DEVELOPMENT OF MATRIX ASSESSMENT LEVEL OF SAFETY PRACTICE FOR RADIATION RISK IN MALAYSIAN RADIATION FACILITIES

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2019

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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

UNIVERSITY OF MALAYA
ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: HAZMIMI BINTI KASIM

Matric No: KHA 140052

Name of Degree: DOCTOR OF PHILOSOPHY

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

DEVELOPMENT OF MATRIX ASSESSMENT LEVEL OF SAFETY PRACTICE FOR RADIATION RISK IN MALAYSIAN RADIATION FACILITIES

Field of Study: OCCUPATIONAL SAFETY AND HEALTH

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ABSTRACT

The substantial research has investigated the nature of safety climate, and its importance as a leading indicator of safety performance, however much of this research has been conducted in Western countries, with high risk operations. This study focused on the exploratory factors of safety practice in the industrial context of Malaysian radiation facilities. Therefore, this study aims to determine the affecting factors, relationship between safety climate and risk estimate and level of safety practices. The six-factor Malaysian Safety Tool Kit (MSTK) and safety culture and practice suggested by International Atomic Energy Agency (IAEA) safety series was adopted and adapted as Malaysian radiation safety tool kit (MRSTK). An alternative nine-factor model was developed consisting of 32 items of questioning attitude, work environment, management commitment and communication, safety priority, communicative information, supportive environment, personal view, involvement and prudent approach. A repeated measure ANOVA with a Greenhouse-Geisser correction and Bonferroni post hoc test $F(3.20, 994.46) = 635.80$, $p < 0.005$, $\eta 2=0.67$) indicated the difference among factors was statistically significant. Structural equation modeling (SEM) and path analysis using AMOS software was analyzing the linkages among the variables. The reliability and validity of the relationship between six safety climate factors and three determinants of risk estimate have been successfully demonstrated. The path coefficients are significant and the overall model has achieved an acceptable fit to the data.

Thus, whilst these findings were consistent with common safety climate themes, it demonstrated a need to take account of individual response and organization cultural factors in the development of safety practice level assessment matrix intended for use in radiation sector. Safety practice level assessment matrix was developed through Delphi Technique with the consensus of experts' opinion through three rounds of interviews on the level of the safety practices, safety practice criteria and indicators.

Triangulation was used to ensure that there was validity in the themes that were arrived at across cases. Safety practices levels were determined. Discrepancies were discussed and adjustments were made to propose the best practices and strategies in strengthening the safety culture and practice based on the assessment matrix and other code of the data mutually arrived at. The safety practice level matrix indicated that the organization can be at different level with the same dimensions. The difference in the level is good to be indicators in controlling the radiation risk and improving the area of safety culture dimension.

These findings provide valuable guidance for researchers, practitioners, regulators and policy makers for identifying the best mechanisms to strengthen the safety culture and risk management of radiation hazard in Malaysia.

Keywords: safety climate, culture, assessment, safety practices matrix, radiation safety

PEMBANGUNAN MATRIK PENILAIAN TAHAP AMALAN KESELAMATAN BAGI RISIKO RADIASI DI KEMUDAHAN TEKNOLOGI SINARAN DI MALAYSIA

ABSTRAK

Kajian sifat iklim keselamatan dan kepentingannya sebagai penunjuk utama prestasi keselamatan telah diakui, namun kebanyakannya dijalankan di negara-negara Barat terhadap operasi berisiko tinggi. Kajian ini memberi tumpuan kepada amalan budaya keselamatan dalam konteks kemudahan sinaran dalam sektor perindustrian di Malaysia. Oleh itu, kajian ini bertujuan untuk menentukan faktor-faktor yang mempengaruhi, mengenalpasti hubungan antara iklim keselamatan dan anggaran risiko; dan tahap amalan budaya keselamatan. Enam faktor dalam kit amalan keselamatan Malaysia (MSTK) dan amalan kebudayaan keselamatan yang dicadangkan oleh Agensi Tenaga Atom Antarabangsa (IAEA) telah diterima pakai dan disesuaikan dengan kit amalan keselamatan sinaran Malaysia (MRSTK). Sembilan faktor dalam model alternatif MRSTK telah dikenalpasti, terdiri daripada 32 perkara termasuk sikap mempersoalkan, persekitaran kerja, komitment pengurusan dan komunikasi, keutamaan keselamatan, maklumat komunikatif, sokongan persekitaran, pandangan peribadi, pendekatan berhemat dan penglibatan pekerja. Pengukuran ANOVA berulang dengan pembetulan Greenhouse-Geisser dan ujian post hoc Bonferroni $F (3.20, 994.46) = 635.80$, $p < 0.005$, $\eta 2 = 0.67$) menunjukkan terdapat perbezaan yang signifikan secara statistik di antara faktor-faktor tersebut. Pemodelan persamaan struktur (SEM) dan analisis hubungan menggunakan perisian AMOS menganalisis hubungan di antara pembolehubah. Kebolehpercayaan dan kesahihan hubungan bagi enam faktor iklim keselamatan dengan tiga penentu anggaran risiko telah berjaya ditunjukkan. Pekali hubungan dan indeks kesesuaian model memberikan data yang signifikan. Oleh itu, penemuan ini adalah selaras dengan sifat iklim keselamatan yang mempengaruhi prestasi keselamatan. Ini menunjukkan keperluan untuk mengambil kira tindakbalas individu dan faktor budaya organisasi bagi pembangunan kerangka tahap amalan budaya keselamatan yang akan digunakan untuk sektor teknologi sinaran di Malaysia.

Matrix penilaian tahap amalan keselamatan dibangunkan menggunakan teknik Delphi dengan mengambilkira keseluruhan pandangan pakar melalui tiga pusingan temubual mengenai dimensi, indikator dan tahap amalan budaya keselamatan.

Kaedah triangulasi digunakan bagi menentukan kesahihan tema-tema yang telah dikenalpasti dalam beberapa situasi berbeza. Amalan dan pengajaran telah dibincangkan dan disuaipadan bagi menyediakan cadangan amalan terbaik dan strategi bagi meningkatkan amalan budaya keselamatan sinaran. Tahap amalan budaya keselamatan dikenalpasti. Matriks amalan budaya keselamatan menunjukkan bahawa setiap organisasi berada pada tahap yang berbeza dengan dimensi pengukuran yang sama. Perbezaan ini penting sebagai petunjuk dalam meningkatkan tahap keselamatan sinaran di Malaysia.

Penemuan ini memberi panduan berharga bagi penyelidik, pelaksana, penguatkuasa dan pembuat dasar untuk mengenal pasti mekanisme bagi mengukuhkan keselamatan dan pengurusan risiko sinaran di Malaysia.

Kata kunci: faktor iklim keselamatan, budaya, matrik amalan keselamatan, keselamatan sinaran.

ACKNOWLEDGEMENTS

First and foremost grateful thanks to Allah s.w.t for guiding and helping me in the completion of this research and thesis.

I would like to thank and extend my deep gratitude and appreciation to my supervisors Assoc. Prof. Dr. Che Rosmani Che Hassan and Dr. Mahar Diana Hamid for their continuous support, ideas, contribution, guidance and motivation throughout this research implementation.

Thank you to all the managers and representatives' from these respective organizations involved for their cooperation, data, information, documents and explanation:-

Malaysian Nuclear Agency

Nuclear Malaysia Training Centre

Atomic Energy Licensing Board

Department of Occupational Safety and Health Malaysia

PERKESO

I am also thankful to the Ministry of Energy, Science, Technology, Environment and Climate Change and Malaysian Nuclear Agency for giving me an opportunity to further my studies. My appreciation also goes to the Public Service Department for the financial support. On my personal note, I would like to thank my husband Md. Rashidi Johari, my daughters and family for their support, encouragements in this journey. I would also to thank all my friends and colleagues in providing me with all the material, data and supports to complete this research.

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LIST OF SYMBOLS AND ABBREVIATIONS

AELB	:	Atomic Energy Licensing Board
ALARA	:	As Low As Reasonably Achievable
ANOVA	:	Analysis of Variance
AVE	:	Average Variance Extracted
BSS	:	Basic Safety Standards
CFA	:	Confirmatory Factor Analysis
CR	:	Composite Reliability
DOSH	:	The Department of Safety and Health
FA	:	Factor Analyses
GDP	:	Gross Domestic Product
HIRARC	:	Hazard Identification, Risk Assessment and Risk Control
IAEA	:	International Atomic Energy Agency
ILO	:	International Labor Organization
ISO/IEC	:	International Organization for Standardization/International Electro technical Commission
MI	:	Modification Index
MRSTK	:	Malaysia Radiation Safety Tool Kit
MSTK	:	Malaysia Safety Tool Kit
mSv	:	millisievert
NORM	:	Naturally Occurring Radioactive Materials
NDT	:	Non- Destructive Testing
OHS	:	Occupational Health and Safety
OSHA	:	Occupational Safety And Health Act
OHSAS	:	Occupational Health and Safety Assessment Series
PCA	:	Principal Component Factor Analysis
PEMANDU	:	Malaysia's Performance Management & Delivery Unit
PRA	:	Probabilistic Risk Assessment
QRA	:	Quantitative Risk Assessment
R&D	:	Research and Development
RBI	:	Risk Based Inspection
RIA	:	Radiation Impact Assessment
RIDM	:	Risk Informed Decision-Making
RPO	:	Radiation Protection Officer
RSMS	:	Radiation Safety Management System
SAR	:	Safety Assessment Report
SEM	:	Structural Equation Models
SHE-MS	:	Safety Health and Environment Management System
SHO	:	Safety Health Officer
SOCSO	:	Social Security Organization
SPSS	:	Statistical Package for the Social Sciences
SPSS-	:	Statistical Package for the Social Sciences- Analysis of Moments

AMOS		Structures
SPM	:	Sijil Pelajaran Malaysia
TENORM	:	Technologically Enhanced Naturally Occurring Radioactive Materials
TECDOC	:	Technical Documents

LIST OF APPENDICES

CHAPTER 1: BACKGROUND OF THE STUDY

1.1 Introduction

As far as Malaysia is concerned, its involvement in nuclear technology has been marked since the establishment of Malaysian Nuclear Agency in year 1972. This technology has not only probed into the medical line, but also industrial, agricultural, healthcare, and environmental applications. In fact, the 1 Megawatt (MW) research reactors was developed in year 1972. Since its operation, this technology has contributed to approximately 0.032% of the country's gross domestic product (GDP) between years 2006 and 2008 (Malaysia, 2010). The international networking and cooperation between Malaysia and International Atomic Energy Agency (IAEA) has led to successful implementation of nuclear and radiation technologies in the country. The IAEA plays an important role to establish accredited training agencies and certification system, apart from promoting several cutting-edge technologies, such as radiographic testing (Plonsky, 2015; IAEA, 2017). In 2014, some 4959 organisations that applied for nuclear and radiation techniques were awarded licenses under the Act 304. Based on the Malaysian economic transformation plan, Malaysia has been actively exploring nuclear power plant to cater to the national energy security demand (PEMANDU, 2010).

