additionally, organisational learning is not adopted as a formal method for workers to learn from other sectors. Learning needs to occur as part of a routine system before during and after an incident with effective counter-factual thinking and consequential management process. However, it is understandable that how work is performed differs across the three sectors. Nonetheless, the nuclear sector should address the challenges posed by some of these inadequacies on the use of the four pillars for safety management.

5.2.3 To design and create a holistic framework (with key processes, principles, terms, and toolkits) to support isomorphic lesson opportunities.

To solve some of the NTS challenges facing the nuclear sector, producing a framework, principles and toolkits is expected to make significant changes to the nuclear industry on how safety is learned and managed in the UK. Another important highlight of the result is the kind of human analysis framework that will be most suitable to manage safety in the UK nuclear power plant.

Equally, having identified some changes that have occurred in the working environments across the three sectors because of Covid-19, the onus is on the sectors to develop plans to accommodate some of the rules set out by the government to manage safety. Some of the guidelines have direct or indirect influence on the four pillars. Active learning and risk mitigation strategies, mandatory wearing of PPE such as face masks, and marking out of spaces for social distancing in the workplace should not be undermined. Ultimately, risk is about the effect of uncertainty on objectives, therefore continuous learning may be vital for managing uncertainty and maintaining the objectives of “Covid-19 safe” conditions.

In conclusion, the research objectives identified by this research were critically investigated and results provided to resolve future challenges facing the UK nuclear sector.

CHAPTER 6
RECOMMENDATIONS

6. Introduction

The recommendations which stemmed from the outcome of this research is designed to benefit the nuclear industry in the UK. It is expected that when some of the recommendations are applied, it will help facilitate and reduce accidents and near-misses in the nuclear sector.

The recommendations will be categorised using numbers for easy reading and understanding. The first set of recommendations will be based on results from the online survey, as it helped to address the research questions. Other recommendations will be derived from findings from interviews and secondary data collections.

6.1 Recommendations from Online Survey (232 Respondents) and the entire Framework

These recommendations are new insights the data has contributed and the consequences they have for both theory and practice. It is also targeted at ensuring humans are properly trained and managed using NTS, isomorphic lessons, organisational learning and risk characterisation to avert some avoidable accidents in the nuclear sector. Therefore, the recommendation are as follows:

Non-technical Skills

Recommendation 1.1

The UK nuclear sector should train staff formally in the workplace, as opposed to using informal training strategy which leaves staff with no in-depth knowledge.

Recommendation 1.2

NTS should become organisational practice to further enhance worker’s performance. It should be holistically incorporated effectively into training, exercises and safety practices to boost workers knowledge.

How effective individuals working in high-risk environment depends on the quality of instructions and training provided and received.

Isomorphic Lessons

Recommendation 1.1

The nuclear sector should work to absorb isomorphism into formal training and ensure staff encounter isomorphic lessons in workplace environment, instead of relying on informal approach. With this, staff would be able to learn from past errors or incidents and proffer solutions early enough to curtail a repeat of such events.

Recommendation 1.2

The UK nuclear sector may seek to examine the impact of industry and adopt a cross sector sharing forum for synergistic isomorphic learning.

Organisational Learning

Recommendation 1.1

A detailed organisational learning system should be developed for the nuclear industry to include review and learning at individual, group and organisational levels.

Recommendation 1.2

Organisational learning should be incorporated through training, exercise and safety practices in the UK nuclear sector; and should be made to formally encounter organisational learning.

Risk Characterisation

Recommendation 1.1

The UK nuclear sector should ensure workers encounter risk characterisation within working environment; and incorporate risk characterisation effectively into training, exercises and safety practices.

Recommendation 1.2

Tasks should be properly assessed, and risks classified as it will help establish possible hazard associated with tasks before they are executed.

General Recommendations

Recommendation 1.1

Training should draw on aviation based NTS principles for frontline nuclear workers in critical safety settings.

Recommendation 1.2

Examination of critical incidents should be compared to other sector approaches as a platform for informing risk-based safety systems in the nuclear sector.

Recommendation 1.3

The nuclear industry should develop a continuous supervision and development system to engender safety factors spanning isomorphic lessons imbedded in linear and non-liner failure modes within complex systems.

Recommendation 1.4

The nuclear industry should develop counter measures connected to human based agents operating in complex settings.

Recommendation 1.5

A better fatigue management strategy should be put in place and special attention should be paid to stress in the nuclear sector, especially where stress could be a result of changed Covid-19 working practices.

Recommendation 1.6

Contractors and third parties will need to have a basic comprehension of NTS where they manage or operate critical safety infrastructure.

Toolkit

Recommendation 1.1

The nuclear industry should develop a toolkit for all four pillars and apply it in coordination with other high-risk sectors such as aviation.

Recommendation 1.2

Nuclear safety case planning should be integrated into the toolkits as a means of continuous improvement and learning.

On-going research

Recommendation 1.1

Accident investigation data should be used in a pooled data format and reside with the Office for Nuclear Regulation (ONR), Civil Aviation Authority (CAA) and the Oil and Gas Authority (OGA).

Future Technology

Recommendation 1.1

New technologies for countering risks and hazard events can be better shared between each industry sector.

Recommendation 1.2

Artificial Intelligence (AI), replacing human with robots could reduce accidents; and improving cooperation and communication between similar organisations around the globe. This idea will increase the understanding on how new safety measures could impact existing safety measures, as well as learn from other industries.

6.2 Limitations and Recommendation for Further Research

Security implications attached to the UK nuclear power plants, however, affected this research. The researcher could not gain access to any NPP to possibly examine training or accidents documents related to the research area. Furthermore, the recently introduced General Data Protection Regulation (GDPR) almost thwarted data collection in this research, as industry operators literally refused to attend to the online survey nor share the link to colleagues.

Nonetheless, ongoing research should match the recommendations as listed above, spanning the four pillars, and this may engender academic and practice language barriers**.** The research should also focus on all NTS elements to determine which of them are adequately used by operators. Additionally, some of the toolkits developed in this research could be further expanded to serve industry interest in a more holistic way and capable of managing workplace safety.

Further research could be undertaken to specify the exact training exercise and awareness needs for nuclear operators. The need for a spine of workplace training courses would need to be adequately researched and supported by inputs from nuclear regulators, supply chain and other key stakeholders. This is beyond the scope of this project, but the researcher believes this could be the next logical step.

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APPENDICES

Appendix 1: Research questionnaire 1

PhD Primary Data: Research Questions on Nuclear, Aviation and Oil and Gas Sectors
[Bristol Online Survey]

Introduction to the questionnaire
Purpose:

The aim of this research is to undertake a critical evaluation and benchmark the current and potential gains that could be made from Non-Technical Skills, Isomorphic Lesson, Organisational Learning and Risk Characterizations between Nuclear, Aviation, and the Oil and Gas industries.

Explanation of terms:
NTS: The cognitive, social and personal skills that support technical skills in job performance (Flin et al 2003).

Isomorphic lesson: This is the faculty to learn from similar experience of others (Toft and Reynolds 2005).

Organisational learning: Refers broadly to an organisation's acquisition of understanding, know-how, techniques and practices of any kind and by any means (Argyris and Schön 1978).

Risk characterisation: This is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (Stern and Fineberg 1996:1).

The questions below are categorised into three to five boxes. You are expected to tick the appropriate box. It will take roughly about 5 - 10 minutes to answer all the questions.

PART 1: Experience and position

Q1: I currently work in the following industry:

Nuclear industry in the UK

Aviation industry in the UK

Oil and Gas industry in the UK

Others, please specify

Q2: What position do you hold within your company?

Senior manager

Manager

Supervisor

Operator

Technical

Non-technical

Other, please specify

Q3: Total years of service (individually or combined) across the following options listed below.

[TICK BOX]

Nuclear

1-5 years

6-10 years

10 years and above

Aviation

1-5 years

6-10 years

10 years and above

Oil and Gas

1-5 years

6-10 years

10 years and above

PART 2: General questions

Q4: Have you encountered any of the following within your working environment. (See definition and introduction above). [Formally/Informally/ Not at all/ Don't know]

1. Non-technical skills
2. Isomorphic learning
3. Organisational learning
4. Risk characterisation

Q5: Using a scale of 1-10 (1 = lowest, 10 = highest) rate the following on their ability to promote a stronger safety culture, specifically within your organisation? [1-10 SCALE + N/A]

1. Non-technical skills
2. Isomorphic learning
3. Organisational learning
4. Risk characterisation

PART 3: Practice

Q6: My organisation incorporates NON-TECHNICAL SKILLS effectively into training, exercises, and safety practices. [LIKERT]

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

Q7: What types of Non-Technical Skills training have you had in your current organisation? [DROP DOWN MENU]

Situational Awareness: Formal training provided / Informal training provided/ No training provided

Decision Making: Formal training provided / Informal training provided/ No training provided

Communications: Formal training provided / Informal training provided/ No training provided

Teamwork: Formal training provided / Informal training provided/ No training provided

Leadership: Formal training provided / Informal training provided/ No training provided

Managing Stress: Formal training provided / Informal training provided/ No training provided

Coping with Fatigue: Formal training provided / Informal training provided/ No training provided.

Q8: On a scale of 1-10 (1 = lowest, 10 = highest) how effective is your organisation in terms of the following: [DROP DOWN MENU]

1. Anticipating critical incidents (including near miss events)
2. Assessing critical incidents (including near miss events)
3. Preparing for critical incidents (including near miss events)
4. Responding to critical incidents (including near miss events)
5. Recovering from critical incidents (including near miss events)
6. Review and learning from critical incidents (including near miss events)

Q9: Non-technical skills are a strong feature of my organisation's practice.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

[WHY? ADD QUALITATIVE STATEMENT BOX]

Q10: Isomorphic learning is a strong feature of my organisation's practice.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

[WHY? ADD QUALITATIVE STATEMENT BOX]

Q11 Organisational learning is a strong feature of my organisation's practice.
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree
[WHY? ADD QUALITATIVE STATEMENT BOX]

Q12: Risk deliberation and risk analysis are a strong feature of my organisation's practice.
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree
[WHY? ADD QUALITATIVE STATEMENT BOX]

Q13: Lessons learned from other high-risk sectors (e.g. aviation, nuclear, oil and gas) can help inform risk-based decisions in my organisation.
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree

Q14: A combined framework, with benchmarking and a toolkit (between aviation, oil and gas, and nuclear) would be useful for cross industry learning on similar underlying risks [Likert]
Strongly Agree
Agree
Neither agree nor disagree
Disagree
Strongly Disagree

Q15: On a scale of 1-10 (1 = lowest, 10 = highest) rate the following options as essential contributors to incidents [1-10 SCALE]
Human factors
Mechanical factors
Environmental factors (working environment)
Acts of God (Natural factor/mystery)

Q16: Which human analysis framework will be most suitable for the management of safety in your industry in the UK? (For senior managers only)
Nuclear Safety Human Reliability Analysis Method (NSHRAM)
Human Factors Classification System (HFACS)
Maintenance Error Decision Aid (MEDA)
Others

Q17: What additional measures do you think should be put in place to reduce accidents in your industry? [TEXT BOX]

[Limit 200 words text feedback]

Thank you for taking part in this questionnaire.
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Appendix 2: Interview questions across the three sectors

Table 60: Sets of interview questions asked to interviewees from the three sectors

Interview Questions		
Nuclear	**Aviation**	**Oil & Gas**
Q1: Have you come across the term NTS in managing safely in your sector?	Q1: Have you come across the term NTS/CRM in managing safely in your sector?	Q1: Have you come across the term NTS in managing safely in your sector?
Q2: Which aspect of NTS element does the nuclear industry provide effective training, education and awareness (TEA) on?	Q2: Which aspect of NTS element does the aviation industry provide effective training, education and awareness (TEA) on?	Q2: Which aspect of NTS element does the oil and gas industry provide effective training, education and awareness (TEA) on?
Q3: Is there spirit of learning in nuclear and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?	Q3: Is there spirit of learning in aviation and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?	Q3: Is there spirit of learning in oil and gas and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?
Q4: How is risk characterised in the nuclear sector?	Q4: How is risk characterised in the aviation sector?	Q4: How is risk characterised in the oil and gas sector?
Q5: What are the major factors that causes accident in high-risk industries and any reason for that?	Q5: What are the major factors that causes accident in high-risk industries and any reason for that?	Q5: What are the major factors that causes accident in high-risk industries and any reason for that?
Q6: Does the UK legislation influence in any direct or indirect way the requirement for the nuclear industry to develop NTS/CRM capabilities or training in their workforce?	Q6: Does the UK legislation influence in any direct or indirect way the requirement for the aviation industry to develop NTS/CRM capabilities or training in their workforce?	Q6: Does the UK legislation influence in any direct or indirect way the requirement for the oil and gas industry to develop NTS/CRM capabilities or training in their workforce?

Appendix 3: Interview Responses

Table 61: Interview response from the three sectors

Questions to sectors	Response According to Sectors (5 Experts Interviewed per Industry)		
	Nuclear	Aviation	Oil & Gas
Q1: Have you come across the term NTS in managing safely in your sector?	It is different from country to country. It is a compulsory part of training for operational personnel before they are commissioned. The real challenge is training new-comer countries, as there is no tradition of operating a nuclear power plant and teaching them and examining them.	NTS is used in commercial aviation all the time and can be applied to any industry.	If by non-technical you mean the softer skills set, then yes, it is quite common. Currently there is a lot of work going on to educate the workforce in the areas of human factors and major accident hazard recognition. Not familiar with crew resource management but all installations ensure that appropriate skill sets are available on an installation, e.g. fire and emergency team.
Q2: Which aspect of NTS element does the nuclear industry provide effective training, education and awareness (TEA) on?	Stress management, communication and leadership.	I would say all of them.	All of these are covered, and all are important. You should also be aware of the offshore MIST training carried out using CBT.
Q3: Is there spirit of learning in nuclear and how is it regarded, i.e. individual learning, organisational learning or just normal learning strategy? Can lesson learned be applied to other high-risk industries?	On operational side, the industry has an excellent and well-developed set of systems for operational learning both internally, in terms of lesson learned, reviews and shared lesson learned through the WANO. On the project side, I think there has not been any organised disciplined process of learning either internally from companies or between companies and I think this is lacking.	There is spirit and aspiration to learn in the industry.	It's either formal, while OPITO set the standard, through Step Change in Safety or it is bespoke company training. There is 70% on the job training – the problem though is ensuring you have a robust programme that map out how this is achieved and how success is measured. And then 20% is what the individual can do. Staff also join professional bodies such as IOSH and attend conferences and meetings and watch relevant webinars. And finally, 10% is achieved through formal training. Yes, it can be applied across all industries.

		opportunities to identify what went wrong.	
Q5: What are the major factors that causes accident in high-risk industries and any reason for that?	Organisational culture, human factor, equipment factor and environmental factor.	All of the above. Human Factors particularly relevant.	All the factors are main causes of accident; however, natural disaster is very rare.
Q6: Does the UK legislation influence in any direct or indirect way the requirement for the nuclear industry to develop NTS/CRM capabilities or training in their workforce?	IAEA has a common regulation considered as a global standard. Nevertheless, there are countries that have stricter regulatory standard. There is need to consider the local regulatory standard when building new power plants. There is need for a global regulatory which is not in place, instead what is obtainable is country by country, with different approach. IAEA sets a minimum bar, and then different countries with different approaches and standards. No unified approach.	In aviation the CAA make stipulations in regulation for a minimum requirement. However, airline and operators implement higher standards which will be submitted to the CAA for approval before it is implemented.	In a broad sense yes. But never the specifics. Legislation is goal setting.