To date, the application of nuclear technology in radiation facilities, in support of the Malaysian industrial sector competitiveness, has been accepted. Even though the technology is matured and has been vastly proven, the research and development (R&D) of the technology in this industrial sector appears to be innovative so as to ensure the safety and security of nuclear material, as well as the operation of radiation facilities. This highlights the radiation risk management systems to be reliable and innovative, especially to increase the level of knowledge, understanding, and awareness concerning risks and hazards, including near miss incidents (Martin et al., 2018; Wheatley, Sovacool, & Sornette, 2016).

According to the International Labour Organisation (ILO), 2.78 million workers face death annually due to occupational accidents and work-related diseases. Some 2.4 million (86.3%) of these fatalities were due to work-related diseases, while over 380,000 (13.7%) resulted from occupational accidents (Kiat, 2017). The Fukushima nuclear power plant accident that occurred in year 2011 exerted an enormous impact and had major implications on risk management within the nuclear industry. The event was scaled as a level 7 accident. No fatality or case of radiation illness was reported, but more than 100,000 people had to be evacuated (ILO, 2011; World Energy Council, 2012). Some countries announced a halt in their reactor operation in order to affirm their policies and review their safety program at the plants (Caballero-Anthony et al., 2014). This is because; preference for nuclear power is deteriorating and people have begun losing trust in nuclear safety and regulations (Arikawa et al.,2014).

With accidents being reported at the global scale and the unfortunate case of Fukushima nuclear accident, Malaysia is positioned at the phase of sustaining its nuclear technology application after 46 years of operation and planning towards the progression of a nuclear power plant. This highlights its safety culture, risk assessment and awareness, which demand assessments and enhancement. Hazard and risk of radiation exposure may arise, hence requiring sufficient management. Unfortunately, quantitative study regarding the safety culture and practice in radiation safety is in scarcity (Ali, 2011[A1][H2]).

In Malaysia, issues related to nuclear and radiation of Asean Rare Earth (ARE) have had an impact on the public acceptance towards nuclear technology (Malaysia, 2010). ARE refers to a Japanese-Malaysian joint venture company established in 1982. The factory was set up at Bukit Merah located in Perak to manufacture rare earth mineral; a process that involves the generation of radioactive by-products. After stumbling upon mishandling of nuclear waste in 1984 and fear of irradiation and lead poisoning, the High Court in Ipoh, on 14th October 1985, ordered ARE to stop 'producing, storing, and keeping radioactive wastes on their land in such a manner as to cause the escape of radioactive gases and wastes'; wherein the injunction imposed specific requirements for storage of waste (Harding, 1995). Lack of preparation, including laws and regulation, enforcement, safety precautions, and technical expertise, was the most critical challenge for Malaysia to handle in managing the processes linked to nuclear material and wastes at that time. With poor management of radioactive waste from ARE, public trust in radiological and nuclear technology began to decline.

In 2012, the operation of Lynas Advanced Material Plant (LYNAS), which is a rare earth separation plant with thorium as the by-product of the process, was approved after several demonstrations and licensed under the Malaysian Atomic Act (Act 304) with supervision and monitoring responsibilities held by the Atomic Energy Licensing Board (AELB) (2014). However, the public has nested fear and distrust towards the management of risks in the related operations, especially after the occurrence of several major nuclear accidents (Nagai & Hayashi, 2000; Greenberg et al., 2014). On top of that, there is limited external and internal risk communications, individual responses, and commitment to risk assessment, including information-sharing on risk analysis.

The statistics displays a staggering number of industrial accidents in Malaysia. From year 2012 until 2016, industrial accidents have escalated tremendously. A total of 66,618 accident cases were reported throughout 2016, reflecting an increment by 3,781 cases or 6.02%, when compared to 62,837 cases recorded in 2015 (Organisation, 2016). As for the case of radiation, more than 20.0% of accidents had been reported from year

2012 until 2016, which caused permanent disability or fatality and the figure was the highest in 2015 (Organisation, 2016). This portrayed a bad perspective on risk management that deteriorated the level of trust amongst the public towards high risk technology. The public would easily oppose the planning and development of any emerging technology, especially nuclear power programs or technologies related to nuclear and radiation.

In conjunction with that, the framework of integrated managing risk systems for radiation hazard has to be devised. The safety practices assessment should be integrated in decision-making, aside from being clearly informed and communicated to all stakeholders as part of the risk assessment process within the related organisations. Fading trust, acceptance, and credibility towards radiation safety management would distract the sustenance and the progression of nuclear technology in the nation. Thus, the development of safety practice assessment framework of radiation risk amidst Malaysian radiation facilities should embed managing risk systems to enhance the safety aspect.

1.2 Problem Statement

Malaysia has in place a legislation system for Occupational Health and Safety [H3](OHS[A4]), with procedures, regulators, and workers to control and monitor the industrial safety and health aspects. Nonetheless, it lacks certain human factors, such as individual response to safety and enforcement of regulation (Isha, 2012). A study by Hassan et al. (2009) suggested that human error assessment must be included in the failure frequency analysis to minimise the likelihood of incorrect risks estimates being assessed. The lessons learned and the best practices from the greater process safety of the petrochemical industry with respect to greater process safety may serve as a role model and a viable benchmark for Malaysia to develop its own integrated risk assessment framework in addressing radiation hazard.

The safety culture assessment has been studied for decades since the Chernobyl Accident that occurred in 1986. Following that, Collins (2002), Guldenmund (2000), Sorenson (2002), Lee (2000), Wahlström and Rollenhagen (2014), and Zohar (2010) associated safety culture with the norms, beliefs, roles, and practice of handling hazard and risks. Unfortunately, these practices differ by culture, nation, organisational priority, employment, and people's attitude towards work safety, as typically performed in Western environments (Chauvin et al.,2007; Mearns & Yule, 2009).

Safety climate assessments have indicated the existence of multiple safety cultures that can negate the effectiveness of safety programs, risk assessments and communication, although they may vary between plants, departments, and job positions (Findley et al.,2007; Rollenhagen et al.,2013; Mbaye & Kouabenan, 2013). The International Conference on Human and Organisational Aspect of Assuring Nuclear Safety, which took place in February 2016, had highlighted the scarcity of safety information dissemination and communication. Translation from the safety management system developed to the individual basis for effective implementation appears to be a challenge to organisations. Besides, several safety culture assessment instruments in nuclear technology, along with their characteristics (reliability and validity), require enhancement for cutting-edge applications (do Nascimento et al., 2017; Guldenmund, 2000).

The safety culture in Malaysia has been practiced in numerous industrial sectors. Several studies concerning safety culture (see Abdullah, 2009; Ali, 2004; Desa, 2013; Hee, 2014; Isha, 2012; Ismail et al.,2009; Ramli, 2014; Rashid, 2012; Sukadarin et al., 2012) have described how certain factors, such as safety management, safety priority, involvement, management, supportive environment, and personal views, have been identified as the influential factors in safety culture that successfully decreased the number of occupational accidents. The factor of commitment from individuals, managers, and policymakers in the light of radiation hazard has yet to be unravelled, especially when compared to other sectors within the Malaysian radiation workplace. Furthermore, it is imminent to address the lack of correlation and the limited significant studies that probe into safety culture variables in relation to safety performance (Ali, 2007).

In another note, the number of industrial accidents in Malaysia has always remained high. Based on the statistical data obtained from the Social Security Organisation of Malaysia (SOCSO), Figure 1.1 presents a decreasing trend in the number of industrial accidents from year 2006 until 2016 (Organisation, 2016). In year 2008, the number of accidents due to work-related activities did not show any improvement. The collaborative and continuous improvement efforts on safety have been implemented to promote safe and healthy workplaces. Responsibilities and commitment exerted by employers and employees towards law and regulations of health and safety are the key elements in minimising the number of industrial accidents (Hui-Nee, 2014).

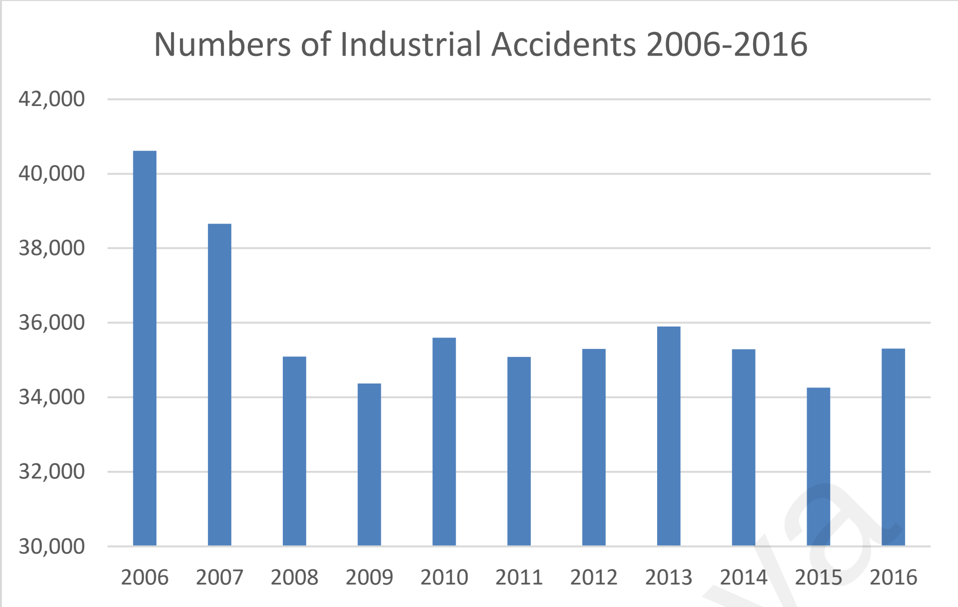

Figure 1.1: Industrial accidents 2006–2016 reported by SOSCO

Radiological and chemical hazard has been classified as Hazardous Material, Substance, and Radiation in the annual report of SOSCO. Table 1.1 illustrates the number of industrial accidents that have occurred in Malaysia due to hazardous material, substances, and radiation. The identified causal agents were explosive materials, flying fragments, radiation, dust, gases, liquids, and chemicals. SOSCO also reported that the number of accidents caused by those agents within the industrial sector has always remained high. Although accidents due to radiation hazard seem to remain low, the trend is inconsistent. This signifies that comprehensive action has to be taken by all parties so as to ensure that the radiation safety management can be strengthened and improvised in sustaining the safe operation of radiation technology in the country.

Table1.1: Number of industrial accidents and causal agent 2012-2016 reported by SOSCO

Causal Agent	Accidents caused by Hazardous Material, Substance and Radiation									
	2012	**%**	**2013**	**%**	**2014**	**%**	**2015**	**%**	**2016**	**%**
Explosives	18	4.0	15	4.1	18	2.0	14	5.3	4	1.5
Flying fragments	89	19.6	83	22.6	151	38.	100	37.6	99	37.5
Radiation	5	1.1	10	2.7	13	3.3	2	0.8	7	2.7
Dust, gases, liquids and chemicals	342	75.4	260	70.6	221	56.2	150	56.4	154	58.3

In addition, it has been observed that efforts are undertaken by the government and other agencies related to the health and safety of industrial players to address greater occupational health and safety challenges (Masilamani, 2010). Safety measures that improvise performance in management of occupational safety, health, and the environment in every industrial sector should emphasise to overcome this problem (Hee, 2014). In radiation protection, the Basic Safety Principles of Radiation Protection, the concept of as low as reasonable and acceptable (ALARA), as well as defence in-depth, have been well implemented in nuclear and radiation facilities to strengthen their safety practices, apart from reducing the number of accidents (Bryant et al.,2017; IAEA, 2002a). However, most of the workers and operators are required to adhere to some bureaucratic and procedural operations that have been translated as a rule among the workers (Hopkins, 2011). The workers and operators, nonetheless, appear to fail to accept the instructions as benefits for their safety, but instead, they opined that the procedural was closely linked with management routine and to comply with the regulators. In some cases, the facilities implemented the safety system due to regulation, licensing, and permit requirement purposes, which reflects solely for their business intention (Basri et al., 2016).

Awareness seems to be lacking amidst the workers who deal with new hazardous and high risk jobs. Knegtering (2009) mentioned that new events occur due to the hazard and risks from the new evolution in industry, society, and technology, which are strongly connected with the organisation, safety culture, as well as lack of knowledge and awareness. Aven and Krohn (2014) highlighted that the concept of mindfulness is related to awareness and sensitivity of workers and operators as a new way of thinking in managing risks. Knowledge sharing and awareness of the hazards and risks need to be updated and informed frequently and continuously with similar level of understanding to hinder unfortunate consequences.

Organisations with safety responsibility and high risks, such as petrochemical plants and nuclear power plants, have developed and assessed their safety culture and practice (Klinke, 2002). As such, the safety framework developed was meant to fulfil the international standard and requirement. Unfortunately, several factors, leading indicators, and maturity level on organisational factors to assess and strengthen the safety culture management practice have been omitted. The drawbacks and loop-hole in managing radiation risks and insecure radiation safety management happen to further tarnish the trust, credibility, and transparency to technology and occupational safety.

The Hazard Identification, Risk Assessment and Risk Control (HIRARC), which identifies hazard, analyses and assesses its associated risks, and then, applies suitable control measures that emerge as extremely important in risk assessment, has been implemented in most of the organisations and industrial sectors in Malaysia (Department of Safety and Health [DOSH], 2008; Gunasekaran, 2006). However, the deterministic elements were excluded from the risk level assessments and were not clearly communicated to those involved at the facilities. The risk information shared in the form of matrix index framework also might reduce the level of misunderstanding and miscommunication among internal and external parties (MacKenzie, 2014). Risk communication is deemed to facilitate and support the inter agency coordination due the emergency response.

Therefore, this study has taken the effort to develop viable monitoring and assessment of safety practices level to effectively manage radiation safety that can strengthen the safety culture, besides improving public trust and acceptance on nuclear technology application. By doing so, the safety of workers, public, and environment is also secured and assured.

1.3 Research Objectives

1. To explore and measure safety climate and factors of safety practices at the Malaysian radiation facilities.
2. To determine the measurement model and the relationships between safety climate factors, risk control measures, decision-making attitude, and risk estimate.
3. To develop the safety practice level assessment matrix and indicators to monitor the risk of radiation hazard in order to minimise risk impact.
4. To validate the practicality of safety practice assessment matrix and to develop safety culture strategies for radiation facilities established in Malaysia.

1.4 Scope of the Research

This study focused on developing a safety practices level assessment framework matrix by using the mixed method technique for industrial radiation facilities established in Malaysia. Generally, the radiation application has been explored and applied in agricultural, healthcare, and environmental sectors. This study looked into the perspectives of employees at the radiation facilities in the industrial sector at peninsular

Malaysia encompassing manufacturing, processing, non-destructive testing, as well as R&D. Those facilities mainly deal with radiation and chemical hazard. In dealing with radiation hazard, several types of safety practices have been devised to handle radiation source, exposure dose rate, and waste management. Both the workers and the management have played their roles and responsibilities in managing the risks. In carrying out the work of supervision, front-line workers are constantly exposed to radiation and danger of accidents. The management fully supports and controls the safety performance due to the cost benefit and the safety of both the public and the environment. The outcomes derived from this study had been based on the work experience of selected participants involved in the facilities mentioned above.

The assessment framework matrix developed in this study had been based on the safety climate factors that influenced the safety performances, but not the direct assessment of safety practice and culture per se. In precise, studies concerning safety practices and safety culture require a broad area to be covered. Hence, this study measured and applied safety climate factors as assessment criteria and leading indicators to determine the level of safety practices so as to strengthen the safety culture at the facilities. Prior studies showed that safety climate can reflect the level of safety culture and safety performance, apart from reducing the number of accidents (Marín et al.,2017; Rodrigues et al., 2015).

In this study, the level of safety practices and its association to risk level, lessons learnt, and best practices were based on the present radiation and chemical hazard reported at the facilities. The practices disregarded hazard and risk from the nuclear power plant although this framework matrix serves as a preliminary assessment to assess the safety practice level in sustaining the nuclear application and [H5]preparing the development of nuclear power plant in the country[A6]. This framework allows the users (workers, regulators, and policy makers) to freely interact with the technical support and facilities that possess the ability to answer all problems linked with the radiation safety management and practices. Additionally, there is a pressing need to assess, improve, and develop specific strategies and recommendations pertaining to the safety culture of radiation management system due to the technology acceptance and trust by the stakeholders. As such, this study strengthens and improves the safety culture, particularly in controlling and monitoring radiation safety due to the horrendous consequences of the hazard.

1.5 Outline of the Thesis

This particular thesis is structured as follows:-

- Chapter 1: the introduction, explains radiation technology and safety management background, as well as the reason for selecting this particular area of study.
- Chapter 2: reviews the concepts of safety culture and safety climate assessment, safety practices in radiation industry, factors that contribute to the safety practices, modelling of safety climate and risk estimate, and the development of safety practices assessment matrix, which form the theoretical and conceptual framework for this study.
- Chapter 3: explains the use of mixed method; quantitative and qualitative analyses of Delphi technique, semi-structured qualitative interviewing, and case studies approach, as the methodology of the study. It justifies the link between the conceptual framework and the choice of methodology, along with the details of its benefits.
    - Chapter 4: Besides the investigation and interpretation of these findings, which were associated with the first phase of the research, the key findings are

presented. The contributing factors of the validity and reliability of the association, hypotheses testing, and safety practices are elaborated.

- Chapters 5: The key findings from the attributes of the assessment matrix of safety practice level, the leading indicators, Delphi Technique on the establishment of safety practice levels assessment matrix, which were associated with the second phase of the research, are elaborated.
- Chapters 6: The key findings of case studies, the methods applied to implement effective strategies and practices for reinforced safety practices against radiation risk, and the validation of the assessment matrix of safety practice level are presented.
- Chapters 7: The findings of the study are elaborated.
- Chapters 8: A conclusion is presented on the research through reflective commentaries on the procedures in overall. This is followed by research limitations, suggestions for practice, and areas for more detailed studies.

1.6 Summary of the Chapter

This chapter outlines the topic and the scope of the study. This research explored and determined the factors that affected the safety practices in Malaysian radiation safety, while concurrently developed the assessment level framework matrix. This matrix can be used to evaluate the safety practice level and its impact on the risk level to enhance the safety culture and to effectively manage radiation risk.

The following chapter explores the literature review with regard to the topic.

CHAPTER 2: LITERATURE REVIEW

Organisation and employers in every workplace have a general duty to ensure the occupational safety and health (OSH) of workers in every aspect related to their work. Over the past decades, significant advances have been made in OSH as many countries have realised its importance and the need to give higher priority to prevent accidents and ill-health at work. The ILO in the 2018 World Day for Safety and Health at Work promotes a safe and healthy generation in the achievement of Sustainable Development Goal (SDG) 8 on decent work and economic growth, apart from the vision of hitting Target 8.8 on safe and secure working environments for all workers by 2030 (Organization, I. L.2018).

The Fukushima nuclear power accident in 2011 had an enormous impact and had major implications on risk management and OSH in the nuclear industry. The event was scaled as a Level 7 accident. Although no death or cases of radiation illness was reported, more than 100,000 people had to be evacuated (ILO, 2011; World Energy Council, 2012).

In consequence to that major accident, the perspective on management of radiation safety and health changed significantly across the globe. People tend to refuse the application of nuclear technology, especially for power generation. The safety culture and practices in non-power facilities have become significant in radiation safety management. The trust level on radiation safety management decreased and respondents tend to focus on accident risks. It requires the radiation managing bodies to competently manage existing hazards, manage new facilities, and communicate honestly with them (Cheok et al.,1998; Kitada, 2016). After the accident, trust in the managing bodies was found to have a stronger influence on perceived risk, and pro-environmental orientation was found to have a stronger influence on trust in the managing bodies (Tsujikawa et al.,2016).

It is observed that after the Fukushima nuclear accident, the management commitment of the radiation risk seems more challenging and important to regain public trust and acceptance towards nuclear technology (Bowers et al.,2017). The radiation risk observed needs to be managed and controlled due to their impact on workers, public, and environment.

The literature review aims to review and investigate safety climate, the practices of safety implemented in the organisation safety culture, and the management of hazard and radiation risk which required monitoring and assessment in radiation facilities.

Safety culture is known as the set of culture which takes organisation (i.e. safety policy, safety management system, and audit), behaviour (i.e. safety-related practices), individual relation (i.e. attitude, psychological, perception), and the attributes of every method of measurement into account (Parker et al., 2006). On the other hand, the safety climate is emphasised in the evaluation of perception for the environment, features, and attributes of the behavioural and situational organisation. Through the climate, it could be seen that the performance and culture of safety have been implemented into the organisation.

Safety climate and safety culture are not identified as separate entities. However, they are known as various methods used to gain the same objective, which is to identify the rule of safety in the organisation. Furthermore, there has been an independent and constant relationship between the perspective of organisational safety culture and corporate safety performance (Fernández-Muñiz et al., 2014). Before new transformations or changes are executed, the safety climate is evaluated to assure the extent of the performance of organisational safety. However, there would be a substantial difference between the relevant safety issues discussed in various studies. These differences could range from global scales which are representative of a single factor to the evaluations which elaborate up to sixteen different dimensions (Flin, 2000).

Safety practice: safety practices present individuals' practices, conducts, and reactions towards the safety culture in the organisation. The evaluation and development of safety practices are highly influenced by perspectives, conducts, and knowledge regarding occupational hazards (Aluko et al., 2016). Additionally, the evaluation of safety practices would be the most preferred method of measuring the performance and culture of safety. It also functions in managing and reducing the possibility of damages to occur at the facilities.