Appendix 4: Kruskal-Wallis Test

	Q2: What position do you hold within your company?	Length of Service	Non-technical Skills	Isomorphic learning	Organisational learning	Risk characterisation	Non-technical skills	Isomorphic learning	Organisational learning	Risk characterisation	Q6: My organisation incorporates NON-TECHNICAL SKILLS effectively into training, exercises, and safety practices.
Kruskal-Wallis H	4.841	3.166	25.072	4.253	1.239	7.249	8.275	2.930	3.583	1.021	21.359
df	2	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.089	.205	.000	.119	.538	.027	.016	.231	.167	.600	.000

a. Kruskal Wallis Test

b. Grouping Variable: Q1: I currently work in the following industry:

```
CROSSTABS
  /TABLES=Q1 BY Q16
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT ROW
  /COUNT ROUND CELL
  /METHOD=EXACT TIMER(5).
```

Test Statistics[a,b]

Situation Awareness (knowing your environment)	Decision Making	Communications	Teamwork	Leadership	Managing Stress	Coping with Fatigue	Anticipating critical incidents (including near miss events)	Assessing critical incidents (including near miss events)	Preparing for critical incidents (including near miss events)	Responding to critical incidents (including near miss events)	Recovering from critical incidents (including near miss events)	Review and learning from critical incidents (including near miss events)
36.666	25.694	20.234	23.810	13.764	4.242	32.188	1.421	.652	1.787	3.708	2.055	2.266
2	2	2	2	2	2	2	2	2	2	2	2	2
.000	.000	.000	.000	.001	.120	.000	.492	.722	.409	.157	.358	.322

Q9: Non-technical skills are a strong feature of my organisation's practice.	Q10: Isomorphic learning is a strong feature of my organisation's practice.	Q11 Organisational learning is a strong feature of my organisation's practice.	Q12: Risk deliberation and risk analysis are a strong feature of my organisation's practice.	Q13: Lessons learned from other high-risk sectors (e.g. aviation, nuclear, oil and gas) can help inform risk-based decisions in my organisation.	Q14: A combined framework, with benchmarking and a toolkit (between aviation, oil and gas, and nuclear) would be useful for cross industry learning on similar underlying risks.	Human factors	Mechanical factors	Environmental factors (working environment)	Acts of God (Natural factor/mystery)
8.132	5.280	3.714	1.432	6.624	.853	6.469	.560	12.613	4.304
2	2	2	2	2	2	2	2	2	2
.017	.071	.156	.489	.036	.653	.039	.756	.002	.116

Appendix 5: Overall result analysis using SPP

```
NPAR TESTS
  /K-W=Q2 Q3New Q4_1_a Q4_2_a Q4_3_a Q4_4_a Q5_1_a Q5_2_a Q5_3_a Q5_4_a Q6 Q7_1_a Q7_2_a Q7_3_a
    Q7_4_a Q7_5_a Q7_6_a Q7_7_a Q8_1_a Q8_2_a Q8_3_a Q8_4_a Q8_5_a Q8_6_a Q9 Q10 Q11 Q12 Q13 Q14
    Q15_1_a Q15_2_a Q15_3_a Q15_4_a BY Q1(1 3)
  /STATISTICS DESCRIPTIVES
  /MISSING ANALYSIS.
```

NPar Tests

Kruskal-Wallis Test

Ranks

	Q1: I currently work in the following industry:	N	Mean Rank
Q2: What position do you hold within your company?	Nuclear industry in the UK	124	108.32
	Aviation industry in the UK	59	120.99
	Oil and Gas industry in the UK	49	131.79
	Total	232	
Length of Service	Nuclear industry in the UK	124	119.66
	Aviation industry in the UK	59	120.19
	Oil and Gas industry in the UK	49	104.05
	Total	232	
Non-technical Skills	Nuclear industry in the UK	121	114.26
	Aviation industry in the UK	58	91.72
	Oil and Gas industry in the UK	47	138.43
	Total	226	
Isomorphic learning	Nuclear industry in the UK	116	106.65
	Aviation industry in the UK	55	98.43
	Oil and Gas industry in the UK	43	121.41
	Total	214	
Organisational learning	Nuclear industry in the UK	122	115.16
	Aviation industry in the UK	57	106.80
	Oil and Gas industry in the UK	45	112.50
	Total	224	

Risk characterisation	Nuclear industry in the UK	119	116.09
	Aviation industry in the UK	57	98.46
	Oil and Gas industry in the UK	47	118.07
	Total	223	
Non-technical skills	Nuclear industry in the UK	118	106.72
	Aviation industry in the UK	58	130.29
	Oil and Gas industry in the UK	45	97.37
	Total	221	
Isomorphic learning	Nuclear industry in the UK	112	107.68
	Aviation industry in the UK	53	108.83
	Oil and Gas industry in the UK	43	90.87
	Total	208	
Organisational learning	Nuclear industry in the UK	120	118.41
	Aviation industry in the UK	59	109.53
	Oil and Gas industry in the UK	44	97.84
	Total	223	
Risk characterisation	Nuclear industry in the UK	118	112.03
	Aviation industry in the UK	57	112.24
	Oil and Gas industry in the UK	44	101.66
	Total	219	

Q6: My organisation incorporates NON-TECHNICAL SKILLS effectively into training, exercises, and safety practices.	Nuclear industry in the UK	124	126.02
	Aviation industry in the UK	59	84.27
	Oil and Gas industry in the UK	49	131.21
	Total	232	
Situation Awareness (knowing your environment)	Nuclear industry in the UK	124	131.41
	Aviation industry in the UK	59	76.44
	Oil and Gas industry in the UK	46	120.22
	Total	229	
Decision Making	Nuclear industry in the UK	124	126.97
	Aviation industry in the UK	59	81.25
	Oil and Gas industry in the UK	47	128.23
	Total	230	
Communications	Nuclear industry in the UK	124	124.22
	Aviation industry in the UK	59	87.12
	Oil and Gas industry in the UK	47	128.13
	Total	230	
Teamwork	Nuclear industry in the UK	124	126.23
	Aviation industry in the UK	59	84.41
	Oil and Gas industry in the UK	48	128.42
	Total	231	
Leadership	Nuclear industry in the UK	124	121.28
	Aviation industry in the UK	58	91.84
	Oil and Gas industry in the UK	47	127.02
	Total	229	
Managing Stress	Nuclear industry in the UK	124	118.72
	Aviation industry in the UK	59	101.64
	Oil and Gas industry in the UK	47	124.39
	Total	230	

Coping with Fatigue	Nuclear industry in the UK	123	133.11
	Aviation industry in the UK	59	77.18
	Oil and Gas industry in the UK	47	115.09
	Total	229	
Anticipating critical incidents (including near miss events)	Nuclear industry in the UK	121	115.64
	Aviation industry in the UK	59	119.76
	Oil and Gas industry in the UK	48	105.16
	Total	228	
Assessing critical incidents (including near miss events)	Nuclear industry in the UK	121	115.89
	Aviation industry in the UK	58	115.56
	Oil and Gas industry in the UK	48	107.34
	Total	227	
Preparing for critical incidents (including near miss events)	Nuclear industry in the UK	121	117.64
	Aviation industry in the UK	58	115.46
	Oil and Gas industry in the UK	48	103.07
	Total	227	
Responding to critical incidents (including near miss events)	Nuclear industry in the UK	121	121.58
	Aviation industry in the UK	59	102.20
	Oil and Gas industry in the UK	48	111.77
	Total	228	
Recovering from critical incidents (including near miss events)	Nuclear industry in the UK	120	119.80
	Aviation industry in the UK	59	107.68
	Oil and Gas industry in the UK	48	107.28
	Total	227	
Review and learning from critical incidents (including near miss events)	Nuclear industry in the UK	121	119.00
	Aviation industry in the UK	59	115.11
	Oil and Gas industry in the UK	48	102.40
	Total	228	

Q9: Non-technical skills are a strong feature of my organisation's practice.	Nuclear industry in the UK	124	121.16
	Aviation industry in the UK	59	96.75
	Oil and Gas industry in the UK	49	128.49
	Total	232	
Q10: Isomorphic learning is a strong feature of my organisation's practice.	Nuclear industry in the UK	124	124.85
	Aviation industry in the UK	59	102.67
	Oil and Gas industry in the UK	49	112.03
	Total	232	
Q11 Organisational learning is a strong feature of my organisation's practice.	Nuclear industry in the UK	124	122.67
	Aviation industry in the UK	59	103.48
	Oil and Gas industry in the UK	49	116.56
	Total	232	
Q12: Risk deliberation and risk analysis are a strong feature of my organisation's practice.	Nuclear industry in the UK	124	119.31
	Aviation industry in the UK	59	108.13
	Oil and Gas industry in the UK	49	119.48
	Total	232	
Q13: Lessons learned from other high-risk sectors (e.g. aviation, nuclear, oil and gas) can help inform risk-based decisions in my organisation.	Nuclear industry in the UK	124	116.92
	Aviation industry in the UK	59	102.72
	Oil and Gas industry in the UK	49	132.02
	Total	232	
Q14: A combined framework, with benchmarking and a toolkit (between aviation, oil and gas, and nuclear) would be useful for cross industry learning on similar underlying risks.	Nuclear industry in the UK	124	114.63
	Aviation industry in the UK	59	122.86
	Oil and Gas industry in the UK	49	113.56
	Total	232	

Human factors	Nuclear industry in the UK	123	122.41
	Aviation industry in the UK	59	118.55
	Oil and Gas industry in the UK	49	96.85
	Total	231	
Mechanical factors	Nuclear industry in the UK	123	113.20
	Aviation industry in the UK	59	117.52
	Oil and Gas industry in the UK	49	121.21
	Total	231	
Environmental factors (working environment)	Nuclear industry in the UK	122	118.49
	Aviation industry in the UK	59	132.04
	Oil and Gas industry in the UK	49	88.13
	Total	230	
Acts of God (Natural factor/mystery)	Nuclear industry in the UK	121	116.21
	Aviation industry in the UK	59	125.42
	Oil and Gas industry in the UK	49	99.45
	Total	229	

Appendix 6: Pearson’s Correlation (HFACS)

Table 62: Pearson’s Correlation results for HFACS analysis

Correlations

	SBE	DE	PE	RV	EV	PhE	TE	AMS	APS	PML	CRM	PR	IS	PIO	FCP	SV	RM	OC	OP
SBE																			
DE	.496**																		
PE	-0.206	0.048																	
RV	0.033	0.048	-0.175																
EV	0.033	0.048	0.161	-0.175															
PhE	0.256	.318*	0.166	-0.108	.577**														
TE	0.042	0.121	-0.120	0.142	-0.120	0.061													
AMS	b	b	b	b	b	b	b												
APS	-0.157	0.106	.352*	-0.062	-0.062	-0.086	0.096	b											
PML	0.047	0.102	0.243	0.049	.437**	.589**	0.074	b	-0.051										
CRM	0.131	0.236	.404**	-0.204	.556**	.459**	0.081	b	.303*	.534**									
PR	-0.024	0.140	.556**	-0.160	.556**	.507**	0.110	b	.385**	.695**	.786**								
IS	.369*	0.033	0.030	0.189	0.189	0.135	0.076	b	0.067	0.156	0.220	0.173							
PIO	-0.009	0.134	0.021	0.143	.386**	.313*	-0.222	b	0.179	.419**	.370*	.334*	0.142						
FCP	0.186	0.167	-0.225	.376**	-0.105	-0.063	.350*	b	-0.164	0.032	0.002	-0.041	0.048	-0.132					
SV	0.042	-0.173	0.011	0.272	0.011	-0.045	-0.221	b	0.096	0.225	0.199	0.110	.448**	.347*	-0.024				
RM	-0.060	-0.136	-0.153	0.087	-0.273	-0.256	.331*	b	-0.138	-0.047	-0.023	-0.103	-0.142	-0.251	.586**	-0.042			
OC	-0.137	0.154	0.075	0.075	0.221	.292*	0.225	b	-0.077	.326*	0.275	0.268	-0.180	-0.110	0.154	-0.230	0.242		
OP	0.111	-0.046	-0.033	0.087	.326*	0.233	0.238	b	-0.138	.368*	.302*	0.280	0.084	0.009	.328*	-0.135	.316*	.346*	

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

*. Correlation is significant at the 0.05 level (2-tailed).

b. Cannot be computed because at least one of the variables is constant.

Table 63: Chi-square test results for HFACS analysis for nuclear industry

	Pearson chi-square Value	Asymptotic Significance
DE * PhE	4.744	0.029
PE * PML	5.839	0.016
PE * CRM	7.669	0.006
PE * PR	14.545	0.000
EV * PhE	15.668	0.000
EV * PML	8.981	0.003
EV * CRM	14.520	0.000
EV * PR	14.545	0.000
PhE * PIO	4.607	0.032
TE * FCP	5.771	0.016
PML * PIO	8.246	0.004
CRM * PIO	6.449	0.011
PR * PIO	5.258	0.022
FCP * RM	16.127	0.000
FCP * OP	5.071	0.024

HFACS Analysis

First, accident data were inputed into Microsoft Excel, and thereafter imported into the SPSS software, which was then coded with 1 and 0 as being present and absent (accident) respectively for different years. After the coding, it was then analysed. All human factor components (levels) of the HFACS framework were loaded into separate columns, according to their hierarchy in the framework. Unsafe acts formed the first set of human factors, preconditions for unsafe acts formed the second batch, the third stream of human factors was formed by unsafe supervision, while the last category was formed by organisational influences. See Appendix 6 for Pearson correlation.

The data were analysed for different active and latent causal factors that prompted the accidents using information from their incident descriptions. In order to codify the results using the HFACS taxonomy, the HFACS event description worksheet was used to understand the various events in each accident that could aid in determining each human factor that played a role in its causation (**Omole and Walker 2015**) (See Figure 28 for HFACS Analysis).

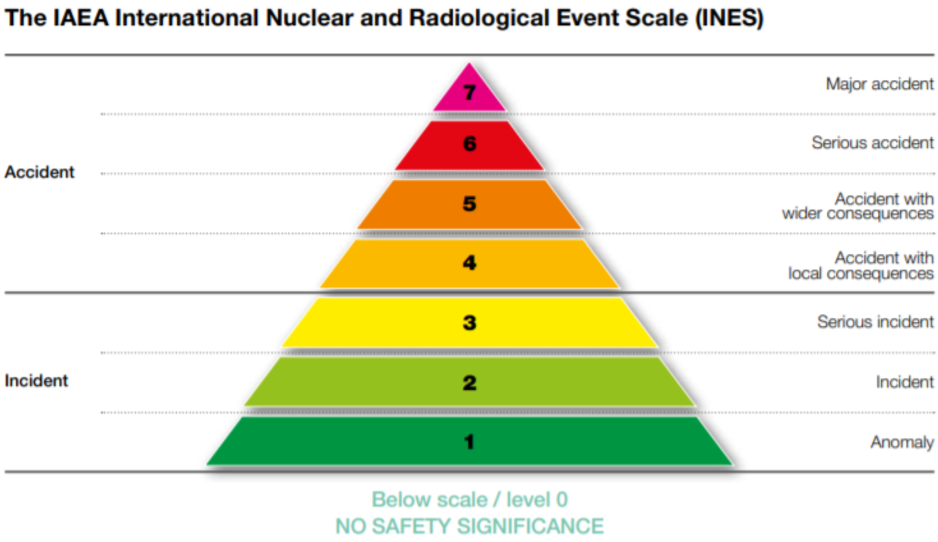
A deductive approach was engaged by this research for the secondary data analysis, Creswell (2013) submits that it establishes the connections and differences between a given set of data to respond to any stated research questions and fill knowledge gaps.

On analysing the accidents in the nuclear sector which occurred between 1998 – 2018. Pearson's correlation was used to determine the relationship that existed in two causal factors in the accident (**Clarke 2006)**, The statistical technique aided to establish the extent of connection between two pairs of variables, which otherwise are human factors (**Sneddon, Mearns, and Flin 2013**). Pearson's correlation provided the covariance of examining two variables as a ratio to the product of their standard deviations, therefore was used to establish the relationship between two human factors in accident causation (**Clark 2006**). See appendix 6 for Pearson correlation.

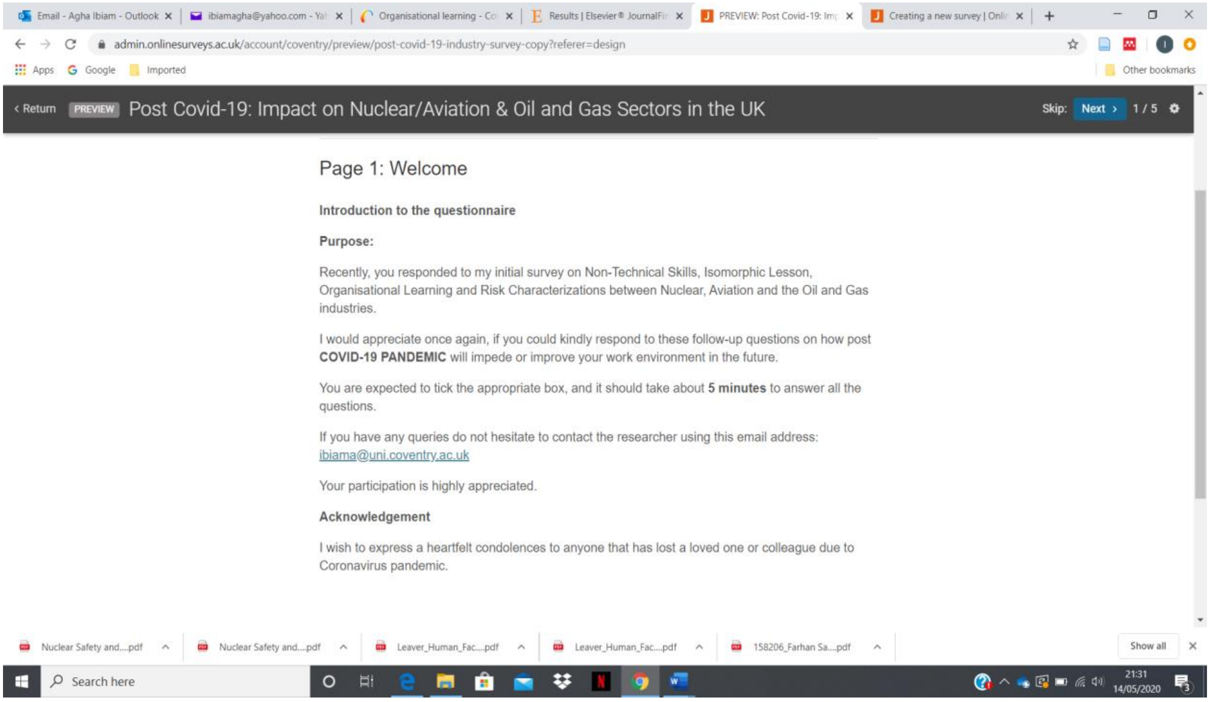
Subsequently, a bivariate correlation test was carried out with the years selected that served as independent variables and the human factors selected as the dependent variables. And then two levels of significance were chosen for the hypothesis test on human factors, which was selected at $p < 0.05$. It implied that any Pearson's r-value gained after the analysis is significant as it is < 0.05 and 0.01. Completely, all significant human factor relationships were symbolised with one and two stars, where one star is significance at < 0.05- and two-stars meaning significance at 0.01. Positive values indicated a progressive or linear relationship between two human factors, while the negative values indicated the strength of inverse relationships also between two human factors. See appendix 6 for Pearson's Correlation.

Pearson's chi-square test was used to indicate the effect each level of HFACS had on the lower level (**Siu, Phillips, and Leung 2004**). It was adopted by this research to gauge the level of independence of various human factor levels on each other in the HFACS framework (**Agresti and Kateri 2013**). A chi-square 'p'<0.005 justifies that there is significant relationship between two human factor levels (**Restrepo, Simonoff, and Zimmerman 2009**). The accident data was analysed using descriptive statistics in SPSS and crosstabs analysis selected. Chi-square tests and correlation options were selected as the statistical tools displayed in the results and only the significant relationships with 'p' < 0.05 were selected for analysis. See appendix 6 for Chi-square Test. See result on Trend analysis on Figure 30.

Appendix 7: IAEA INES SCALE



Appendix 8: Post covid-19: Impact on Nuclear/Aviation and Oil and Gas (Questionnaire 2)



Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

Page 1: Welcome

Introduction to the questionnaire

Purpose:

Recently, you responded to my initial survey on Non-Technical Skills, Isomorphic Lesson, Organisational Learning and Risk Characterizations between Nuclear, Aviation and the Oil and Gas industries.

I would appreciate once again, if you could kindly respond to these follow-up questions on how post **COVID-19 PANDEMIC** will impede or improve your work environment in the future.

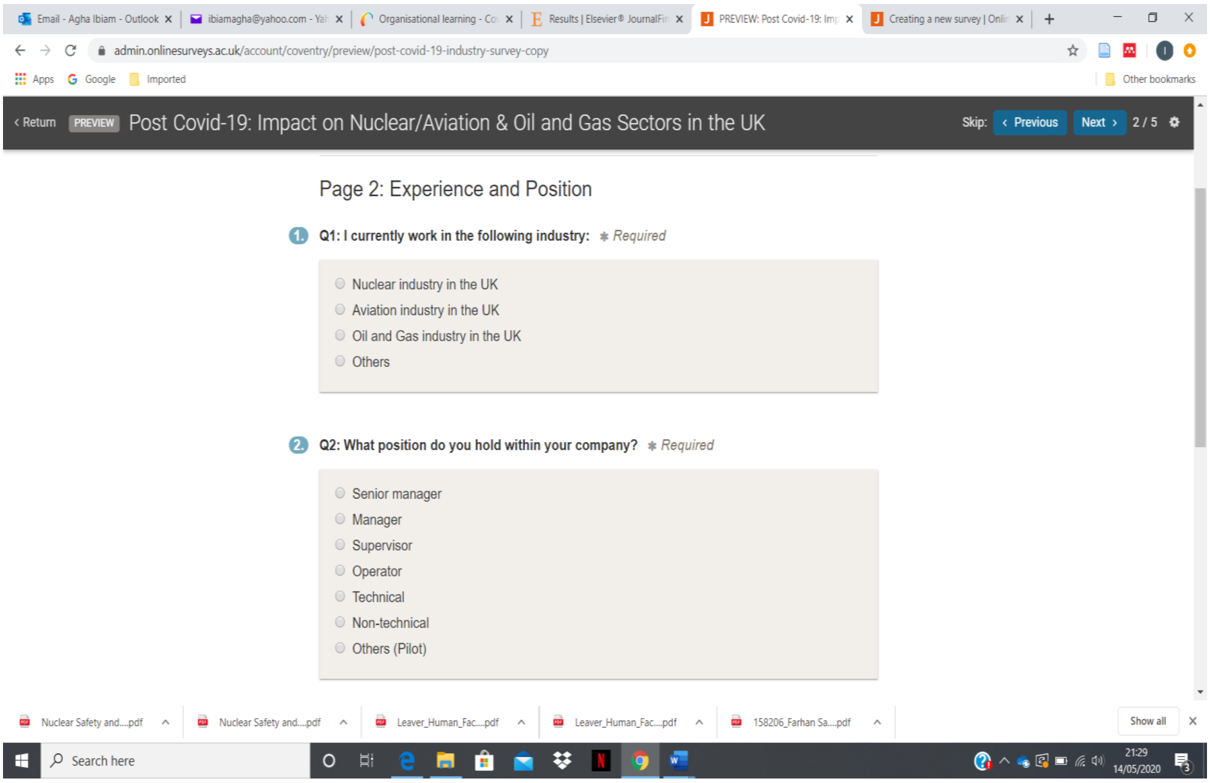
You are expected to tick the appropriate box, and it should take about **5 minutes** to answer all the questions.

If you have any queries do not hesitate to contact the researcher using this email address: ibiama@uni.coventry.ac.uk

Your participation is highly appreciated.

Acknowledgement

I wish to express a heartfelt condolences to anyone that has lost a loved one or colleague due to Coronavirus pandemic.



Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

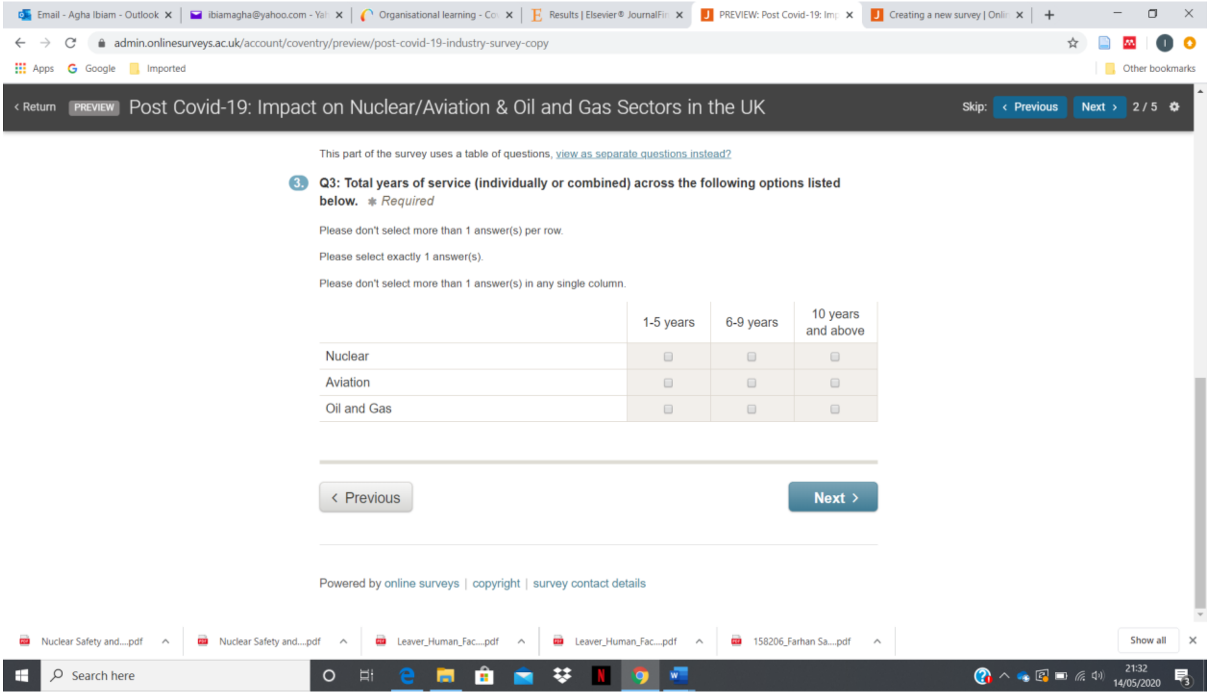
Page 2: Experience and Position

1. **Q1: I currently work in the following industry:** * *Required*

- Nuclear industry in the UK
- Aviation industry in the UK
- Oil and Gas industry in the UK
- Others

2. **Q2: What position do you hold within your company?** * *Required*

- Senior manager
- Manager
- Supervisor
- Operator
- Technical
- Non-technical
- Others (Pilot)


‹ Return PREVIEW Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

Skip: ‹ Previous Next › 2 / 5

This part of the survey uses a table of questions, view as separate questions instead?

3. **Q3: Total years of service (individually or combined) across the following options listed below.** ✱ *Required*

Please don't select more than 1 answer(s) per row.

Please select exactly 1 answer(s).

Please don't select more than 1 answer(s) in any single column.

	1-5 years	6-9 years	10 years and above
Nuclear			
Aviation			
Oil and Gas			

‹ Previous Next ›

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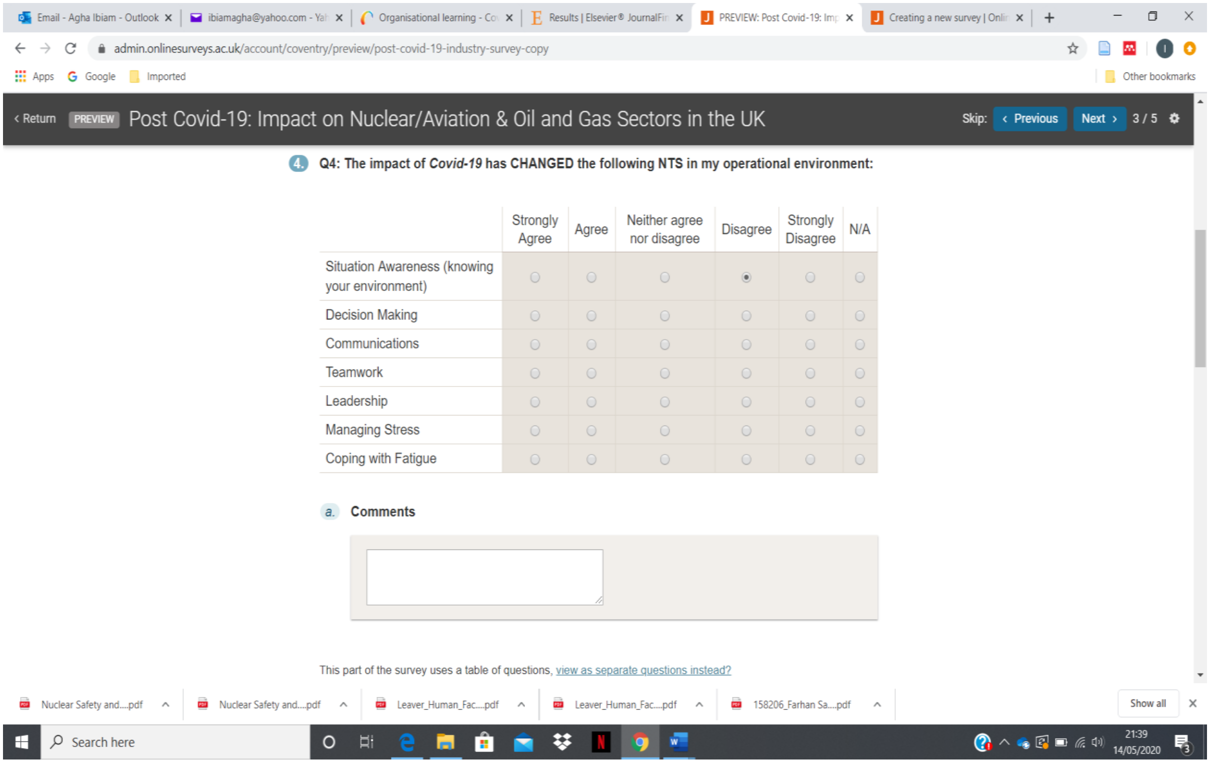