2.1 Safety Culture

A good safety culture is comprised of three characteristics: (1) norms and rules for dealing with risk, (2) safety attitude, and (3) reflexivity on safety practice (Cox et al., 1998). It can be described as the routine practice in managing risk and hazard, which differs according to organisational priority and people's attitude towards work safety (Chauvin et al., 2007).

In the nuclear industry, the IAEA's Safety Series of Safety Culture is defined as follows:

> Safety culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding

priority, nuclear plant safety issues receive the attention warranted by their significance. (Safety series No. 75, INSAG 4, p. 4)

A review by the human engineering group of UK Health and Safety Executive on safety culture definition concluded that the term ‘safety culture’ refers to the behavioural aspects (i.e. ‘what people do’), and the situational aspects of the company (i.e. ‘what the organisation has’). Guldenmund (2000) reviewed the safety culture models for the past 20 years and concluded that the assessment of organisation basic assumption and the core of the culture on safety assumed to be explanatory to its attitude, which is equated to safety climate.

Safety culture can be explained by three characteristics in the relationship of practice and theory on safety, people’s attitude and behaviour, as well as safety system in the organisation. The strong believes and norms on safety assumption lead to the explanatory of the safety performance of people’s attitude and safety management system in the organisation. According to Guldenmund (2017), safety culture assessment refers to the process that offers both cultural insight and opportunities to influence the culture more towards a culture for safety.

There are multiple perspectives on the safety culture model that nurture the safety assessment framework. Coyle et al. (1995) reviewed that safety climate as the perception of organisation reality and the framework suggested that there is a need to include the attitude measurement to complement the assessment. This assessment framework was depicted as unclear on the unit of measurements. The adapted Berends Model by Guldenmuld (2000) defined two categories on safety culture; norm and belief. Norm is divided into individual and interaction, while belief is broken down into six sub-categories. Although the model was built on the basis of perception, behavioural, and situational aspects, the factor analysis presents norm-factors, while the belief-factors were not verified.

Based on the definition and reviews by Cole et al. (2014), Karanikas, Melis, & Kourousis (2017), Kastenberg (2015), Marín et al. (2017), Cooper (2000), and Huang et al.,(2007) with multiple safety culture assessments, the concept of safety culture in this study comprised of three main aspects of physiological, behavioural, and management aspects. Cooper (2000), in his review towards the safety culture model, described that the Bandura's safety culture model explained that the individual physiological factors, the environment, and the behaviour they engage in, operate as interacting determinants that influence each other. The reciprocal safety culture model in Figure 2.1 depicts the impacts of internal and external factors on safety culture.

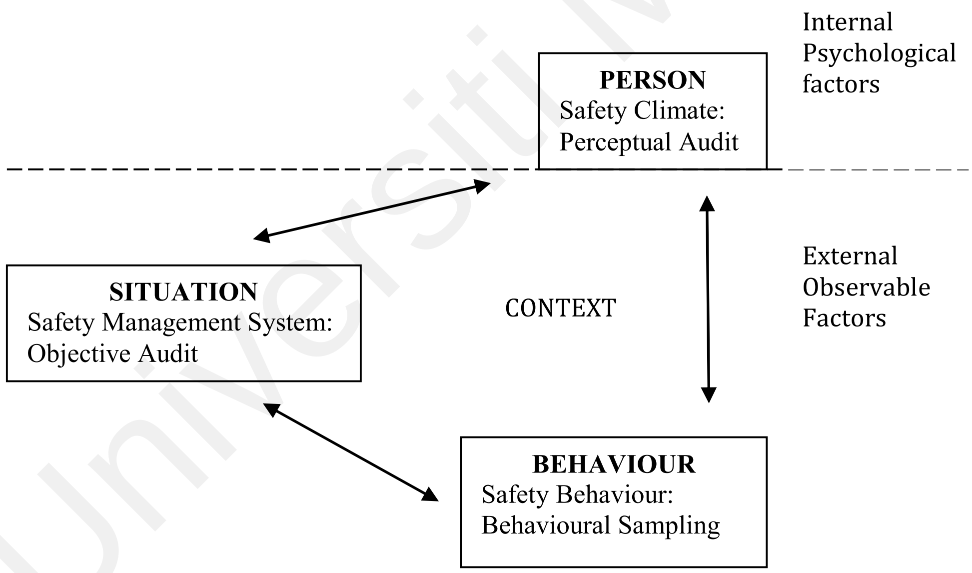

Figure 2.1: Reciprocal safety culture model (Cooper, 2000)

Cooper (2000) also defined safety climate as a summary of molar perceptions shared by employees regarding their working environment and its measurement is thought to provide an early warning of potential safety system failure(s) in the organisation. With regard to safety within an organisation, safety climate has been referred to psychological characteristics of employees (i.e. 'how people feel'), corresponding to the values, attitudes, and perceptions on safety and selected features of their organisational environment (Health and Safety Executive, 2005; Zohar, 2010).

Guldenmund (2000) argued that safety climate to be deemed as an alternative indicator of safety performance with emphasis on its validity. Huang et al., (2006, 2007) suggested that safety climate must be distinguished from other types of organisational perceptions with its ability and the variety of perception-based constructs in safety management researches that contribute to safety culture improvements.

2.2 Safety Climate Assessment

Generally, factors contributing to the safety climate that refer to psychological and perception of the workers was assessed using several assessment tools for various sectors. Based on Table 2.1, several instruments, which were used and reviewed in the industries of nuclear power, petrochemical, oil and gas, and railway in the evaluation of safety climate, is presented (Health and Safety Executive, 2005).

Table 2.1: Safety climate assessment tools

Tool	Factors	Sectors	Reference	Strength and Weaknesses
Aberdeen University Offshore Safety Questionnaire (OSQ99)	- Communication - Involvement in safety - Satisfaction with safety activities - Attitudes to safety - Safety behaviour	Off shore, gas, as well as power generating industries.	Health and Safety Executive (1999, p. 15-18)	Used in offshore, oil and gas, as well as power generating industries. It can, however, be applied to other industries. Applicable to western countries

Table 2.1, continued

Tool	Factors	Sectors	Reference	Strength and Weaknesses
HSE Health and Safety Climate Survey Tool (CST)	- Organisational commitment and communication - Line management commitment - Supervisor's role - Personal role - Workmate's influence - Competence - Risk-taking behaviour and some ontributory impacts - Some obstacles to safe behaviour - Permit-to-work systems - Reporting of accidents and near misses	Industry sectors, including oil and gas companies.	Rail Safety and Standards Board (2003, p. 41)	More safety climate variables assessed. It is used to assess managers, supervisors and the workforce. Applicable to western countries
Occupational Psychology Centre Safety Culture Questionnaire (SafeCQ)	- Management commitment to safety - Willingness to raise concerns - Decision-making - Supervisor responsibility for safety - Questioning attitude - Safety communication - Personal responsibility for safety - Prioritising safety - Training quality	Railway industry and transportation.	Rail Safety and Standards Board (2003, p. 145)	Designed for railway industry. It has only been applied in one organisation from UK and US, respectively

Table 2.1, continued

Tool	Factors	Sectors	Reference	Strength and Weaknesses
Serco Assurance Safety Culture Assessment Tool	- Management & Organisational Factors - Enabling Activities - Individual Factors	UK Nuclear, Eastern European Nuclear, Railway, Oil and Gas industries	Rail Safety and Standards Board (2003, p. 150)	Can be used to assessed safety of nuclear industry Applicable to western countries
INPO's Principles for a Strong Nuclear Safety Culture	- Management commitment to safety - Willingness to raise concerns - Decision-making - Supervisor responsibility for safety - Questioning attitude - Safety communication - Personal responsibility for safety - Prioritising safety - Training quality	US Nuclear Power Plant	Morrow et al., (2014)	Design specific to nuclear power plant More variables assessed Applicable to western countries
Safety Climate Assessment Tool kit,	- Management Commitment - Priority of safety - Communication - Safety rules - Supportive Environment - Personal priorities and need for safety - Personal appreciation of risk - Involvement - Work environment	Offshore environment	Cox and Cheyne (2000)	It can, however, be applied to other industries. Most referred tools in safety climate assessment Applicable to western countries

Table 2.1, continued

Tool	Factors	Sectors	Reference	Strength and Weaknesses
Malaysia Safety Tool Kit (MSTK) 2012	- Safety management & environment - Safety priority - Involvement - Management Commitment - Supportive Environment & Communication - Personal Views	petrochemical	(Isha, 2012)	Design specific to petrochemical industry Applicable for Malaysian culture

(Parker et al., 2006; Cooper & Phillips, 2004; Mearns & Flin, 1999; Swedler et al., 2015) to describe that safety climate can be defined as a summary of molar perceptions, attitudes, and belief to safety, which is often seen as a reflection of an organisation's current underlying culture. Safety climate has become a systematic tool, typically measured by questionnaire surveys in analysing safety culture and improving safety compliance behaviour and safety management (Abdullah, 2009; Kapp, 2012; Kouabenan et al., 2015; Cox, 2000; Casey et al., 2017). Neal (2006), Arezes (2008), and Vinodkumar and Bhasi (2009) showed that lower workplace accident rates are associated with improved safety climates. The safety climate is assessed prior to monitoring the perception on the safety practices through the self-assessment tool kit. Safety climate research is the most common assessment that has led to general consensus on the importance of safety climate as a 'leading indicator' of organisational safety (Zohar, 2010; Curcuruto et al., (2018). Although there are evidences that safety climate may generalise across employment groups (Tomás et al.,2011; Cheyne, 2003), organisations (Mearns et al., 2003) and industries (Hahn, 2008), there has been limited attention in components of safety climate associated with particular industrial sectors or cultural differences. The actual item components of each theme are varied and are likely to be industry or even company specific, related to a particular work practice or policy (IAEA, 1996). According to Guldenmund (2000), the distinctions between assessments of the organisation's basic assumption are more important, since these are assumed to be explanatory to its attitude to safety.

Factors that contribute to the practices of safety in safety climate have been assessed by using several assessment tools for various sectors. Aberdeen University Offshore Safety Questionnaire (OSQ99), HSE Health and Safety Climate Survey Tool (CST), and Safety Climate Assessment Tool kit have been used in offshore, oil and gas, as well as power generating industries. It can, however, be applied to other industries. Occupational Psychology Centre Safety Culture Questionnaire (SafeCQ) and Serco Assurance Safety Culture Assessment Tool have been widely used in railway industry and energy. INPO's Principles for a Strong Nuclear Safety Culture was used in US Nuclear Power Plant (Health and Safety Executive, 2005). Malaysia Safety Tool Kit (MSTK) was initiated in Malaysia's petrochemical industry.