‹ Return PREVIEW Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

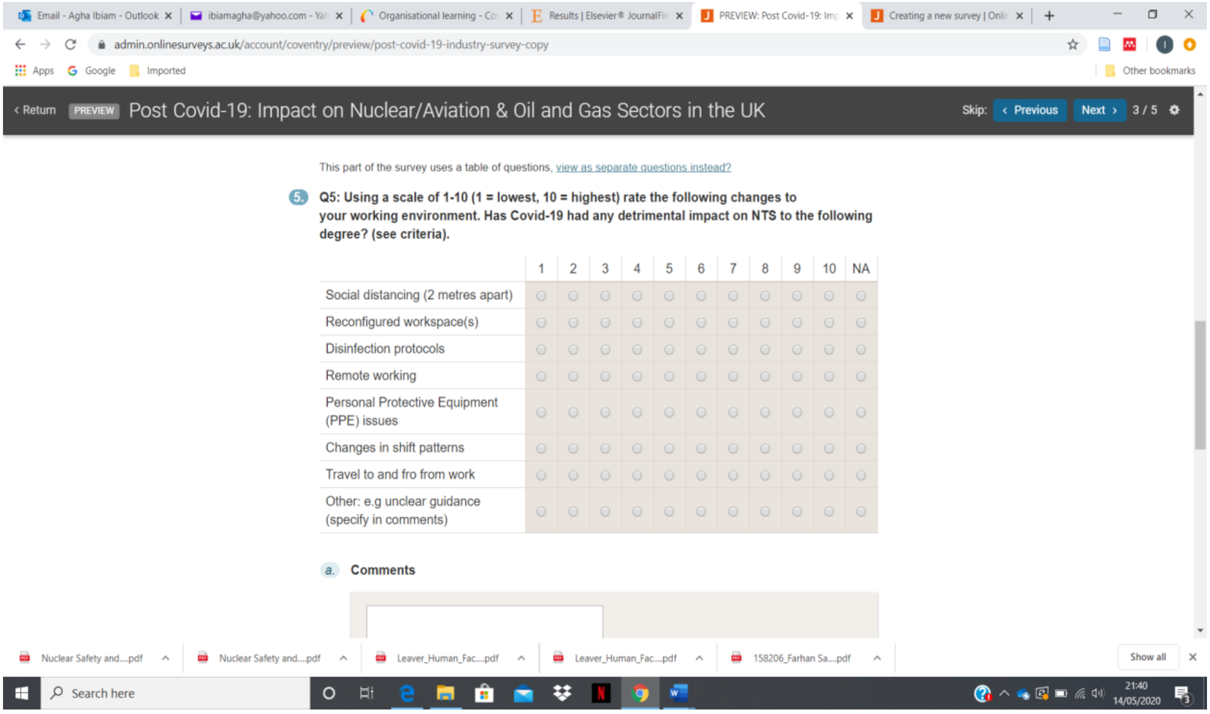
Skip: ‹ Previous Next › 3 / 5

4. **Q4: The impact of *Covid-19* has CHANGED the following NTS in my operational environment:**

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	N/A
Situation Awareness (knowing your environment)				◉		
Decision Making						
Communications						
Teamwork						
Leadership						
Managing Stress						
Coping with Fatigue						

a. **Comments**

This part of the survey uses a table of questions, view as separate questions instead?



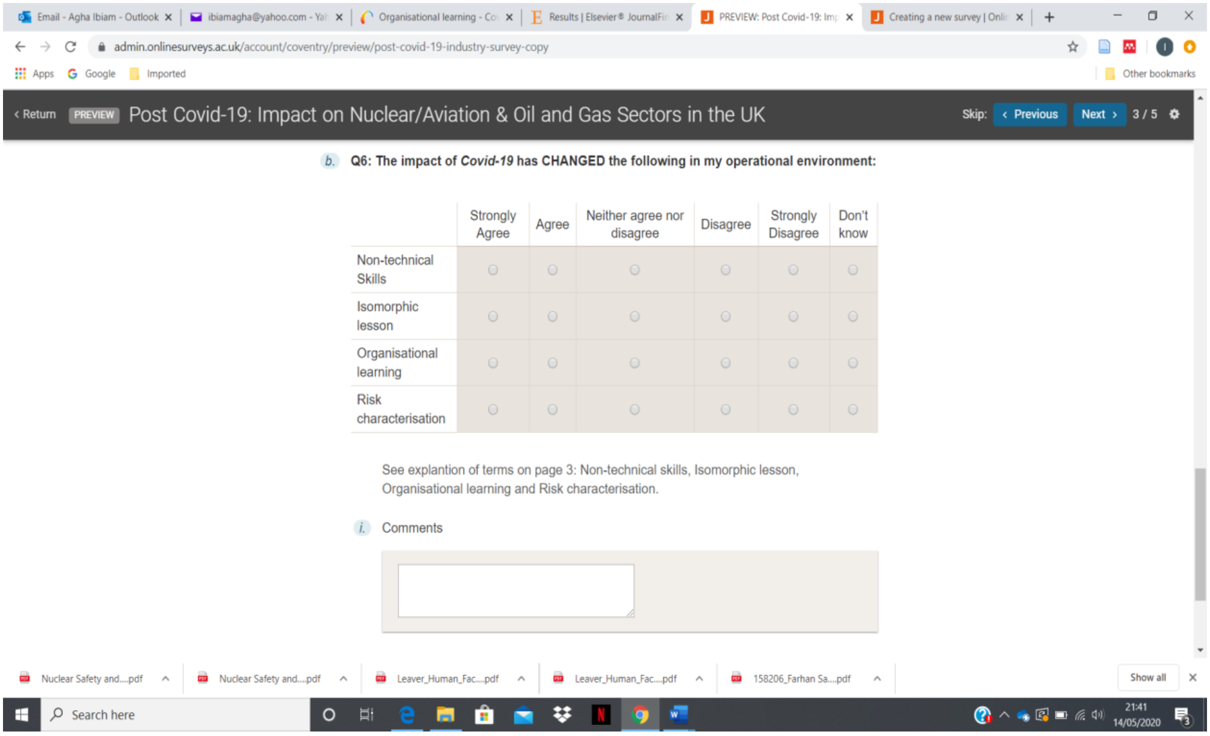
Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

This part of the survey uses a table of questions, view as separate questions instead?

5. Q5: Using a scale of 1-10 (1 = lowest, 10 = highest) rate the following changes to your working environment. Has Covid-19 had any detrimental impact on NTS to the following degree? (see criteria).

	1	2	3	4	5	6	7	8	9	10	NA
Social distancing (2 metres apart)	○	○	○	○	○	○	○	○	○	○	○
Reconfigured workspace(s)	○	○	○	○	○	○	○	○	○	○	○
Disinfection protocols	○	○	○	○	○	○	○	○	○	○	○
Remote working	○	○	○	○	○	○	○	○	○	○	○
Personal Protective Equipment (PPE) issues	○	○	○	○	○	○	○	○	○	○	○
Changes in shift patterns	○	○	○	○	○	○	○	○	○	○	○
Travel to and fro from work	○	○	○	○	○	○	○	○	○	○	○
Other: e.g unclear guidance (specify in comments)	○	○	○	○	○	○	○	○	○	○	○

a. Comments



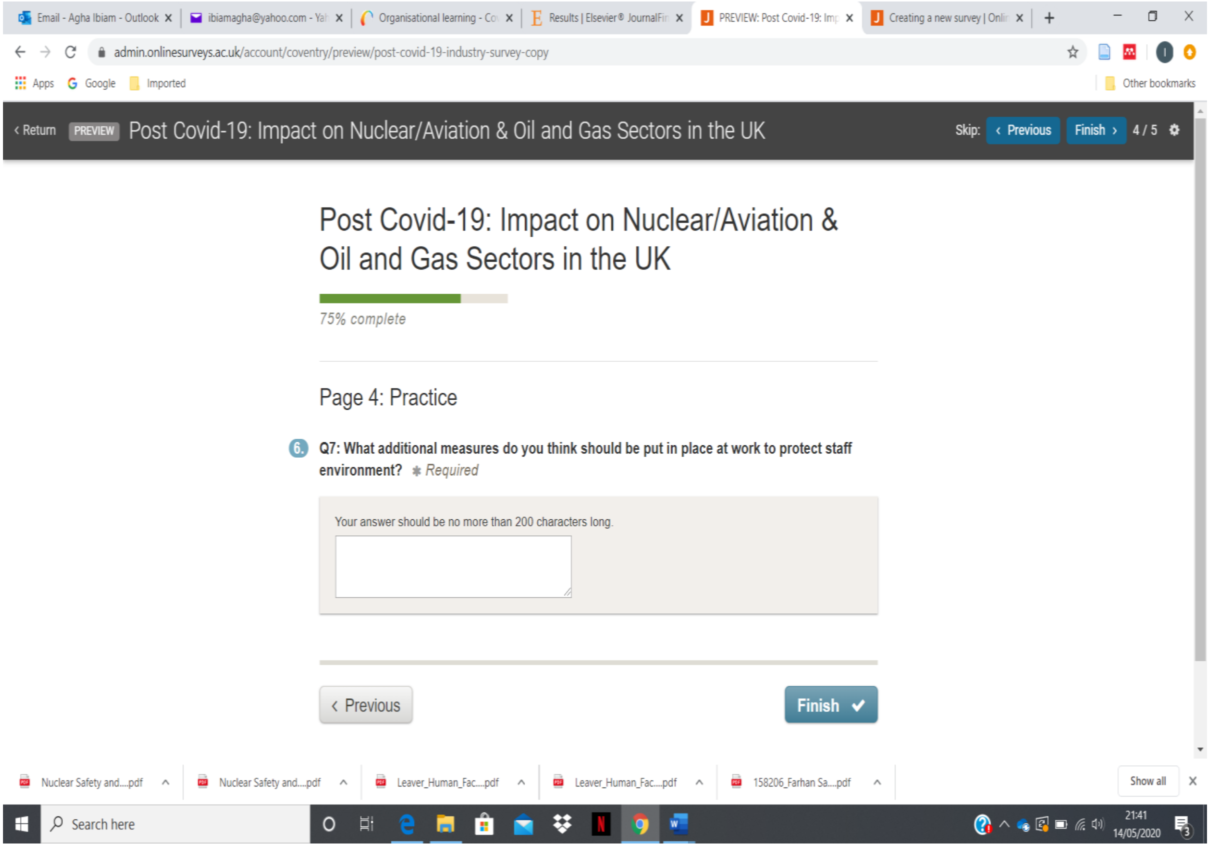
Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK

b. Q6: The impact of *Covid-19* has CHANGED the following in my operational environment:

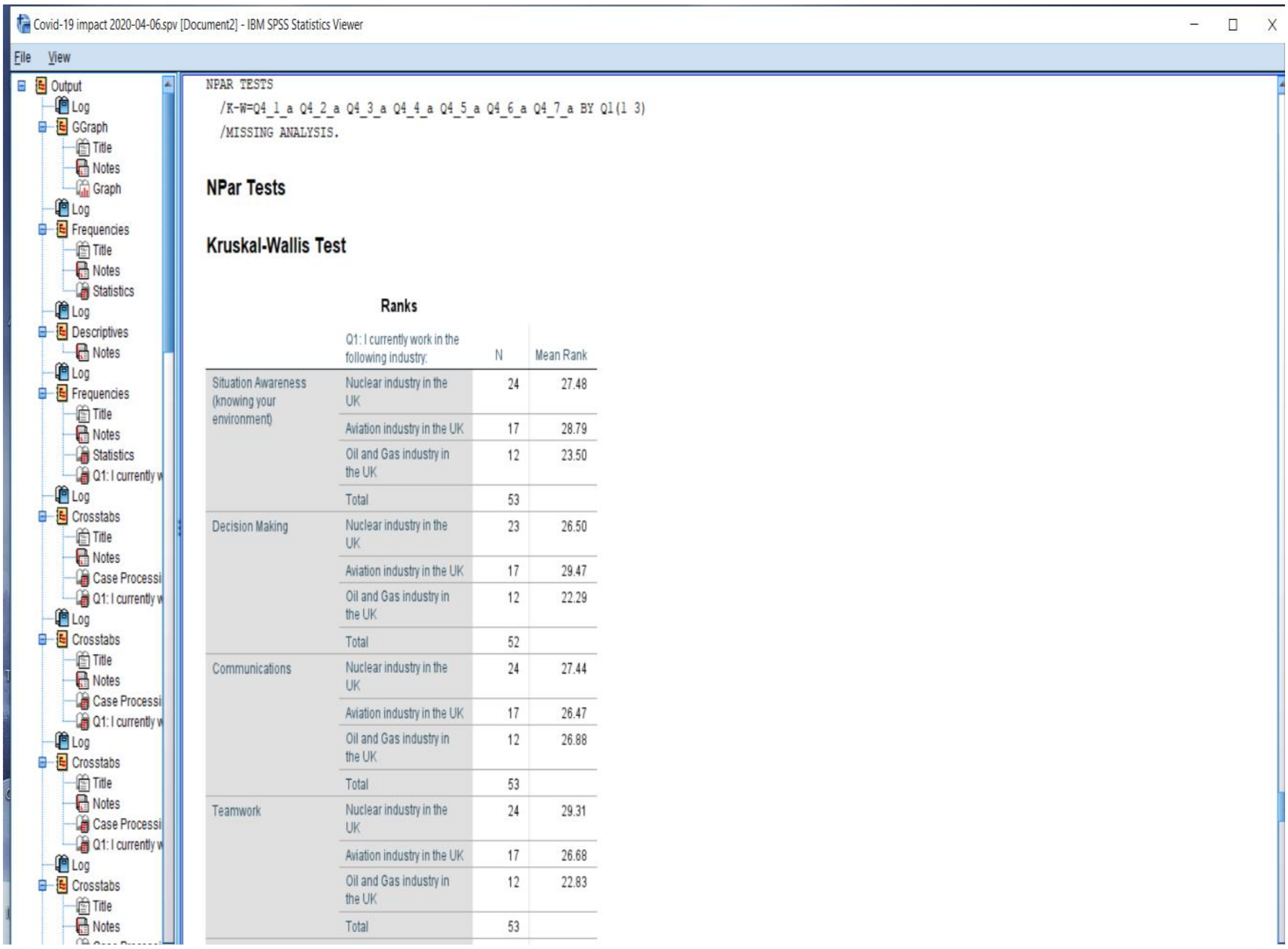
	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	Don't know
Non-technical Skills	○	○	○	○	○	○
Isomorphic lesson	○	○	○	○	○	○
Organisational learning	○	○	○	○	○	○
Risk characterisation	○	○	○	○	○	○

See explantion of terms on page 3: Non-technical skills, Isomorphic lesson, Organisational learning and Risk characterisation.

i. Comments


Post Covid-19: Impact on Nuclear/Aviation & Oil and Gas Sectors in the UK
75% complete
Page 4: Practice
Q7: What additional measures do you think should be put in place at work to protect staff environment? * Required
Your answer should be no more than 200 characters long.
Previous
Finish

Appendix 9: Result on Kruskal-Wallis on impact of Covid-19 result



Covid-19 impact 2020-04-06.spv [Document2] - IBM SPSS Statistics Viewer

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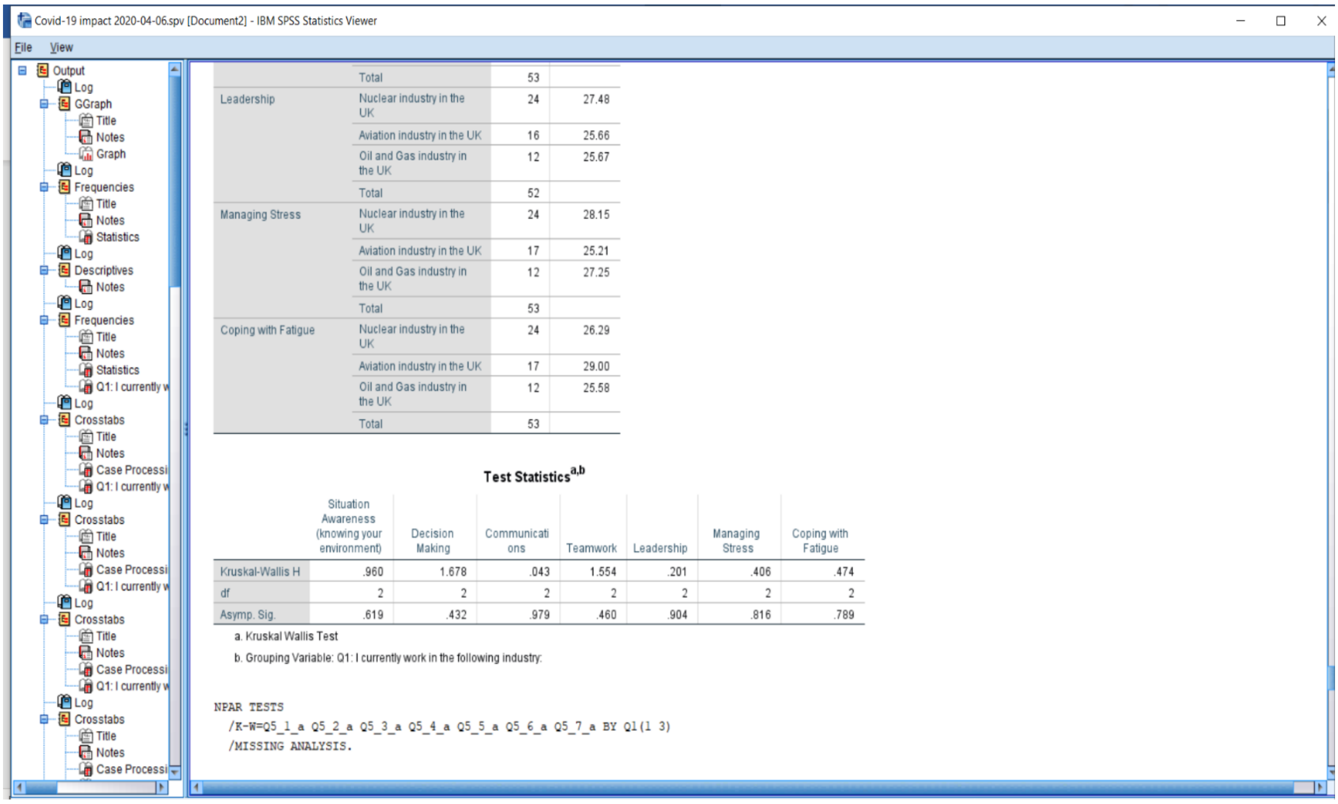
NPar Tests

Kruskal-Wallis Test

Ranks

	Q1: I currently work in the following industry:	N	Mean Rank
Situation Awareness (knowing your environment)	Nuclear industry in the UK	24	27.48
	Aviation industry in the UK	17	28.79
	Oil and Gas industry in the UK	12	23.50
	Total	53	
Decision Making	Nuclear industry in the UK	23	26.50
	Aviation industry in the UK	17	29.47
	Oil and Gas industry in the UK	12	22.29
	Total	52	
Communications	Nuclear industry in the UK	24	27.44
	Aviation industry in the UK	17	26.47
	Oil and Gas industry in the UK	12	26.88
	Total	53	
Teamwork	Nuclear industry in the UK	24	29.31
	Aviation industry in the UK	17	26.68
	Oil and Gas industry in the UK	12	22.83
	Total	53	



	Total	53	
Leadership	Nuclear industry in the UK	24	27.48
	Aviation industry in the UK	16	25.66
	Oil and Gas industry in the UK	12	25.67
	Total	52	
Managing Stress	Nuclear industry in the UK	24	28.15
	Aviation industry in the UK	17	25.21
	Oil and Gas industry in the UK	12	27.25
	Total	53	
Coping with Fatigue	Nuclear industry in the UK	24	26.29
	Aviation industry in the UK	17	29.00
	Oil and Gas industry in the UK	12	25.58
	Total	53	

Test Statistics[a,b]

	Situation Awareness (knowing your environment)	Decision Making	Communications	Teamwork	Leadership	Managing Stress	Coping with Fatigue
Kruskal-Wallis H	.960	1.678	.043	1.554	.201	.406	.474
df	2	2	2	2	2	2	2
Asymp. Sig.	.619	.432	.979	.460	.904	.816	.789

a. Kruskal Wallis Test

b. Grouping Variable: Q1: I currently work in the following industry:

```
NPAR TESTS
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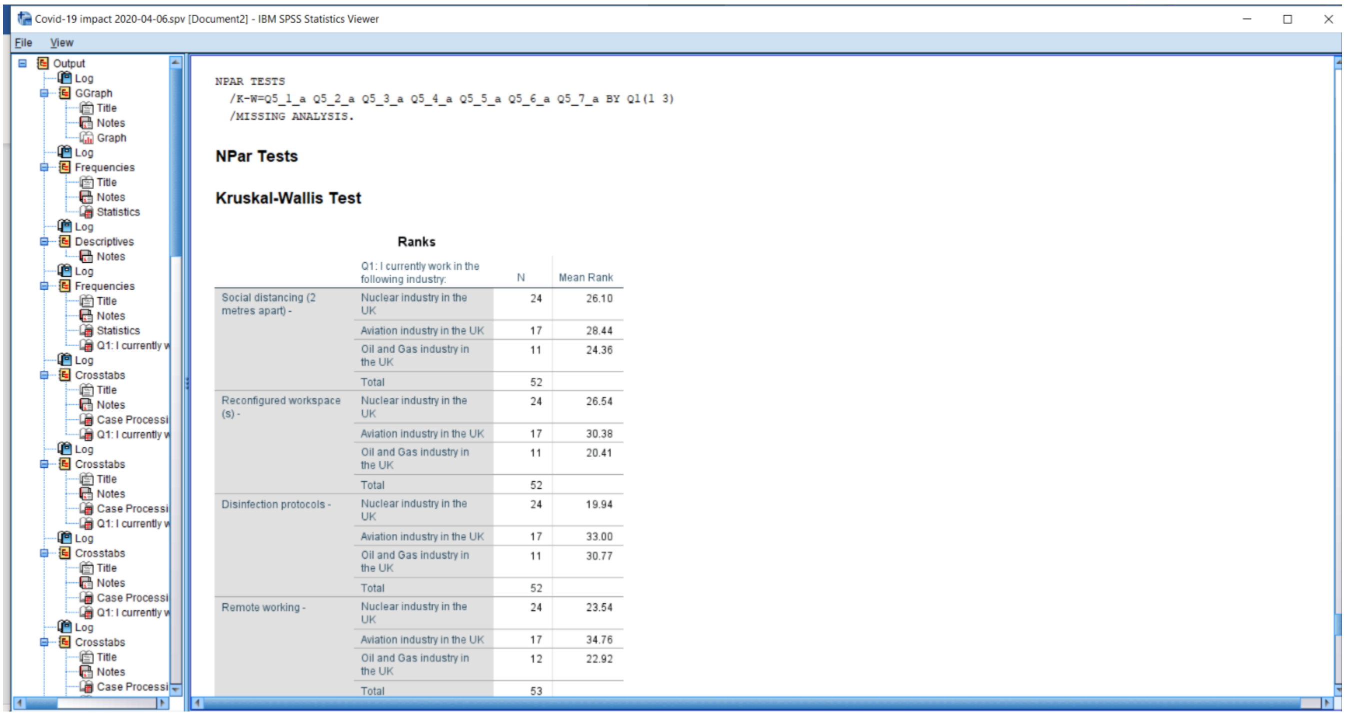

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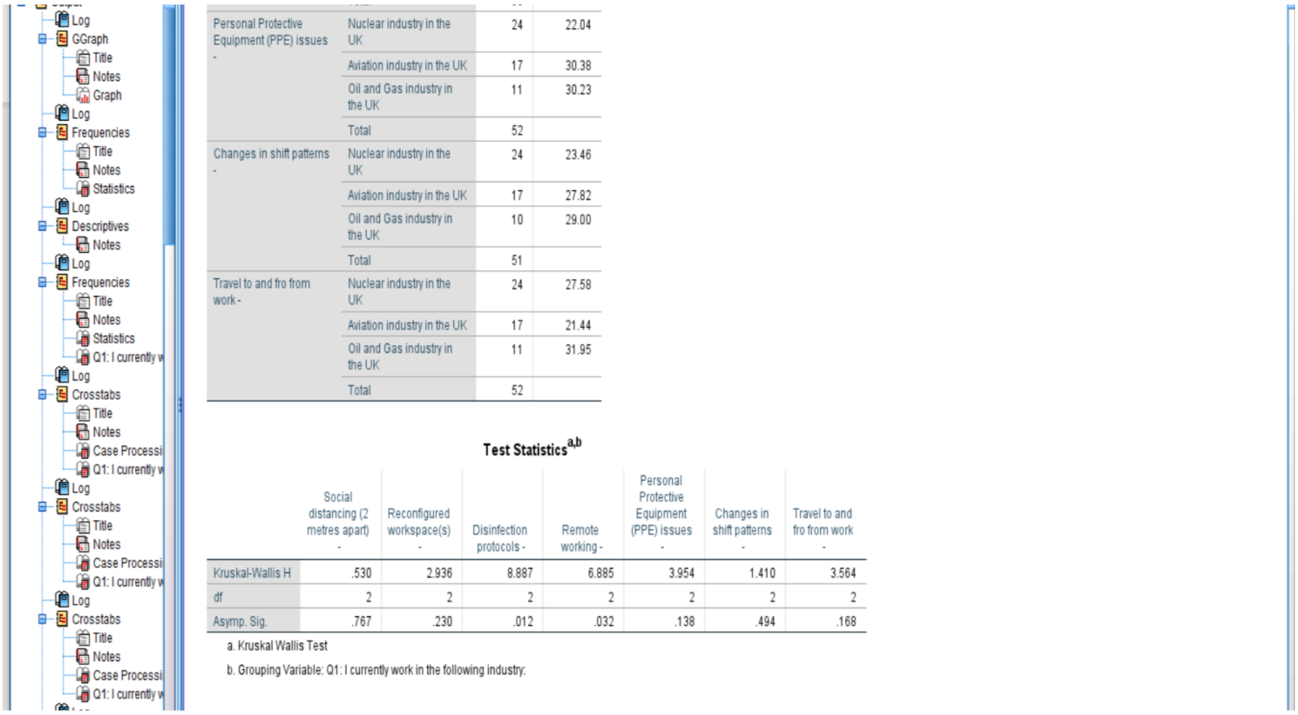
```

NPar Tests

Kruskal-Wallis Test

Ranks

	Q1: I currently work in the following industry:	N	Mean Rank
Social distancing (2 metres apart) -	Nuclear industry in the UK	24	26.10
	Aviation industry in the UK	17	28.44
	Oil and Gas industry in the UK	11	24.36
	Total	52	
Reconfigured workspace (s) -	Nuclear industry in the UK	24	26.54
	Aviation industry in the UK	17	30.38
	Oil and Gas industry in the UK	11	20.41
	Total	52	
Disinfection protocols -	Nuclear industry in the UK	24	19.94
	Aviation industry in the UK	17	33.00
	Oil and Gas industry in the UK	11	30.77
	Total	52	
Remote working -	Nuclear industry in the UK	24	23.54
	Aviation industry in the UK	17	34.76
	Oil and Gas industry in the UK	12	22.92
	Total	53	



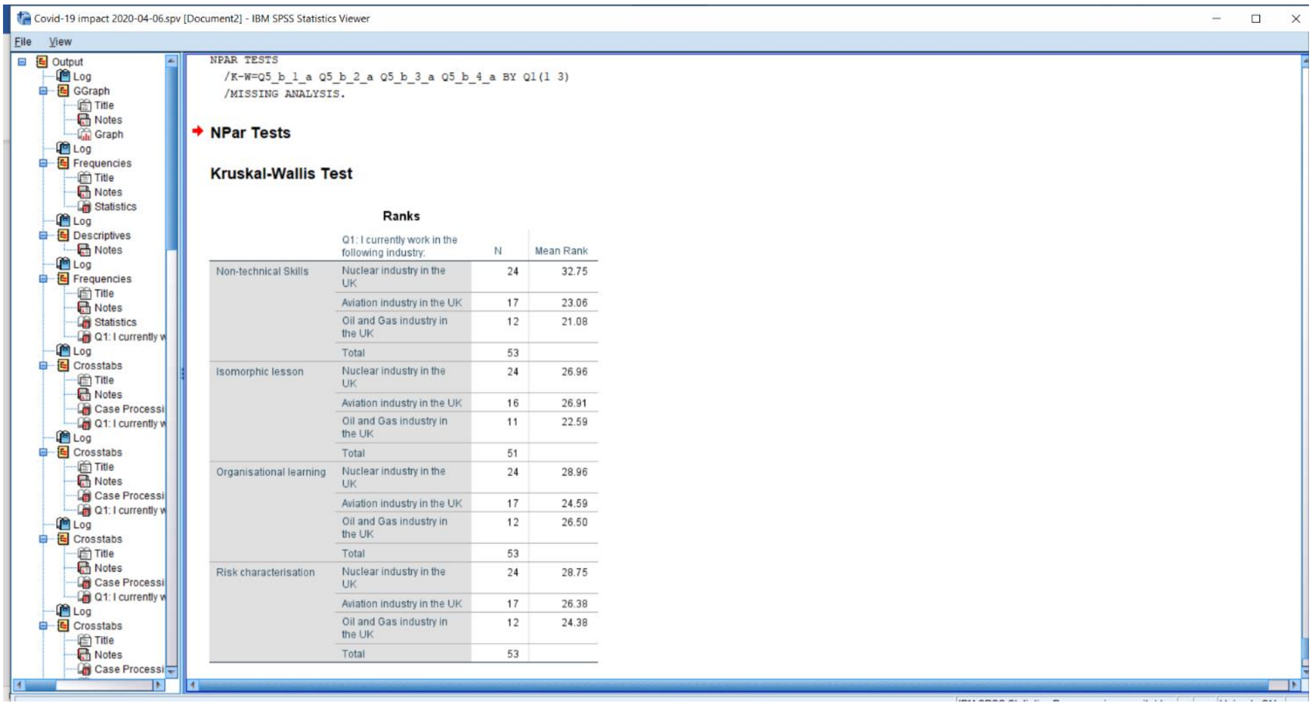
		N	Mean Rank
Personal Protective Equipment (PPE) issues -	Nuclear industry in the UK	24	22.04
	Aviation industry in the UK	17	30.38
	Oil and Gas industry in the UK	11	30.23
	Total	52	
Changes in shift patterns -	Nuclear industry in the UK	24	23.46
	Aviation industry in the UK	17	27.82
	Oil and Gas industry in the UK	10	29.00
	Total	51	
Travel to and fro from work -	Nuclear industry in the UK	24	27.58
	Aviation industry in the UK	17	21.44
	Oil and Gas industry in the UK	11	31.95
	Total	52	

Test Statistics[a,b]

	Social distancing (2 metres apart) -	Reconfigured workspace(s) -	Disinfection protocols -	Remote working -	Personal Protective Equipment (PPE) issues -	Changes in shift patterns -	Travel to and fro from work -
Kruskal-Wallis H	.530	2.936	8.887	6.885	3.954	1.410	3.564
df	2	2	2	2	2	2	2
Asymp. Sig.	.767	.230	.012	.032	.138	.494	.168

a. Kruskal Wallis Test

b. Grouping Variable: Q1: I currently work in the following industry.