Although some evidence on safety climate factors have been explored successfully, much of this evidence is drawn from across particular industry (Lee et al., 2014; Swedler et al., 2015; Zohar et al., 2014; Beus, 2010; Hahn, 2008; Huang et al., 2013; Flin, 2000; Smith et al., 2006; Rundmo, 2000; Marín et al. 2017; Rodrigues et al., 2015). On a more important note, it should be noted that a comparison across industries, culture, and country is still lacking despite the evidence that safety climate and safety management system may be generalised across employment groups (Cheyne et al., 2003), organisations (Mearns et al., 2003; 2004), and industries (Hahn & Murphy, 2008), while the current assessment tool was found to be more focused on the particular industrial sectors or culture. Safety practices also differ based on the nature of the job and risk level at the facility. Safety culture studies have been typically carried out in western environments (Guldenmund, 2000). There is also a lack in identifying the safety culture maturity level, after certain assessment of safety culture had been carried out. Organisations need to understand their own level of safety culture maturity by assessing the level of compliance with various key elements of safety culture across a number of stages that represent different levels of maturity (Goncalves Filho et al., 2010).

Despite the substantial amount of studies designed on assessment tools, they are generally developed for application in specific industry and country, such as oil and gas, nuclear, or rail industry in the United States of America, United Kingdom, Brazil, Mexico, and China. The Safety Climate Assessment Tool kit (Cox & Cheyne, 2000) was designed to assess the safety culture in offshore environments, which combined several assessment methods, including questionnaire survey, focus groups, behavioural observations, and situational audits, which collectively described and explored the efficacy of health and safety management systems. Adaptation and adoption of the instrument as the Malaysian Safety Tool Kit (MSTK) were done. This tool was involved in a study titled "Occupational Health and Safety Practices in the Petrochemical Industries of Malaysia" (Isha, 2012). Furthermore, MSTK was used for the evaluation of the combination of individual attitudes, perspectives on the commitment of management, and work environment. Contributions have been constantly provided by the six-factor model to the practice and analysis of OHS. As a result, its reliability as an evaluation instrument for culture of safety in Malaysia has been enhanced. These findings were supported by Abdullah et al. (2009), Ali (2004), Desa et al. (2013), Hee (2014), Ismail et al. (2009), Ramli (2014), Rashid (2012), and Sukadarin et al. (2012). In these studies, elaboration was made on management, supportive environment, safety management, involvement, safety priority, and personal views as the influencing elements of the safety practices in Malaysia's construction and manufacturing sectors. Therefore, MSTK was selected as the main instrument for the evaluation of safety climate.

Past studies have shown that safety climate correlates with safety practices that have been implemented. (Varonen & Mattila, 2000) found that safety climate correlated both with the safety level of work environment and with the safety practices of the company. The results of the safety climate also correlated to the accident rate. This result is similar with the studies that looked into safety climate that the distinctions between the assessments of the organisation's basic assumption are more important and had given a variety on the individual's perception and safety-related behaviour of employees (Guldenmund, 2000; Xia et al.,2017). More often, employees' beliefs about the importance of safety are commonly shaped by the safety culture of the organisation, which will influence their attitudes towards safety, perceived norms for working safely, and perceptions of control measures over safe working behaviours (Morrow et al., 2014).

Investigation on the influence of leadership practices towards safety compliance showed that safety climate condition improved as supervisor's leadership practices increases (Kapp, 2012). Zohar (2000) described that safety climate is about the shared perceptions of organisational policies, procedures, and practices of certain features of organisational climate. The study on the simplicity and cross-situational practices by the leader and supervisor showed that the safety practices can enhance safety climate (Zohar & Luria, 2004).

The International Conference on Human and Organisational Aspect of Assuring Nuclear Safety, which took place in February 2016, concluded that there is a lack of safety information dissemination and communication in the nuclear industry. It is very challenging for an organisation to effectively implement the translation from the safety management system to the individual basis. Safety climate assessments indicate the existence of multiple safety cultures that can negate the effectiveness of safety programs and communication. Furthermore, it should be noted that there are a few safety culture assessment instruments with characteristics (reliability and validity) and needs adjustments to manage risks of new application (do Nascimento et al., 2017).

Safety climate assessment has been described differently across nations, people, and job specification. The factors of safety climate correlated with the safety practices and behaviour of the organisation. These points out arguments that organisation with different safety cultures have different practices. The safety practices implemented may reflex the climate and the culture of the organisation. The best practices in an organisation may be adapted by other organisations. This encourages benchmarking among the facilities and to develop good interagency networking amongst the sectors.

2.3 Safety Practices in Radiation Industry

In radiation facilities, the safety culture framework is answerable to the management hierarchy and staff attitude across levels in responding to and benefiting from the framework (IAEA, 1991). IAEA safety series, in particular, have recommended the factors of questioning attitude, rigorous and prudent approach, and the necessary communication in assessing the staff's attitude towards effectively monitoring individual response to safety. Therefore, the effectiveness of the system was determined by the person or related personal (Wachter & Yorio, 2014). Attitude of staff was evaluated based on responsibility and response of the individuals.

After the Fukushima incident, the perspective on safety culture and risk management in nuclear power plant and facilities have changed (Tsujikawa et al., 2016; Kastenberg, 2015; Wakeford, 2016). Nuclear facilities have taken initiatives to strengthen their safety practices to control and to monitor radiation risk. The discussion ranges on the relationships between safety culture, safety practices, ethics, and risks. Whitton et al. (2015) argued that safety culture and societal culture are incongruent of each other, thus influencing and reflecting the Fukushima accidents.

Past studies have reported that safety climate assessments in nuclear facilities indicate the existence of multiple safety practices that can negate the effectiveness of safety performance, but they differ between plants, departments, and job positions (Findley et al., 2007; Rollenhagen et al., 2013; Mbaye & Kouabenan, 2013). The personal safety survey and information on the risk must be enhanced and be useful to deliver multi-perspective and comprehensive assessment (Kim et al., 2008; Keller & Modarres, 2005; Lee, 2000; Ahn & Park, 2009).

Experience of several nuclear power plants showed that the management of safety culture, including regulatory commitment, policy, management commitment, and individual response, has to be undertaken in the same manner as with any other business objective. However, there are needs to be a mechanism for separately identifying the safety culture improvements (IAEA, 1997). Therefore, it is necessary to continue efforts to increase comprehension, as well as promote and enhance safety culture in the plant and facilities. It is also suggested that safety culture self-assessments being implementing to assess and strengthen the safety culture of nuclear facilities and any other practices or circumstances, in which people may be exposed to radiation (IAEA, 1999, 2016b, 2016d).

Nevertheless, the effectiveness and the validity of the safety practice assessment tool must be assessed and developed, tailored to each industry respectively, whereby difference may present across sectors and organisations. Varying levels of understanding may pose as a challenge to organisations, rendering it as necessary for leadership and communication skills to be evaluated and improved for the purpose of managing risk and hazard-related accounts. The nuclear industry specifically must extend beyond its hub to learn and strengthen its safety culture approaches (IAEA, 2016a) and every personnel in the facilities is suggested to be responsible and play their role in strengthening the safety practices (Yang, 2014).

2.3.1 State of Safety Practices in Malaysia

Safety culture in Malaysia has been practiced in various sectors of industry. Several studies on safety culture and practices (Abdullah, 2009; Ali, 2004; Desa, 2013; Hee, 2014; Isha, 2012; Ismail et al., 2009; Ramli, 2014; Rashid, 2012; Sukadarin et al., 2012) described how several factors, such as safety management, safety priority, involvement, management commitment, supportive environment, and personal views, serve as the influential factors in safety culture and reduced the number of occupational accidents. Amirah et al. (2013) found that the levels of safety culture in the manufacturing sector in Malaysia were influenced by three main independent variables: i) individuals' commitment, ii) managers' commitment, and iii) policy commitment. The preliminary survey in the construction sectors had identified leadership, organisational commitment, management commitment, safety training, and resource allocation as practices, which embedded safety culture into organisational culture (Ismail et al., 2010), while in the manufacturing sector, leadership support, management commitment, and safety management system were important factors that contributed to safety culture (Hee, 2014). Safety practice in petrochemicals organisations refers to the combination of work environment, individual's attitude and perception about safety, as well as management commitment. Safety management has been practiced widely in the petrochemical industry, starting with commitment and planning by the management level that manages the entire activity for the health, safety and welfare for the workers (Hanafi, 2007;

Bowers & Fleming, 2017). The most influential factors, such as personal factors and safety awareness, should be included in the safety practice framework of the organisation (Zubaidah et al., 2012). Effective safety culture in individuals contributes to a high level of safety practice and generates personal pride in dealing with important tasks (IAEA, 2002b).

However, there is still lacking of quantitative study on the factors of safety practice in radiation (Ali, 2011). In radiation safety, Ali (2014) reviewed the needs and challenges in promoting safety culture and safety practice. Factors of individuals' commitment, managers' commitment, and policy commitments had not been identified and were not quantifiable compared to other sectors in the Malaysian workplace. There was also lacking in correlation and a significant study between safety climate variables and safety performance (Ali, 2007). Sangau (2012) determined that job safety, supervisor safety, as well as safety program and policy had a significant relationship with safety behaviour of industrial radiographers. However, there is no evidence on the reliability and validity of the relationship.

The mishandling of nuclear waste in 1984 and fear of irradiation and lead poisoning decreased public trust in the radiological and nuclear technology. In 2012, the operation of LYNAS, the rare earth separation plant with thorium as a by-product of the process, has been approved and licenced under the Malaysian Atomic Act (Act 304) with supervision and monitoring by the AELB, after several demonstrations (AELB, 2014). The public still has fear and distrust of the management of the risks of the operation especially after major nuclear accidents happened worldwide (Greenberg et al., 2014; Nagai & Hayashi, 2000). There is also lacking in external and internal risk communication, individual response and commitments to risk assessment, as well as information-sharing on risk analysis to be practiced.

2.3.2 Factors that Contribute to the Safety Practices in Malaysian Radiation Facilities

Malaysia's involvement in nuclear technology began in earnest following the setting up of Malaysian Nuclear Agency in year 1972. The technology has been explored in industrial, agricultural, environment, and medical sectors. The 1 MW research reactors had been developed in year 1972. Since its operation, this technology has contributed about 0.032% to the country's GDP for years 2006-2008 (Malaysia, 2010). To date, the application of nuclear technology in radiation facilities in supporting the Malaysian industrial sector competitiveness has been accepted. The variety of nuclear and radiation techniques being applied are significant to the environmental-friendly, socio-economic benefits, as well as high quality training and education. Malaysia needs to improve and upgrade its self-assessment safety culture systems due to the demands of technology and the needs of the nation (Desa, 2013).