Covid-19 impact 2020-04-06.spv [Document2] - IBM SPSS Statistics Viewer

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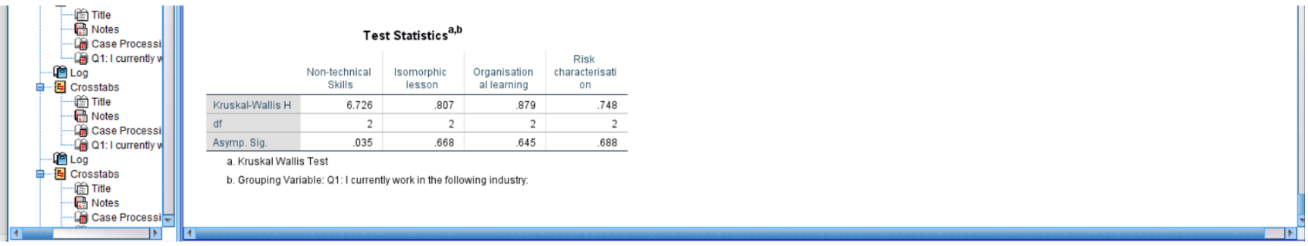
  /MISSING ANALYSIS.
```

NPar Tests

Kruskal-Wallis Test

Ranks

	Q1: I currently work in the following industry:	N	Mean Rank
Non-technical Skills	Nuclear industry in the UK	24	32.75
	Aviation industry in the UK	17	23.06
	Oil and Gas industry in the UK	12	21.08
	Total	53	
Isomorphic lesson	Nuclear industry in the UK	24	26.96
	Aviation industry in the UK	16	26.91
	Oil and Gas industry in the UK	11	22.59
	Total	51	
Organisational learning	Nuclear industry in the UK	24	28.96
	Aviation industry in the UK	17	24.59
	Oil and Gas industry in the UK	12	26.50
	Total	53	
Risk characterisation	Nuclear industry in the UK	24	28.75
	Aviation industry in the UK	17	26.38
	Oil and Gas industry in the UK	12	24.38
	Total	53	



Test Statistics[a,b]

	Non-technical Skills	Isomorphic lesson	Organisational learning	Risk characterisation
Kruskal-Wallis H	6.726	.807	.879	.748
df	2	2	2	2
Asymp. Sig.	.035	.668	.645	.688

a. Kruskal Wallis Test

b. Grouping Variable: Q1: I currently work in the following industry.

Appendix 10: Focus Group Questionnaire/Participant Information Leaflet

Focus Group Discussion

Research topic:

"Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil & Gas Sectors."

Definition of terms (investigative tools) used in this research across the three sectors (Nuclear, Aviation and Oil & Gas)

Non-Technical Skills (NTS):

NTS as stated by Flin et al. (2008) comprise cognitive, social, and personal resource skills that underpin technical skills (Flin et al., 2008).

Isomorphic lessons:

Isomorphic learning as advocated by Toft and Reynolds (2006) is the ability of organisations to learn from similar experiences of others. They argue that lesson learned from different events or organisation could be applied to another setting to manage disasters effectively (Toft and Reynolds 2006).

Organisational learning:

Organisational learning is an effective procedure to process, interpret and respond to internal and external information of a largely clear nature (Easterby-Smith et al. 1999).

Risk characterisation:

Risk characterisation is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (Stern and Fineberg 1996: 1).

Participant Information Leaflet

Research Topic: "Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from the Aviation and the Oil and Gas Sectors."

The aim of the research: The aim of this research is to undertake a critical evaluation of organisational learning for the UK nuclear sector and benchmark the current and potential gains that could be made from Non-Technical Skills (NTS), Isomorphic lessons, Organisational learning and Risk characterizations between nuclear, aviation and the oil and gas industries. The research will develop a combined framework, guiding principles, and toolkit to inform on the management of accidents/incidents, and emergencies specifically engineered to benefit the UK's nuclear industry.

This project initiated primary research hosted on Bristol Online Survey (which you participated in) as a means of gathering data to support each of the four research questions and objectives listed. Therefore, some of the online survey results and a toolkit will be presented to this focus group for individual critique and inputs.

Kindly respond to the email stating your **availability and time** to enable us set up a Microsoft Team invitation. You may choose from the following days: **Tuesday 14th or Tuesday 28th July 2020 either for morning session (11am-12 noon) or afternoon session (2-3pm)** respectively. Part A (review of findings) and Part B (inter-industrial learning system). Each session will last approximately 30 minutes.

Thanks for the usual support.
Best regards,

A Ibiam

Researcher contact details
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Appendix 11: Feedbacks from the Three Sectors

Focus Group Discussion (Nuclear)

Research topic:

"Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil & Gas Sectors."

Definition of terms (investigative tools) used in this research across the three sectors (Nuclear, Aviation and Oil & Gas)

Non-Technical Skills (NTS):

NTS as stated by Flin et al. (2008) comprise cognitive, social, and personal resource skills that underpin technical skills (Flin et al., 2008).

Isomorphic lessons:

Isomorphic learning as advocated by Toft and Reynolds (2006) is the ability of organisations to learn from similar experiences of others. They argue that lesson learned from different events or organisation could be applied to another setting to manage disasters effectively (Toft and Reynolds 2006).

Organisational learning:

Organisational learning is an effective procedure to process, interpret and respond to internal and external information of a largely clear nature (Easterby-Smith et al. 1999).

Risk characterisation:

Risk characterisation is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (Stern and Fineberg 1996: 1).

Questions to the Focus Group Members

Part A (Review of findings after result presentation)

Tick if Yes or No	Non-technical Skills	Isomorphic lessons	Organisational learning	Risk characterisation
From the presentation, do you think your sector has **ENCOUNTERED** any of the following four domains stated above within the working environment?	Yes	Yes	Yes	Yes
Does your organisation **INCORPORATE** the four domains effectively into training, exercises and safety practices?	Mostly – 5 out of 7	Yes	Yes	Yes
Are the four domains **STRONG FEATURES** of your organisation's practice?	Yes, via HuP	Yes – via corrective active	Yes, via LFE	Yes, via safety case process

NTS Seven Element	Situation Awareness	Decision-making	Communication	Leadership	Teamwork	Managing Stress	Coping with Fatigue
Which of these seven elements on NTS shown above have you received **TRAINING** on in your working environment? (**Tick YES/NO**)	Yes	Yes	Yes	Yes	Yes	Partially	Less

Part B (inter-industrial learning system)

Toolkits	Lexicons	Benchmarking Data	Accident Examples	Training Logs	List of Publications	Archiving of Incidents
Will producing a toolkit which is stated above help inter-industrial learning system especially in the nuclear sector. **(Please tick YES/NO**).	Yes – common terminology will help	Yes – we would benchmark conventional safety v O&G	Yes – we have already used Nimrod, Texas City	Unsure	Yes – useful to understand the formal regulatory and trade governance models	Yes – strong internal use by INPO

Focus Group Discussion (Aviation)

Research topic:

"Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil & Gas Sectors."

Definition of terms (investigative tools) used in this research across the three sectors (Nuclear, Aviation and Oil & Gas)

Non-Technical Skills (NTS):

NTS as stated by Flin et al. (2008) comprise cognitive, social, and personal resource skills that underpin technical skills (Flin et al., 2008).

Isomorphic lessons:

Isomorphic learning as advocated by Toft and Reynolds (2006) is the ability of organisations to learn from similar experiences of others. They argue that lesson learned from different events or organisation could be applied to another setting to manage disasters effectively (Toft and Reynolds 2006).

Organisational learning:

Organisational learning is an effective procedure to process, interpret and respond to internal and external information of a largely clear nature (Easterby-Smith et al. 1999).

Risk characterisation:

Risk characterisation is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (Stern and Fineberg 1996: 1).

Questions to the Focus Group Members

Part A (Review of findings after result presentation)

Tick if Yes or No	Non-technical Skills	Isomorphic lessons	Organisational learning	Risk characterisation
From the presentation, do you think your sector has **ENCOUNTERED** any of the following four domains stated above within the working environment?	Yes	No	Yes	Yes
Does your organisation **INCORPORATE** the four domains effectively into training, exercises and safety practices?	Yes	No	Yes	Yes
Are the four domains **STRONG FEATURES** of your organisation's practice?	Yes	No	Yes	Yes

NTS Seven Element	Situation Awareness	Decision-making	Communication	Leadership	Teamwork	Managing Stress	Coping with Fatigue
Which of these seven elements on NTS shown above have you received **TRAINING** on in your working environment? (**Tick YES/NO**)	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Part B (inter-industrial learning system)

Toolkits	Lexicons	Benchmarking Data	Accident Examples	Training Logs	List of Publications	Archiving of Incidents
Will producing a toolkit which is stated above help inter-industrial learning system especially in the nuclear sector. **(Please tick YES/NO**).	Yes	Yes	Yes	No	Yes	Yes

Focus Group Discussion (Oil & Gas)

Research topic:

"Non-Technical Skills: A Critical Evaluation of Organisational Learning for the UK Nuclear Industry from Aviation and Oil & Gas Sectors."

Definition of terms (investigative tools) used in this research across the three sectors (Nuclear, Aviation and Oil & Gas)

Non-Technical Skills (NTS):

NTS as stated by Flin et al. (2008) comprise cognitive, social, and personal resource skills that underpin technical skills (Flin et al., 2008).

Isomorphic lessons:

Isomorphic learning as advocated by Toft and Reynolds (2006) is the ability of organisations to learn from similar experiences of others. They argue that lesson learned from different events or organisation could be applied to another setting to manage disasters effectively (Toft and Reynolds 2006).

Organisational learning:

Organisational learning is an effective procedure to process, interpret and respond to internal and external information of a largely clear nature (Easterby-Smith et al. 1999).

Risk characterisation:

Risk characterisation is geared towards a decision-driven activity, aimed at informing choices and targeted at problem solving (Stern and Fineberg 1996: 1).

Questions to the Focus Group Members

Part A (Review of findings after result presentation)

Tick if Yes or No	**Non-technical Skills**	**Isomorphic lessons**	**Organisational learning**	**Risk characterisation**
From the presentation, do you think your sector has **ENCOUNTERED** any of the following four domains stated above within the working environment?	Yes	Yes	Yes	Yes
Does your organisation **INCORPORATE** the four domains effectively into training, exercises and safety practices?	No	No	Yes	No
Are the four domains **STRONG FEATURES** of your organisation's practice?	No	No	Yes	Yes

NTS Seven Element	**Situation Awareness**	**Decision-making**	**Communication**	**Leadership**	**Teamwork**	**Managing Stress**	**Coping with Fatigue**
Which of these seven elements on NTS shown above have you received **TRAINING** on in your working environment? (**Tick YES/NO**)	Yes	No	Yes	Yes	Yes	No	No

Part B (inter-industrial learning system)

Toolkits	Lexicons	Benchmarking Data	Accident Examples	Training Logs	List of Publications	Archiving of Incidents
Will producing a toolkit which is stated above help inter-industrial learning system especially in the nuclear sector. **(Please tick YES/NO**).	Yes	Yes	Yes	Yes	Yes	Yes

Please note: The answers are yes/no however, many of the headings cannot be simply yes / no answers and need further clarification as discussed in today's focus group discussion.

Appendix 12: Toolkits as Research Outputs

A1: Lexicons

Participants suggested that there is need for sectors to have a common language (lexicon) that will cut across each sector. The table below shows examples of lexicons on NTS, isomorphic lessons, organisational learning and risk characterisation.

Documents between the three regulators were checked for lexicon on either for similarities or differences on the four pillars used in this research. They are: The Office for Nuclear Regulation (ONR); the Civil Aviation Authority (CAA) and the Oil and Gas Authority's (OGA).

Nuclear Sector Documents Used for Lexicon

For nuclear sector, the documents checked for lexicon are:

1. Training and Assuring Personnel Competence, published in 2017, review date 2020. Document type: Nuclear Safety Assessment Guide, which contained 27 pages used.
2. Nuclear safety in the unexpected second nuclear era. It was first published in 2019. (Peer review publication and published in the Proceedings of the National Academy of Science of the United States of America).
3. Constructive Leadership in a Strong Nuclear Safety Culture: The Role of Leadership Development and Succession Planning Strategies.
4. Organisational learning – Reflections from the nuclear industry. (Peer reviewed and published in 2009).

On the documents perused, **situation awareness** was regarded as **safety awareness or perception**, while decision-making, communication, leadership, teamwork and stress were referred to as such, though there was no mention of fatigue in the document. There was no mention of isomorphic lessons in the document, while **organisational learning** was regarded as **learning**. But **risk characterisation** was simply mentioned as **risk**. This again suggests that not all the three pillars are common features in the nuclear sector.

From what has been identified in the document, NTS and its elements means the same thing, but are not regarded as NTS. (See figure 32 below on how lexicon is referred to in different sectors and the number of times there were mentioned (hits) in the document).

Aviation Sector Document Used for Lexicon

Top 20 documents were used for lexicon check in the aviation sector. It was drawn from the list of publications in table… In addition to that, another document titled, "Aviation Non-Technical Skills Handbook" was used. It was published by Defense Flight Safety Bureau (DFSB) in 2018 and contained 263 pages.

The document was examined for NTS, isomorphic lessons, organisational learning and risk characterisation. In the document, all the seven elements of NTS was mentioned. However, the document did not delve into most of the three pillars used as training tools especially on isomorphic lessons. Though, **organisational learning** was referred to as **learning** (31 hits), while risk characterisation was regarded as **risk** (159 hits).

It is generally believed that the aviation sector use NTS in its training program as the document perused covered those areas extensively. Therefore, the fact remains that the sector should in future include isomorphic lessons and organisational learning fully into training exercise. (See figure 32 below on lexicons used in the aviation sector as it relates to all the four pillars).

Oil & Gas Sector Document Used for Lexicon

In the oil and gas sector, 20 publications were used to check differences in language. In addition to that, a document titled: "Introducing behavioural markers of non-technical skills in oil and gas operations" was equally examined. It was produced by International Association of Oil and Gas Producers (IOGP). It was produced in 2018 and contained 24 pages.

The result from the document proved that NTS was covered, which translates that the sector is using NTS elements effectively in workplace practice. Though **situation awareness** (15 hits or times) was referred to as such in the IOGP document but in other documents was referred to as **awareness** and or **perception**. **Decision-making** (11 hits or times) was used interchangeably as **decisions** (40); **communications** (16 times or hits); **teamwork** (6 times or hits); **leadership** (11 times or hits); **stress** (1) **and fatigue** (1).

On the other three pillars, isomorphic lesson was conspicuously not mentioned in the document, while **organisational learning** was referred to as l**earning** (3 times or hits) and **risk characterisation** was referred to as **risk** (32 times or hits).

The search on lexicon across the three sectors revealed that while the aviation sector is generally known as the 'inventor' of NTS, which started as Crew Resource Management (CRM), other industries that are learning from aviation refer to NTS as 'soft skills', which diminishes their importance and by extension its meaning. Therefore, there is need for the three sectors to adopt a common language or lexicon on NTS, despite having some similarities in meaning. (See Lexicon on Figure 32).

On isomorphic lesson, the three sectors need to imbibe the culture of introducing this pillar in training exercise, while organisational learning should focus on organisations learning from others and risk should be appropriately characterised to meet the safety needs of the sectors in the context it is meant for.

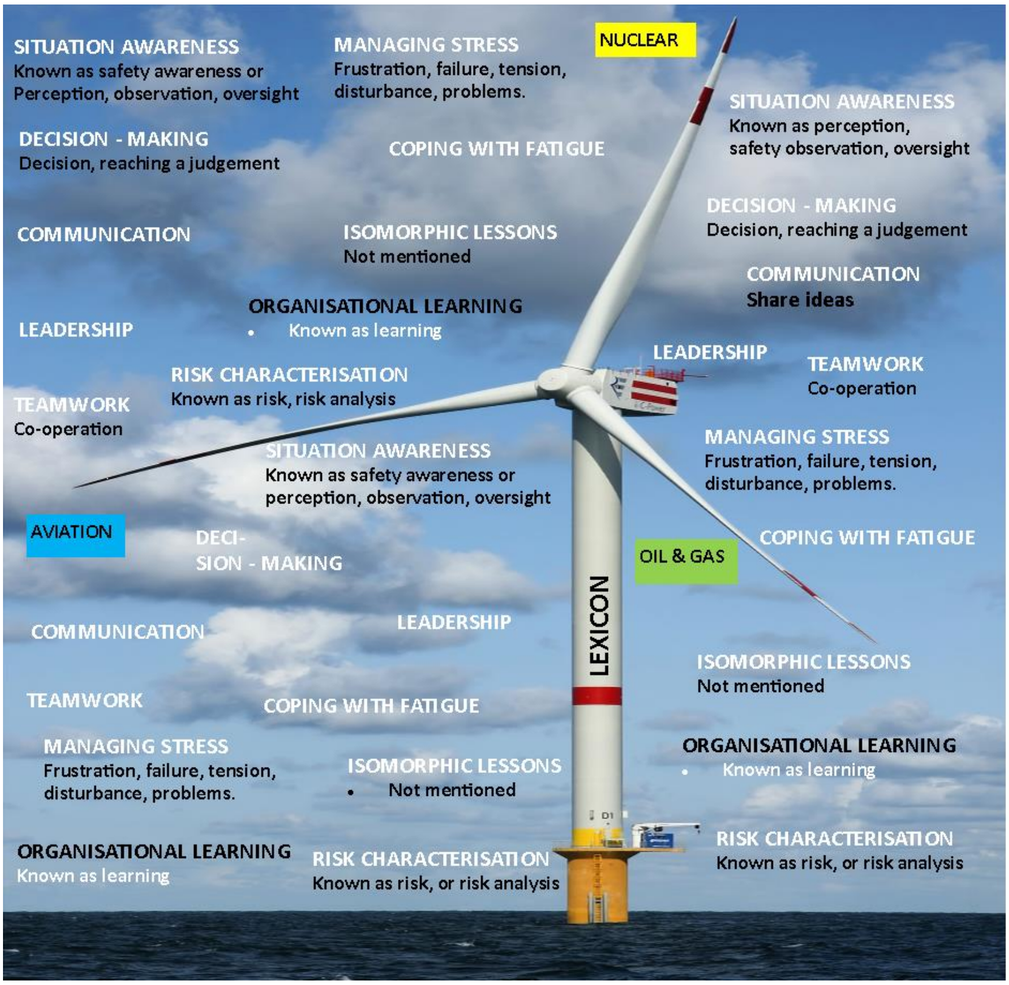

Figure 33: Lexicon on NTS, isomorphic lessons, organisational learning and risk characterisation

A2: Benchmarking Data

This is about the comparative systems used for human performance between different sector approaches on the four pillars. The focus of benchmarking is to track performance in relation to other systems and data. Because organisations find it difficult to share information, it will not be in the interest of this research to produce an example of benchmarking data as it may not meet industry needs and requirement.

A3: 3 Accidents/3 Incidents Examples

Introduction, analysis and conclusion of accidents and incidents examples have been discussed. This shows how minor incidents grow to accidents when there are lapses of NTS, isomorphic lessons, organisational learning and risk characterisation in managing safely. Example of this is the Piper Alpha and Deepwater Horizon. (See page 73-88 on accident and incidents discussions).

B1: Training Logs

This research will not develop a training log for the sectors as it may not be profitable to organisations on how its training logs should look like. However, after listening to participants view during the focus group discussion and recommendations they made, training logs produced by the three sectors should be shared within the three industry regulators. The regulators should able to see the frequency of trainings in the areas of NTS, isomorphic lessons, organisation learning and risk characterisation and the levels of formal trainings that exist. Another reason for individual sectors to develop its trainings logs is because of difference in operation that exists among them. Therefore, organisations should look at their training logs and see if it meets the standard cutting across the four pillars.

B2: List of Publications

Non-Technical Skills

Table 64 - 70 showing top 20 publications as examples produced across the three sectors on NTS elements; while Table 71 – 73 shows the four pillars used in this research.

Situation Awareness

Table 64: List of publication on situation awareness

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
A Review of Situation Awareness Assessment Approaches in Aviation Environments	Situation awareness (SA) is an important constituent in human information processing and essential in pilots' decision-making processes.	2019	Peer Review	NTS	Aviation
Exploring the use of situation awareness in behaviours and practices of health and safety leaders	An understanding of how health and safety management systems (HSMS) reduce worksite injuries, illnesses and fatalities may be gained in studying the behaviours of health and safety leaders.	2018	Peer Review	NTS	Health & Safety
A Cognitive Approach to Situation Awareness: Theory and Application	The importance of 'situation awareness' (SA) in assessing and predicting operator competence in complex environments has become increasingly apparent in recent years.	2017	Book	NTS	Generic
Evaluating Situation Awareness: An Integrative Review	Situation awareness (SA) refers to the conscious awareness of the current situation in relation to one’s environment. In nursing, loss or failure to achieve high levels of SA is linked with adverse patient outcomes.	2017	Peer Review	NTS	Generic
A Quantitative Team Situation Awareness Measurement Method Considering…	Human capabilities, such as technical/nontechnical skills, have begun to be recognized as crucial factors for nuclear safety.	2016	Peer Review	NTS	Nuclear
Study on operator’s SA reliability in digital NPPs. Part 1: The analysis method of operator’s errors of situation awareness.	Situation awareness (SA) is a key element that impacts operator’s decision-making and performance in nuclear power plants (NPPs).	2017	Peer Review	NTS	Nuclear
Human performance metrics for the nuclear domain:	The Nuclear Regulatory Commission (NRC) has developed a tool to support the understanding and evaluation of workload	2019	Peer Review	NTS	Nuclear

	(WL), situation awareness (SA), and teamwork (TW)…				
Measuring Situation Awareness of Operating Team in Different Main Control Room…	Environments in nuclear power plants (NPPs) are changing as the design of instrumentation and control systems for NPPs is rapidly moving toward fully digital	2016	Peer Review	NTS	Nuclear
Situation Awareness Offshore: Relevant Influencing Factors and Risks	Offshore operations are an inherently hazardous activities that can result in catastrophic outcomes. The amalgamation of different hazards, constraints, and demands on offshore platforms can…	2017	Peer Review	NTS	Oil and gas
Situational awareness measurement in a simulation-based training framework for offshore well control operations	Human factors are identified as the major contributor to oil and gas drilling and operations related accidents.	2019	Peer Review	NTS	Oil and gas

Decision-making

Table 65: List of publication on decision-making

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Decision-making in Risk Management.	The definition of risk introduced in the ISO 31000 standard of 2009 (2018) is uncertain goal achievement; thus, both negative and positive outcomes can be considered.	2018	Peer Review	NTS	Generic
Risk averse decision making under catastrophic risk.	A nonstandard probabilistic setting for modelling of the risk of catastrophic events is presented.	2014	Peer Review	NTS	Nuclear
Intellectual decision-making system in the context of…	The article deals with intelligent operation decision support system under condition of potentially hazardous nuclear facilities.	2018	Peer Review	NTS	Nuclear
Dynamic decision-making of airline pilots in low-fidelity simulation.	Dynamic decision-making in aviation involves complex problem solving in a dynamic environment characterized by goal conflicts…	2019	Peer Review	NTS	Aviation
Toward Evidence-Based Decision Making in Aviation.	Academic institutions and airlines have always worked together to develop and conduct research studies. However, most often the expertise or areas of interest of the academics have driven these studies.	2015	Peer Review	NTS	Aviation
Decision Errors and Accidents: Applying Naturalistic Decision Making to Accident Investigations.	When faced with dynamic and often ill-structured situations, experienced decision makers can quickly recognize and respond to the situations they encounter, a process referred to as naturalistic decision making.	2016	Peer Review	NTS	Aviation
How role assignment impacts decision-making in high-risk environments: Evidence from eye-tracking in aviation.	Adequate monitoring of automated systems is an essential aspect of procedure compliance, protective behaviour, and appropriate decisions in ultra-safe environments.	2020	Peer Review	NTS	Aviation
Intelligent decision-making with bird-strike risk assessment for airport bird repellent.	An intelligent decision-making method was proposed for airport bird-repelling based on a Support Vector Machine (SVM) and bird-strike risk assessment.	2018	Peer Review	NTS	Aviation
Decision-making in the oil and gas projects based on game theory: Conceptual process design.	Oil and gas projects are ruled by risks, uncertainties and opportunities within their complex decision-making processes.	2013	Peer Review	NTS	Oil and gas
Cognitive Bias: A Game Changer for Decision Management	There are things happening in the world of psychology that may affect the way decision management is viewed and practiced.	2018	Peer Review	NTS	Generic

Communication

Table 66: List of publications on communication

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Reliability modelling of safety-critical network communication in a digitalized nuclear power plant.	The Engineered Safety Feature-Component Control System (ESF-CCS), which uses a network communication system for the transmission of safety-critical information…	2015	Peer Review	NTS	Nuclear
What constitutes professional communication in aviation: Is language proficiency enough for testing purposes?	This paper aims to identify what aviation experts consider to be the key features of effective communication by examining in detail their commentary on a 17-minute segment of recorded…	2018	Peer Review	NTS	Aviation
Discursive framing in private and public communication by pro-nuclear corporate, political and regulatory actors following the Fukushima disaster	The purpose of this paper is to examine a case of companies cooperating with the State to prevent a public controversy over nuclear power following the Fukushima disaster and achieve mutually beneficial policy outcomes.	2017	Peer Review	NTS	Nuclear
When Communication Should Be Formal	Informality has become ubiquitous in modern organizations: The use of first names for everyone, including executives, is the norm, as are…	2018	Peer Review	NTS	Aviation
Intercultural Communication and Discourse Analysis: The Case of Aviation English	Historically, applied linguistics has tended to shift from a theoretical approach toward a problem-solving approach. Intercultural communication as a field of study has gained its position through…	2015	Peer Review	NTS	Aviation
Future communication solution paths for commercial, personal, and unmanned aviation.	Significant opportunities exist to make better use of existing aviation spectrum. A combination of aviation-specific and commercial links will provide the broadest and most flexible solution but will require some kind of "Delivery Manager".	2014	Peer Review	NTS	Aviation
Communicating Nuclear Power: A Programmatic Review.	Civil and commercial nuclear power production is a material and discursive phenomenon posing theoretical and practical questions warranting further attention by communication scholars.	2016	Peer Review	NTS	Nuclear
What constitutes professional communication in aviation: Is language proficiency enough for testing purposes?	This paper aims to identify what aviation experts consider to be the key features of effective communication by examining in detail their commentary on a 17-minute segment of recorded radiotelephony discourse between…	2018	Peer Review	NTS	Nuclear
Safety Management Systems as communication in an oil and gas producing company.	An IT-based Safety Management System contains procedures, safety standards and checklists on how different tasks should be performed.	2015	Peer Review	NTS	Oil and gas
Poor Communication Skills Means High Risk for Aviation Safety	This article analyses different types of communication used in the aviation operational environment.	2014	Peer Review	NTS	Aviation

Teamwork

Table 67: List of publications on teamwork

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Human Factors and Non-Technical Skills: Teamwork	Making mistakes is part of being human and human error is normal in all areas of life. In some contexts, this is of little consequence…	2016	Peer Review	NTS	Aviation
Human performance metrics for the nuclear domain: A tool for evaluating measures of workload, situation awareness and teamwork.	The Nuclear Regulatory Commission (NRC) has developed a tool to support the understanding and evaluation of workload (WL), situation awareness (SA), and teamwork (TW) metrics used in human factors engineering (HFE) programs…	2019	Peer Review	NTS	Nuclear
Design and Evaluation of a Team Mutual Awareness Toolkit for Digital Interfaces of Nuclear Power Plant Context	In the teamwork of nuclear power plants (NPPs), the maintenance of mutual awareness enables the operators to have an up-to-the-moment understanding of each other's work and makes the collaboration more efficient.	2017	Peer Review	NTS	Nuclear
Teamwork, Leadership, and Continuous Improvement	In this chapter, we describe the enhanced Team STEPPS® curriculum as fundament to creating a "culture of continuous improvement" in nuclear medicine.	2016	Peer Review	NTS	Nuclear
Teamwork competence required across operational states: Findings from nuclear power plant operation	The tasks of Nuclear Power Plant (NPP) operators are highly interconnected, and operators need to engage in teamwork to ensure plant safety. Traditionally, teamwork-competence…	2015	Book	NTS	Nuclear
The science of teamwork: Progress, reflections, and the road ahead	We need teams in nearly every aspect of our lives (e.g., hospitals, schools, flight decks, nuclear power plants, oil rigs, the military, and corporate offices).	2018	Peer Review	NTS	Generic
Aviation-based teamwork skills work for surgeons: time for an 'aviation bundle'?	Aviation systems were developed to improve safety and have achieved remarkable results. Medicine has looked to replicate these systems;	2018	Peer Review	NTS	Aviation
Understanding teamwork errors in royal air force air traffic control	Despite the success of Crew Resource Management (CRM) training in aviation and the development and implementation of Team Resource Management (TRM)…	2018	Peer Review	NTS	Aviation
Investigating Non-technical Skills through Team Behavioural Markers in Oil and Gas Simulation-based Exercises	In recent years there has been increasing acknowledgement in the oil and gas sector about the importance of Non-Technical Skills (NTS) training as a complement to traditional technical and procedural training.	2015	Peer Review	NTS	Oil and gas
Investigating the Impact of Teamwork Quality on the Effectiveness of Managing Multiple Projects in the Oil & Gas Industry	Managing multiple projects (MMP) is a current trend in project management. This type of management has become common in many industries, particularly in the oil and gas industry.	2018	Peer Review	NTS	Oil and gas

Leadership

Table 68: List of publications on leadership

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
New Public Leadership Making a Difference from Where We Sit	Most leadership literature stems from and focuses on the private sector, emphasizing personal qualities that…	2018	Book	NTS	Generic
Teamwork, Leadership, and Continuous Improvement	In this chapter, we describe the enhanced Team STEPPS® curriculum as fundament to creating a “culture of continuous improvement” in nuclear medicine.	2016	Peer Review	NTS	Nuclear
LEADERSHIP FOR TODAY'S CHALLENGES	There are more subtle changes as well: the culture of business aviation is changing; our passengers and their…	2018	Peer Review	NTS	Generic
Leadership effectiveness of collegiate aviation program leaders: A four-frame analysis	The purpose of this study was to examine the perceived leadership effectiveness of aviation program leaders…	2018	Peer Review	NTS	Aviation
Leading High-Risk Teams in Aviation	Despite air travel having become a widely used means of transportation, the technological sophistication and human skill required…	2016	Peer Review	NTS	Aviation
Self-Leadership Strategies & Performance Perspectives Within Student Aviation Teams	The use of teams to achieve organizational goals requires companies to employ individuals that are competent at both performing…	2017	Peer Review	NTS	Aviation
Leadership approaches in multi-cultural aviation environments	In the last few decades, the world has witnessed a phenomenon called globalization, which has shortened distances and transformed cultural contexts.	2014	Peer Review	NTS	Aviation
Leadership influence on aviation safety culture inculcation as it relates to Certified Non-scheduled Air Taxi Operators	A general aviation industry segment member known as a Certified Non-scheduled Air Taxi Operator (CNATO) conducts passenger flights on-demand for hire.	2020	Peer Review	NTS	Aviation