In controlling the risk and in reducing the number of accidents related to radiation risk, Shaluf (2006) described that Malaysia has a good safety management in regard to major hazard control systems. The DOSH regulates the occupational safety and health act, OSHA 1994. Meanwhile, Atomic Energy Act, Act 304 has regulated the application of nuclear and radiation since 1984. The regulation and control of nuclear and radiation application in Malaysia is detailed in the Atomic Energy Licence Act (Act 304), which has been established under the Ministry of Science Technology and Innovation. In 2014, 11,179 radiation workers were recorded in the system, consisting of 1347 workers in industrial radiography and 9832 workers for other activities, inclusive of medical sector. There were 1123 non-medical organisation license holders, comprised of industrial radiography, NORM/TENORM, as well as radiation processing and gauges (AELB, 2014).

Since the publication of the International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources (the BSS) in 1996, the radiation practitioners devoted efforts to continue improving radiation safety by establishing and strengthening national infrastructures for radiation protection. In the Fundamental Safety Principles, there are clear references to quality assurance as an essential component of radiation safety. The development of management system of radiation safety in facilities can improve the quality assurance and quality control of radiation safety. It also demonstrates great efforts of the regulating body, AELB, and Nuclear Malaysia to promote radiation safety awareness among radiation workers through a good radiation protection management programme at the workplace, including quality management, auditing, training, and certification of RPO. Additionally, the implementation of a responsible safety management practice, inclusive of compliance to the safety standards, as well as internal and external parties audit processes, have aided in reducing the number of accidents (Ali et al., 2009).

Hence, it has been observed that Malaysia needs to improve and upgrade its safety culture systems and safety practice as a tool to manage radiation risk and hazards, risk control strategies, and decision-making attitude for the purpose of fulfilling the demands of technology, particularly the preparation for nuclear power plant development (Desa, 2013). Therefore, there is a clear need to develop a model framework of the safety practices and its relation for the purpose of estimating the risk level in order to manage and control radiation risk.

Meanwhile, from year 2008, the number of accidents caused by work-related activities did not show any significant decreasing trend. There were 35304 cases in 2016, an increase of 3.05%, from the year 2015, which saw a total of 34,258 cases (SOSCO, 2016). The accidents happened due to hazardous material, substances, and radiation in industrial sector remained high at the average of 631 accidents per year (SOSCO). This is believed to be caused by the lack of safety indicators and safety performance (Tang et al., 2017), individual response on safety and risk (Hassan et al., 2009; Sangau, 2012), commitments to risk assessment (Sukadarin, 2012), and information-sharing on risk analysis (Amirah et al., 2013). Meanwhile, there is still limited number of quantitative studies that have identified the safety practice in radiation safety (Ali, 2011).

Since an efficient safety culture may reduce the number of accidents, it has called for an investigation regarding factors influencing safety culture in petrochemical and radiation industries. Sorenson (2002) has specifically highlighted that a good safety culture by all personnel can ensure organisational safety, which is affected by the factors of controlling and prioritising to confirm the safety practices of the process. In technology emerging, the preparation to establish an effective risk managing system is necessary to increase public trust and positive perception (Aven & Kørte, 2003). Furthermore, the nuclear and radiation industry will also benefit from learning the practices of other industries with similar cultures in strengthening their safety practices (Morrow et al., 2014).

In Malaysia, the implementation of safety practices in the petrochemical industries has been slowly dominating the landscape, whereby a well-developed safety system fitted to unique field characteristics and processes involved is of paramount importance (Tang et al., 2017). Safety management, in particular, has been practiced widely in the industry, commencing with planning at the management level and encompasses the management of the activity for the workers' health, safety, and welfare (Hanafi, 2007). Meanwhile, safety improvement programs within the industry locally has been recommended to include the development of human capabilities, personality characteristics, and motivation in commitments towards safety in workplace (Salleh, 2010; Fleming, 2012). Therefore, the factors contributing to OSH practices in Malaysian petrochemical industry could be compared to those of the nuclear and radiation industries so as to identify the gap between practices and to strengthen the relevant approaches.

Taking lessons learnt from the safety culture practised and studied in the various sectors in Malaysia, there is lacking in the influencing factor of individual response (Faridah Ismail, 2010; Gunasekaran, 2006; Hee, 2014; Hui-Nee, 2014; Ismail, 2009; Tong et al., 2015). Employees and management alike have highlighted the need to strengthen and highly prioritise safety when dealing with harmful materials, even though the workers in particular have shown compliance with the safety procedures and are aware of the consequences of any hazards. The current situation of safety practices has become a threat that will prevent this nuclear technology from being sustained and developed. Furthermore, there is still a lack of trust among public and stakeholders on the safety practices and regulation in controlling risks of nuclear and radiation facilities (AELB, 2014).

Therefore, detailed examination of the factors and relationships between each factor for the nuclear and radiation safety practice assessment in Malaysia will be undeniably beneficial. These practices can also be improved and strengthened by identifying and adapting contributory individual response and commitment factors in these assessment tools. Additionally, direct comparisons between factor labels and loading items across these measures are also instrumental in delineating the benchmark between industries.

2.4 Safety Practices in Managing and Controlling Major Hazard and High-Risk Processes

In this case, it should be clearly understood that every work-related activity is concerned with risks and hazards, which may be considered as high, medium, or low risk. The identification and assessment of the possible hazards and risks need to be managed and controlled to protect the safety and health of the workers and the environment. Hence, risk management is regarded as a formal process that will be very effective in managing risks consisting of hazard identification, assessment of risk, identification of risk control options, as well as the evaluation, monitoring, and review of the risk at the workplace (Azuddin et al., 2013).

Risk assessment is a main contributor in probability, consequences determinant, and hazards control in safety and risk management system. In short, it can be said that everything is all about probability and uncertainty. On a more important note, two main approaches of the risk assessment have been widely applied in process safety are deterministic and probability approaches. The demands on the integration of all aspects of the safety system, which include the technical and non-technical aspects, have been increasing. However, stakeholders and industrial players may keep their high trust and confidence on the regulators and decision makers, which also acts as a motivation to the top management to give high priority of the safety system in regard to the plant or processes. The deterministic approach has been used for many years to control risk and hazard, despite its limitations (Zio, 2009).

The deterministic approaches emphasise on the capability of the engineering principle, which includes the protection from safety margin, barriers, regulatory compliance, and depth. This principle is also able to manage and reduce the damage and impacts. Meanwhile, as for complex systems, the daily self-tests do not have the capability of showing the potential disadvantages which may restrict the provided barriers from properly functioning (Zio, 2009). A limitation also persists in the process in terms of identifying each aspect of the disadvantage. Meanwhile, the integrated approaches between deterministic and probabilistic risk assessments tend to complement each other, whereby the valuable information obtained from the risk analysis will express, communicate, and influence the decision-making attitude.

Huang et al. (2007) emphasised the importance of company level factors in the attempt of understanding the differences between day shift and night shift work, particularly on individual perception of work injury risk. In this case, the organisational safety culture and probability of the risk seem to influence individual risk estimate. Apart from that, Huang et al. (2006) demonstrated that safety climate is related to self-reported injuries as captured through its various dimensions. The mediator analysis between safety climate and injury revealed that perceived management commitment to safety is the most robust predictor of occupational injuries (Beus et al., 2010). Additionally, there is a significant relationship between safety climate factors and safety performance in managing risk. Moreover, the safety climate is believed to improve the safety performance and minimise risk and hazard. On a similar note, Cox and Cheyne (2000), Sukadarin et al. (2012), Al-Refaie (2013), Mearns et al. (2003), and Smibert and Fleming (2017) also explored the perception of employees towards safety, and the results showed a significant effect on the safety performance and safety management system that are associated with lower accident rates. Meanwhile, Neal (2006), Arezes and Miguel (2008), and Vinodkumar and Bhasi (2009) illustrated that lower workplace accident rates are associated with improved safety climates. Ramli (2014) managed to reveal a relationship between safety climate factors and the level of awareness of OSH.

The strong safety culture may reduce the impact of individual accident (Mearns & Yule, 2009). Safety culture stimulates the risk assessment process and decision-making to manage risk in a proper way, as well as to decrease the number and the impact of major accidents (Wahlström & Rollenhagen, 2014). The major accidents demonstrate the importance of safety practice and risk management to have a comprehensive assurance system that delivers a real picture of how risk and hazard is managed, communicated, and understood, with a robust programme of continuous improvement and monitoring (Gil, 2008).

2.4.1 Risk Control

Risk control utilises any suitable method to control, reduce, or eliminate residual risks that are deemed to contribute to the increasing rates of industrial accidents, which is considered as a vital measure in managing risks (Badri et al., 2012). There are several types of risk control of health and safety at work, as well as choices of control options. McQuaid (2000) summarised the risk control principles into the following four hierarchy levels: (1) eliminating risk by substituting the hazard, (2) combating risk by engineering control, (3) minimising the risk using working system, and (4) minimising risk using personal protective equipment. In addition, regulatory framework plays an important role in controlling risks. The DOSH Malaysia employed the Hazard Identification and Risk Analysis Risk Control (HIRARC) for the purpose of analysing and minimising risks using four types of controls. The first category refers to the elimination and substitution of the hazard that are applied at the source of the hazard. The second category is described as engineering control performed by redesign, isolation, and barrier. The third category is described as administrative control that is carried out using safe work procedure, training, job rotation, and maintenance. Finally, the fourth category refers to the personal protective equipment that is used when other control measures are not feasible (DOSH, 2008). HIRARC has been implemented in most of the organisations and industrial sectors in Malaysia, including the petrochemical sector, as a safety team assessment approach to risk (Gunasekaran, 2006).

The system should be able to estimate risk level for each hazard in a task apart from identifying hazards. According to the Joint Standards Australia, risk estimated for each hazard in a task is influenced by the following four major factors:

- Likelihood - Probability of an accident to occur due to the identified hazard within a certain time frame.
- Severity - Seriousness of an injury to the identified hazard.
- Exposure rate - Frequency of workers to conduct their task (daily, weekly, or even monthly bases).
- Existing control - Identify the control measures and type that exists in the current environment.

There is an increasing number of accidents that occur due to the lack of appropriate hazard evaluation and risk management system (Nicol, 2001). Hence, it is deemed important to find ways to eliminate hazards or control the associated risks in minimising workplace accident, injury, and illness (Kennedy, 1998). Fukushima nuclear power accident shows that there is good and adequate engineering control, while reactors core is made of fuel assemblies, control rods, and neutron monitoring system. Moreover, several control measures have been taken, including reactivity, reactor pressure, containment pressure, temperature, reactor inventory, and emergency cooling system. The report produced from the accident highlights the need to thoroughly instil a safety culture. Apart from that, there is also a lack of leadership and safety culture indicators (NAIIC, 2012)[H7][A8]. In this case, safety culture and safety practices emphasise the continual improvement of nuclear safety and the importance of identifying the weakness to avoid failure.

Risks can be controlled by high level safety practices of every personal in the facilities. Continuous training, awareness on risk, hazard identification, and administrative control will encourage workers to manage risk in regard to their routine job (Scott et al., 2014). The priority to safety, workers involvement, and management commitment practice may influence the implementation of risk control measure. More importantly, employees' beliefs about the importance of safety are shaped by the safety culture of the organisation, which will then influence their attitudes toward safety, working safely, and perceptions of control over safe working behaviours (Morrow et al., 2014).

Therefore, a study on the new technology deployment in nuclear power plant revealed that proper Risk Management (RM) is necessary for the purpose of ensuring the safety and performance of nuclear power plants based on the fact that it provides the mean to identify risks and minimise their impacts, especially risk control and safety culture (Jung & Roh, 2017).

2.4.2 Decision-Making Attitude

Organisation commitment and individual behaviour on safety are believed to contribute significant effects on individual safety awareness and practices (Hsu et al., 2010; Didla et al., 2009), which is also believed to encourage a good decision-making attitude that requires sound knowledge and experience of the object (Rundmo, 2000). Kadak and Matsuo (2007) described that awareness on the risk is an important aspect of RIDM of nuclear safety and operation. In general, the decision-making habits are related to the feeling of the affect, risk, and benefits of the activities, whereby the information about benefit will change perception of risk and vice versa (Slovic et al., 2005). On top of that, the ability of workers to make self-decision on the risk management may vary based on the information, understanding, and experience of the risk (Amendola, 2001). In precise, different understanding may affect the decision-making process which will cause abnormality or accident (Mearns et al., 2004). Meanwhile, the leadership and communication skills that are regarded as safety climate factors are required to be evaluated and improved (IAEA, 2016a). On a similar note, Zio (2009) and Donovan et al. (2018) described that decisions need to be made for the purpose of minimising the impact on the productive and safe operation of the system.

In general, the insights of the probabilistic approach seem to complement those of the deterministic approach. In view of this, the trend has moved towards a risk-informed approach, whereby the insights from the risk information provided by the PRA are formally used as part of the integrated decision-making process. Hence, this is referred as Risk-Informed Decision-Making (RIDM), especially when the integrated process is applied in the decision-making process on safety issues. RIDM is defined as a deliberative process that utilises a set of performance measures, together with other considerations, particularly to "inform" decision-making. The RIDM process acknowledges that human judgment has a relevant role in the decision-making process, while technical information also cannot be regarded as the unique basis for decision-making. This is believed to be caused by the inevitable gaps in the technical information, as well as based on the fact that decision-making is an intrinsically subjective and value-based task. Hence, the cumulative knowledge provided by experienced personnel is essential for the purpose of integrating technical and non-technical elements to ensure dependable decisions can be produced, especially in tackling complex decision-making problems involving multiple and competing objectives (Aven, 2012).

The risk-informing process ensures that the selection of decision alternatives will complement all the competing alternatives. The purpose of this is to encourage the project success without causing any late design changes, sources of risk, cost overshoot, delays, and cancellation (Saji, 2003).

2.4.3 Integrated Risk Assessment for the Risk-Informed Decision-Making (RIDM)

Risk-based on safety management and risk control system has been maturely implemented in petrochemical and oil and gas industry using quantitative risk assessment (QRA) since years ago. Petrochemical and refinery industry was the best implementer of risk-based inspection (RBI). If the inspection is as low as reasonable, the total risk can be markedly reduced, with its applicability and cost reduction being enhanced (Chang et al., 2005). These industries achieved their current levels of performance with the acquisition of good attitudes to safety issues and the application of systematic management of the hazards of the business (Hudson, 2003).

This approach benefits the inspectors and regulators to ensure the safety and health of the process and workers in the plants. From the review for the past two decades, it has seen an evolution of risk-based to risk-informed safety management approaches, in which quantitative outcomes of risk assessment are only one component of the decision-making process, being combined with other criteria, such as social preferences, political concerns and budgetary constraints (Torabi et al., 2006).

According to Chang et al. (2005), an integral inspection methodology on piping should consist not only of an efficient inspection strategy and reasonable inspection planning, but also of reliable inspection methods, professional analysis and continuous improvement of the piping inspection management system. This concludes that, to make decisions in the inspection process, the integrated information is needed to include neither the technical data nor the other criteria (non-technical data) of the safety system. It, sometime, aims to inform the when, where, who and how to inspect based on the risk assessment information analysed. With the integrated approach of RBI and RIDM, the safety management system of petrochemical and refinery industry becomes safer and healthier for workers and the environment.

NASA and USNRC haves developed and designed the RIDM framework to regulate the aerospace system and nuclear power engineering. In the beginning, a deterministic approach was chosen as the basis for making decisions on safety issues. Recently, due to the increasing safety concern from the public and stakeholders, the probabilistic approaches have been chosen to regulate the safety system. The motivation to implement the RIDM was due to the probabilistic risk assessment (PRA) that have been carried out demonstrated that some of the contributions to the risk have not been adequately controlled by the deterministic approach (Zio, 2012). The spirit of the RIDM is to complement the deterministic and probabilistic approaches.

In safety and risk management system, risk assessment is a main contributor in probability, consequences determining, and controlling hazards. It is all about the probability and uncertainty. The NETworked hazard analysis and risk management system (NET-HARMS), was successfully designed to emergent risks that are created when risks across the system interact with one another (Dallat et al., 2018). Two main approaches of the risk assessment, which are deterministic and probability approaches, have been widely applied in process safety. Because of the safety concern of the workers and public increasing due to the emerging technologies, the systematic safety management and control system need to be established. Even though the deterministic approach has some limitations, the approach has been used for many years to control risk and hazard (Zio, 2012). The reviewed by (Zio,2012) described that the integrated approaches between deterministic and probabilistic risk assessments complement each other and the valuable information from the risk analysis will be expressed, communicated, and used by the decision makers, and not only by scientists and engineers.

The RIDM benefits both the technical and non-technical teams. The integrated information on risk assessment of risk control and hazard management of the process will upgrade the performance of the business. Through RIDM, the analysis starts from a comprehensive list of initiating events and sets out to identify all the fault sequences that could lead to system initiating event frequencies and system/component failure probabilities. The information is also explicitly provided and not approximately in the PRA model: thus, through PRA, it is possible to determine if the design is balanced. The analysis for RIDM provides a quantitative estimation of the level of risk from the system. RIDM also aims to provide all valuable data from the risk analysis to ensure the successful implementation of the project. The risk-informing process ensures that the selection of decision alternatives will complement all the competing alternatives. This encourages the project success without late design changes, apart from creating sources of risk, cost overshoot, delays and cancellation (Saji, 2003).

2.5 Methods of Assessment

According to Cooper (2000), there are different assessment approaches for each element; psychological factors (attitudes and perception) are assessed via safety climate questionnaire, safety-related behaviour checklist for on-going safety behaviour, and safety management audit for situational factors.

Such reciprocal concept of safety culture offers varied assessment methods with either single or combined approach that can quantify the significance of safety culture in organisations. Cooper (2000) reviewed that the same concept and common frame of reference will open the opportunity to implement benchmarking in order to improve and to strengthen the culture of safety in an organisation. With different methods of assessment, the triangulation method in the safety assessment provides a valid and reliable assessment framework. The integration of the safety concept from several aspects; internal and external factors, encourages integrated thinking and safety assessment that complement each other.

2.5.1 Mixed Methodology

The mixed method has been used as a research design for decades ago especially in the social research work starting with the formative period in the 1950s until 1980s to the advocacy as a separate design period in the 2000s across multiple disciplines (Creswell & Plano, 2007). The mixed method has been applied in many works of research related to entrepreneurship, marketing of operation management, and organisational behaviour. In general, mixed methods research involves collecting, analysing, and interpreting quantitative and qualitative data in a single study or in a series of studies that investigate the same underlying phenomenon (Leech, 2008; Maxwell, 2016).

There are several purposes to use the mixed method, such as to seek convergent results (triangulation), to explore interconnected aspects of the phenomenon (complementary), to examine similarities, variances, and new perspectives (initiation), to add breadth and scope of the project (expansion), and to complement another method (development) (Greene, 1993b). Broenstein and Kovac (2013) described that mixed methods require a great deal of creative decision-making that goes beyond traditional quantitative study designs, a well-conceived explanation of one's rationale for choosing certain methods, research designs, and steps for helping to assure rigor is required.

Conducting triangulation in research which implements the mixed method research requires the ability to understand both quantitative and qualitative approaches. Each method has advantages and disadvantages that will complement each other in providing in-depth understanding and in exploring the research questions. Ivankova et al., (2006) stated "when used in combination, quantitative and qualitative methods complement each other and allow for more robust analysis, taking advantage of the strengths of each." The strategy for mixing methods must be explicit and justified in terms of the sequence of methods (concurrent, qualitative first, or quantitative first), the priority among methods (equal, or either method prioritised), and the nature and timing of integration (full or partial, during data collection, analysis, or interpretation) (Lingard et al.,2008).

The explorative mixed method is designed to consider that qualitative analysis would usefully supplement and extend the quantitative measures to fulfil the aim of a study (Morse, 2016). The explorative design was selected because the questionnaire data were used as a basis for a deeper understanding on the factors that affect the safety culture and its relationship with radiation risk. The factors of safety culture and safety practices need to be further expanded and explained about the practices of beliefs and use the cross-check of observable behaviour to validate spoken accounts in developing the safety practice assessment matrix.

In this study, the triangulation methods data collection strategies were chosen. Data collected in one phase of an iterative process contributed to the data collected in the next phase with different method. This method was considered because the earlier data were collected in these designs provide broader understanding about the results and analysis, to enable the researcher to select participants who can best provide the next data, or to generalise findings by verifying and augmenting study outcomes from the members of a defined population (Creswell & Plano, 2007).

The triangulation approach is a more experimental approach to creating the safety practice evaluation framework matrix. Furthermore, strategic and comprehensive associations between the methods could be achieved by combining quantitative and qualitative methods. In comparison to a single method, this combination could assure that a more significant comprehension could be created through the data converged or triangulated (Lingard et al., 2008; Maxwell, 2016). Therefore, it is possible for a study where the mixed method is applied to retrieve information from various dimensions, which would be useful to acquire precise and feasible answers to the research questions (Cushinery, 2011).

The Delphi technique is a method suitable in many works of research for consensus-building. It involves a list of questionnaires for the collection of information from a panel of chosen subjects (Hsu et al., 2010). Furthermore, it is a widely accepted and used method to collect information from respondents within their field of expertise. This technique is formed as a group communication procedure, where a convergence of opinions on a particular real-world issue would occur (Hsu, 2007).

This study aims to create the attributes and indicators as the assessment matrix for the evaluation of safety practice level. The underlying problems related to safety practices with different explanations were determined. Specifically, the information determined might lead to an agreement of the framework by the collection and comparison between experts' perceptions from various fields. There are four objectives in this study, which are the most suitable for Delphi, namely 1) when attempting to identify the underlying issues relating to a subject which resulted to various explanations, 2) when data might result in agreement with a specific group, 3) to conduct the collection and comparison between the perceptions of experts from various disciplines, and 4) to create awareness in the group which was examined regarding various and related perceptions on the subject being focused in this study (Keeney et al., 2000).