Senior Managers and Safety Leadership Role in Offshore Oil and Gas Construction Projects	Recent changes in the global construction industry coupled with rising challenges because of the dynamic nature of offshore…	2017	Peer Review	NTS	Oil and gas
Transformational leadership and organisational culture as predictors of employee creativity and innovation in the Nigerian oil and gas service industry	The 21st century global market demands highly skilled workforce who are intellectually active, creative, innovative and capable of critical thinking.	2017	Peer Review	NTS	Oil and gas

Managing Stress

Table 69: List of publications on managing stress

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Stress, fatigue, situation awareness and safety in offshore drilling crews	Drilling for oil and gas on offshore installations is a hazardous occupation and requires personnel to maintain high levels of work situation awareness (WSA).	2012	Peer Review	NTS	Oil & Gas
Modelling the cardiac indices of stress and performance of nuclear power plant operators during simulated fault scenarios	Acute stress can affect cognitive processing and decrease performance in demanding, stressful situations.	2019	Peer Review	NTS	Nuclear
15 - Management of nuclear crises: accidents and lessons learned	The major nuclear accidents at Three Mile Island, Chernobyl and Fukushima Daiichi are discussed from a crisis management viewpoint.	2013	Peer Review	NTS	Nuclear
EMOTIONAL CONSEQUENCES OF NUCLEAR POWER PLANT DISASTERS	The emotional consequences of nuclear power plant disasters include depression, anxiety, post-traumatic stress disorder, and medically unexplained somatic symptoms.	2014	Peer Review	NTS	Nuclear
Safety Culture, Resilient Behaviour, and Stress in Air Traffic Management	n today's rapidly changing air traffic management (ATM) environment, safety culture and organizational resilience are key enablers for effective safety management.	2016	Peer Review	NTS	Aviation
Job stress and job satisfaction among managerial and non-managerial employees of a public sector undertaking	The modern world, which is a world of achievements, is also a world of stress. One finds stress all walks of life. Different people have different views about it as stress can be experienced from a variety of sources.	2016	Peer Review	NTS	Aviation
Stressing the importance of stress	This paper aims to review the latest management developments across the globe and pinpoint practical implications from cutting-edge research and case studies.	2016	Peer Review	NTS	Generic
Importance of personality and career stress for flight attendants' career satisfaction	We examined flight attendants' career satisfaction and addressed how career stress affects the relationship between personality and career satisfaction.	2019	Peer Review	NTS	Aviation
Investigating Non-technical Skills through Team Behavioural Markers in Oil and Gas Simulation-based Exercises	In recent years there has been increasing acknowledgement in the oil and gas sector about the importance of Non-Technical Skills (NTS) training as a complement to traditional technical and procedural training.	2015	Peer Review	NTS	Oil & Gas

MORE SAFETY, LESS STRESS	The oil and gas industry is a demanding, dangerous field. According to NIOSH, it has a fatality rate that's more than seven times higher than the rate for all US workers.	2016	Peer Review	NTS	Oil & Gas

Coping with Fatigue

Table 70: List of publications on coping with fatigue

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Effects of In-Flight Countermeasures to Mitigate Fatigue Risks in Aviation	Fatigue is a frequent phenomenon for pilots doing shift work and working in changing time zones.	2018	Peer Review	NTS	Aviation
Fatigue management in the workplace	Workers' fatigue is a significant problem in modern industry, largely because of high demand jobs, long duty periods, disruption of…	2015	Peer Review	NTS	Generic
Understanding Fatigue: Implications for Worker Safety	If so, then fatigue management can progress from a reactive state (the equivalent of the PPE state in a traditional hazard control hierarchy) to higher/safer levels of engineering controls…	2017	Peer Review	NTS	Generic
The fatigue conundrum:	The fatigue conundrum: whether it's mild sleepiness or mind-numbing exhaustion, the challenge of fatigue on the job can be complex, dangerous, and surprisingly difficult to manage.	2015	Peer Review	NTS	Generic
Risk factors for fatigue among airline pilots	The objective of this study is to determine risk factors for fatigue among airline pilots, taking into account person-, work-, health-, sleep-, and…	2017	Peer Review	NTS	Aviation
Fatigue Monitoring and Management across Different Industries	Fatigue, often defined as a physiological state of reduced mental or physical performance capability resulting from sleep loss…	2016	Peer Review	NTS	Generic
Chapter 22 - Managing fatigue	Fatigue is the mental, physical, or emotional impairment caused by inadequate sleep or excessive wakefulness.	2016	Peer Review	NTS	Generic
Change-Oriented Risk Management in Civil Aviation Operation: A Case Study in China Air Navigation Service Provider	Change-oriented risk management is the key content of civil aviation safety management. Hazard identification is considered as one of the most difficult and flexible parts.	2020	Peer Review	NTS	Aviation

A review on risk assessment techniques for hydraulic fracturing water and produced water management…	he objective of this paper is to review different risk assessment techniques applicable to onshore unconventional oil and gas production	2016	Peer Review	NTS	Oil & Gas
Quantitative risk management in gas injection project: a case study from Oman oil and gas industry	The purpose of this research was to study the recognition, application and quantification of the risks associated in managing projects. In this research,	2018	Peer Review	NTS	Oil & Gas

Isomorphic Lessons

Table 71: List of publications on isomorphic lessons

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Lessons learned from the 2011 debacle of the Fukushima nuclear power plant	The history of nuclear power generation in Japan is analyzed with respect to how the organizational structure of the "nuclear villages…	2014	Peer Review	NTS	Nuclear
Lessons of Chernobyl: the cultural causes of the meltdown. (1986 nuclear power plant meltdown)	The disastrous meltdown was caused by the Soviet Union's penchant for secrecy. The union's interest in nuclear research was primarily focused on increasing atomic power capabilities.	1993	Peer Review	NTS	Nuclear
Thirty years after the accident at the Chernobyl nuclear power plant: historical causes, lessons and legal effects	The article offers historical, political and legal analysis of the causes that led to the accident at the Chernobyl nuclear power plant (NPP) 30 years ago in April 1986.	2016	Peer Review	NTS	Nuclear
Japanese fuel mix strategy after disaster of Fukushima Daiichi nuclear power plant: Lessons from international…	On June 1, 2015, the Japanese government has announced that the fuel mix will consist of nuclear generation with a range between 20% and 22% and renewable generation with	2015	Peer Review	NTS	Nuclear
The Great East Japan Earthquake, Tsunamis, and Fukushima Daiichi Nuclear Power Plant Disaster:	In April 2017, some of the health impacts of the 2011 Great East Japan Earthquake, tsunamis, and resultant Fukushima Daiichi nuclear power plant disaster (Okuma, Fukushima Prefecture, Japan) …	2018	Peer Review	NTS	Nuclear
Lessons from Fukushima: 'more than a year after the accident, we still do not have any…	Nil	2012	Peer Review	NTS	Nuclear

Learning from Fukushima: Institutional Isomorphism as Constraining and Contributing Nuclear Safety	This paper is an analysis of the international institutional isomorphic pressures and lessons learned from the Fukushima accident.	2016	Peer Review	NTS	Nuclear
Isomorphic Learning at a Disciplined. Nuclear Power Plant	In this thesis we have examined the Swedish nuclear power plant Ringhals by asking three questions:	2008	Peer Review	NTS	Nuclear
Lessons for shale oil & gas development from that of tight oil & gas and coalbed methane gas in China	This paper aims to explore a smoother way to success for shale oil gas development in China. Thus, a discussion was made focusing on the technological base successfully	2014	Peer Review	NTS	Oil & Gas
How many blowouts does it take to learn the lessons? An institutional perspective on disaster development	Accident researchers have long tried to understand why similar disasters and near misses keep recurring within and across organizations in high hazard industries.	2019	Peer Review	NTS	Generic

Organisational Learning

Table 72: List of publication on organisational learning

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Organisational learning – Reflections from the nuclear industry	Organisational learning has attracted scholarly interest for some time. In parallel a recommendation has been expressed to nuclear power plants to become learning organisations.	2009	Peer Review	NTS	Nuclear
Naturalistic Decision Making and Organizational Learning in Nuclear Power Plants:	We explore the linkages between naturalistic decision making, which examines decisions in context, and team and organizational learning, which examines how feedback from decisions affects context.	2006	Peer Review	NTS	Nuclear
New Nuclear Power Plants - Learning from History to Understand Costs and Mitigate Risks	Nuclear power is an important fuel source, not only because of cost stability factors, but also for protecting the environment and ensuring a lasting supply of clean, safe and reliable delivery of electric service.	2007	Peer Review	NTS	Nuclear
Learning from adverse events in the nuclear power industry: Organizational learning, policy making and normalization	Nuclear power accidents repeatedly reveal that the industry has an incomplete understanding of the complex risks involved in its operation.	2012	Peer Review	NTS	Nuclear
Learning organizations for nuclear safety	Organizational learning (OL) is a crucial component of operational excellence in nuclear power plants. OL relies on performance assessments,	2002	Peer Review	NTS	Nuclear

e-Learning in Aviation.	e-Learning is extremely cost-effective and therefore an attractive alternative to traditional classroom instruction.	2012	Peer Review	NTS	Aviation
Applying research to save lives: Learning from team training approaches in aviation and health care	In many contexts work-related errors result in little more than headaches and hassles. In other contexts, however, errors result in damages costing millions of dollars and, more critically, the loss of lives.	2012	Peer Review	NTS	Aviation
An Online Language Learning Program for Students in Aviation Departments	This study is the first phase of a project that aims to improve the technical English level of students who study in 10 vocational schools in 10 different cities providing training and education on aircraft maintenance.	2016	Peer Review	NTS	Aviation
Individuals and organisations learning from interfirm collaboration in aviation refuelling industry	The literature does not explicate who is the subject of learning (individual, organisation or both) in interfirm relations.	2017	Peer Review	NTS	Aviation
The Lessons on Performance Management Oil and Gas Can Learn From Aviation	It's a transformative time for the oil and gas industry. OPEC production controls can't overcome a persistent oversupply.	2020	Peer Review	NTS	Aviation/Oil & Gas

Risk Characterisation

Table 73: List of publications on risk characterisation

Title	Executive Summary	Date of Publication	Type of Publication	Areas Covered	Industry Case Study
Comprehensive Health Risk Management after the Fukushima Nuclear Power Plant Accident	Five years have passed since the Great East Japan Earthquake and the subsequent Fukushima Daiichi Nuclear Power Plant accident on 11 March 2011.	2016	Peer Review	NTS	Nuclear
Safety margin sensitivity analysis for model selection in nuclear power plant probabilistic safety assessment	The safety assessment of Nuclear Power Plants makes use of Thermal-Hydraulic codes for the quantification of the safety margins with respect to upper/lower…	2017	Peer Review	NTS	Nuclear
Development of Risk Monitor for Nuclear Power Plant	Risk Monitor is a specific application of probability safety analysis (PSA) in nuclear power plant. This paper introduced the concept of risk monitor.	2012	Peer Review	NTS	Nuclear
Advances in multi-unit nuclear power plant probabilistic risk assessment	The Fukushima Daiichi accident highlighted the importance of risks from multiple nuclear reactor unit accidents at a site.	2017	Peer Review	NTS	Nuclear

Analysis of the Relationship between Risk Perception and Willingness to Pay for Nuclear Power Plant Risk Reduction	With the adoption of new technologies, more risk is introduced into modern society. Important decisions about new technologies tend to be made by specialists,	2016	Peer Review	NTS	Nuclear
Risk Communication and Japan's Fukushima Daiichi Nuclear Power Plant Meltdown: Ethical Implications…	The response of Tokyo Electric Power Company (TEPCO), which has been hobbled by a natural disaster, provides startling lessons in how organizations that disregard public outcry…	2014	Peer Review	NTS	Nuclear
Probabilistic Risk Assessment for Nuclear Power Plants	Probabilistic risk assessment (PRA) is a systematic and comprehensive methodology to evaluate risks associated with a complex technological entity.	2008		NTS	Nuclear
Insights into the Societal Risk of Nuclear Power Plant Accidents	The elements of societal risk from a nuclear power plant accident are clearly illustrated by the Fukushima accident: land contamination,	2017	Peer Review	NTS	Nuclear
Nuclear power: Understanding the economic risks and uncertainties	This paper identifies the fundamental elements and critical research tasks of a comprehensive analysis of the costs and benefits of nuclear power relative to…	2010	Peer Review	NTS	Nuclear
Risk Modelling, Assessment, and Management.	Presents systems-based theory, methodology, and applications in risk modelling, assessment, and management This book examines risk analysis…	2015	Book	NTS	Generic

B3: Archiving of Incidents

This research will not produce any material on archiving of incidents. However, the stand of this research is that the three sectors should as a matter of facts archive incidents for future referencing should the need arise.

What Next for the Nuclear Industry?

There is evidence to believe that the aviation industry has put a lot of measures to manage safely its industry especially on the use of NTS. However, this research has attempted to find out if the nuclear sector is at par with the aviation sector and proactive in their plans. The research also looked at if isomorphic lessons took place and what lessons the nuclear sector has learned from the aviation industry.

Appendix 13

Justification for the triangulated Comparison

The purpose of this tripartite survey was to determine if any valuable practices, lessons, or safety critical approaches could be learned and transferred into the nuclear industry via organisational learning attributed to the aviation and possibly oil and gas sectors.

This study critically evaluated the nuclear industry to determine the extent of probable gaps using the four pillars, which are NTS, isomorphic lessons, organisational learning and risk characterisation, as there is no significant track of literature and research identifying how each of the above areas may independently oppose as challenges to the nuclear industry. Thus, the research undertook a critical evaluation and benchmarked the current and potential gains that were made from the four pillars between the three industries.

Figure 34 is a triangulated diagram indicating the three different sectors and four pillars that served as parameters to assess the industries.

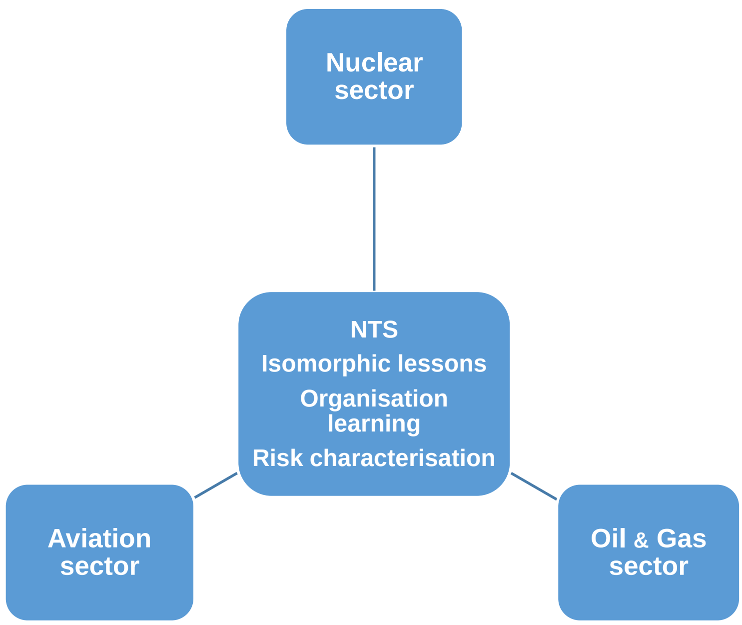

Figure 34: Three sectors and four pillars of the research