In the procedures of decision making to choose the attributes and indicators[A9], data from the expert's perspective and stance were obtained using the Delphi technique. These were important data which required analysis. According to Ziglio[A10], information which was more significant than those obtained from group brainstorming, discussions, or other types of group interactions could be obtained through the Delphi technique. Specifically, information was obtained from the systematic procedures of the collection and analysis of experts' stance (Adler & Ziglio, 1996). Therefore, Dalkey (1972), Musa et al. (2015), Magnuson (2012), and Fefer (2016) highlighted that this technique is applied to create strong information based on the experts' perspective without leaving behind any essential data. Additionally, subject anonymity is one of the merits of the Delphi technique, which could tone down the impacts of dominant individuals[A11]. These impacts are frequently considered as an issue group-based procedures, which are implemented for data collection and synthesis (Dalkey, 1972).

2.6 Modelling the Safety Climate Influence Factors on Individual Risk Estimate in Managing Risk of Radiation Hazard

The increasing number of accidents happening nowadays is due to the lacking of appropriate hazard evaluation and risk management system (Nicol, 2001). Therefore, finding ways of eliminating hazards or controlling the associated risks is the best way to minimise risk and workplace injuries and accidents (Kennedy, 1998).

The relationship between safety climate factors and safety performance has been widely investigated. Al-Refaie (2013) and Sukadarin et al. (2012) explored the safety climate factors and found that they significantly affected safety performance and safety management system associated with lower accident rates and fewer respondents reporting accidents. Arezes (2008), Neal (2006), and Vinodkumar and Bhasi (2009) showed that lower workplace accident rates are associated with improved safety climates. Ramli (2014) revealed the relationship of safety climate factors and the level of awareness of OSH. Huang et al. (2007) described the importance of company level safety climate and injury frequency in predicting individual perceived work injury. The mediator analysis between safety climate and injury revealed that perceived management commitment to safety is the most robust predictor of occupational injuries (Beus, 2010).

After the Fukushima nuclear event, every personnel in nuclear and radiation facilities is suggested to strengthen the safety practices (Yang, 2014). It is believed that during the accidents or in emergency situations, every personnel are not able to make decision based on the risk and hazard that occurs. The good decision-making attitude of workers may help to control the risk and reduce the impact of the consequences. Zio (2009) described the decisions need to be made so as to minimise the impact on the productive and safe operation of the system, especially in maintaining and monitoring processes. A good decision requires knowledge and experience of the risk object, carefully collected and rigorously analysed data and information, and a risk-taking attitude of the individuals involved (Rundmo, 2000; Amendolaa, 2001). He at al. (2011), and Kadak and Matsuo (2007) described that awareness on the risk is an important aspect of a

RIDM of nuclear safety and operation. In general, it relates to the feeling of the affect, risk and benefits of the activities, as information about benefit will change perception of risk, and vice versa (Slovic et al., 2005). Safety culture and practice would direct the workers and supervisors to have a good decision-making attitude and correct action taken to reduce the consequences and impacts of the event. Mullai (2006), and Nesheim and Gressgård (2014) described that there is a need to develop risk communication strategies; with that, all valuable data from risk assessments can be disseminated and shared among all relevant agencies and stakeholders.

Risk control uses any suitable method to control and reduce the residual risks to tolerance in the industry, and control measures are taken to eliminate or reduce the risks that contribute to the increasing rates of industrial accidents (Badri et al., 2012). Training, awareness on hazard identification and administrative control would encourage workers to manage their risk in their routine job. The priority to safety, workers involvement and management commitment practice may influence the implementation of risk control measure. Employees' beliefs about the importance of safety are shaped by the safety culture of the organisation, which then influences their attitudes toward safety, working safely, and perceptions of control over safe working behaviours (Morrow et al., 2014).

Effective control measure was also identified to minimise the impact of the hazard. In this study, the risk levels of chemical and radiation hazards, as well as their effects upon an organization, had been determined. Chemical and radiation hazards are classified as Hazardous Material, Substance, and Radiation, which are believed to cause occupational accidents of explosion and radiation exposure, as reported by the Social Security Organization (SOSCO). The risk levels of these hazards need to be identified, controlled, and monitored so as to ascertain the safety of workers in plants and facilities.

Most studies in the safety climate factors have been carried out when attempting to improve organisational safety performance. The research to date has tended to focus on the relation of safety indicators and safety performance (Tang et al., 2017). In Malaysia, there is still lacking in individual response on safety and risk (Sangau, 2012), commitments to risk assessment (Sukadarin et al., 2012), and information-sharing on risk analysis (Amirah et al., 2013). There is no reliable evidence that there were significant relationships of safety climate factors, risk control measure, decision-making attitude, and individual risk estimation to strengthen the safety culture and effectively manage the risk of nuclear and radiation hazard, as illustrated in Figure 2.2.

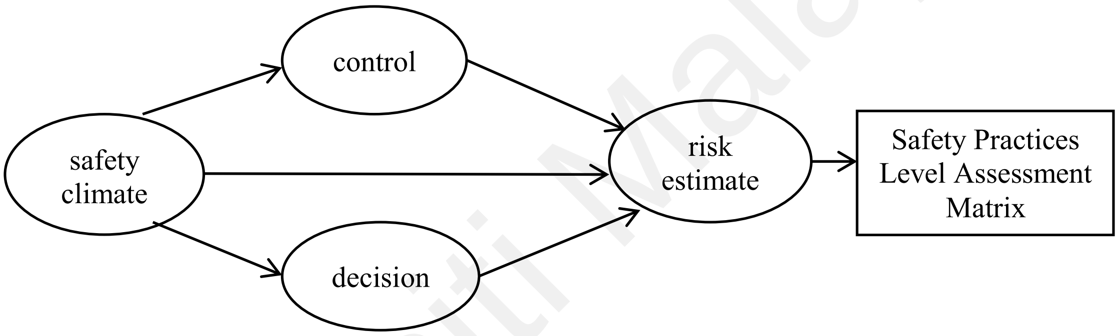

Figure 2.2: The hypothetical model of the current research

The efficient safety practices encourage good decision-making attitude, control measure implementation, and proper risk estimate among the workers. According to Yoo et al. (2015), a series of measures that is capable of determining risks was drawn from the analysis of factors, including legal and institutional framework, material control, physical protection system effectiveness, human resources, and its consequences. Apart from that, risk information with leading indicators can further expand the awareness of the hazard and its consequences among workers, stakeholders, and the public. Therefore, the following five hypotheses are proposed in second objective in phase one of this study:

Hypothesis 1: Safety climate factors influence the individual risk estimate on chemical and radiological hazard, as well as organisational effect.

Hypothesis 2: Safety climate factors influence the risk control measure in reducing the impact of hazard.

Hypothesis 3: Safety climate factors influence the good decision-making attitude of the workers in managing the risk of chemical and radiological hazard.

Hypothesis 4: Safety climate factors influence the individual risk estimate through the implementation of risk control measure that serves as the mediator.

Hypothesis 5: Safety climate factors influence the individual risk estimate through the decision-making attitude that serves as the mediator.

2.7 Indicators and Characteristics of Safety Practices and Performance Assessment

Assessment of safety performance is an approach in controlling and monitoring risk and hazard. Safety indicators were developed to play an important role in providing information on organisational performance, motivating people to work on safety, and increasing organisational potential for safety (Reiman & Pietikäinen, 2010). Typically, indicators were based on the essential phenomena to be measured that come from the critical success factor and the nature of data gathered. The indicators were categorised into two different types of safety performance indicators; leading and lagging indicators.

Lagging indicator has been traditionally identified by 'after the loss' type of safety performance measurements metrics, such as accident and injury rates, incidents, and dollar costs. The criteria of this indicator are to identify trends in past performance and assess outcomes and occurrences (Shipping, 2012). The lagging indicators have commonly been used in safety performance indicators in measuring the outcomes of activities and events (accidents) that have already happened (Reiman & Pietikäinen, 2010). These lagging indicators are dominant to determine the safety performance on system failure and accidents that have occurred.

Over past decades, improved safety performance has been associated with a number of measurable activities in various industries, opening up the possibility that some of these metrics may be leading indicators for safety performance. Leading indicators are identified as data which assist users in their responses towards the transformed circumstances. They also assist users in taking the initiatives so that the desired results could be gained or unfavourable outcomes could be prevented (Reiman & Pietikäinen, 2010). Besides, these indicators could act as the early warnings prior to the occurrences of any accidents and events in order to curb the impacts and risks of the damage..

Examples of metrics for these activities are size of safety budget, safety audit scores, number of safety inspections, and number of safety meetings involving management (Shipping, 2012). The leading indicator was to measure the other side of the safety performance that is related to culture and belief of the workers. It is observed that the leading indicators drive the organisation to be prepared with prevention measure, instead of doing corrective action. The measurement of leading indicators encourages the organisation to improve future performance and take further action to avoid undesired events or accidents from happening.

Leading indicators have become of more interest in benchmarking of organisational health and safety performance assessment to reduce the number of accidents in the workplace. Yang (2014) had identified those technical issues and human, as well as organisational errors, as the two main key issues of the Fukushima accidents.

The translation from the safety management system developed to the individual basis to be effectively implemented is challenges to the organisation. The different understanding may affect decision-making and cause abnormality or accident to happen. Leadership and communication skills as safety climate factors need to be evaluated and improved in managing people dealing with risks and hazard (IAEA, 2016b). Therefore, it is important to establish the leading indicators frameworks to enhance safety practices culture in an organisation.

2.7.1 Leading Indicators in Safety Practices Level Framework Matrix

Westrum (1993, 2004) developed a model to identify types of organisational culture based on how an organisation processes information. There are three types of culture: Pathological, Bureaucratic, and Generative. The flow of information is considered as the most critical issue for organisational safety. According to the IAEA (2002a), there are three stages in developing safety culture that involve different awareness of the effect on safety of human behaviour and attitudes. Fleming (2001) developed a model of maturity of safety culture with the objective of helping organisations to identify the level of maturity of their safety culture.

Safety culture maturity model and its stages were developed as a diagnostic tool. Since there is lack of application on the model, no available data indicates that organisations follow a sequential maturation and the use of averages to determine the level of maturity is appropriate. Hudson (2003) and Westrum (2004) proposed the evolution of a safety culture maturity model from the Pathological stage to the Generative stage (Westrum, 1993). Parker et al. (2006) then designed a framework that which organisations could utilise to develop comprehension of the maturity of their safety culture through Hudson's (2001) model. The framework of safety culture maturity model, with some leading indicators has been applied in petrochemical, oil, and health care companies, including in some countries, such as Oman (Hudson, 2000), the United Kingdom (Hudson, 2007), and Brazil (Anastacio Pinto Goncalves Filho 2010), wherein the societal cultures differ from the Malaysian culture.

Patient Safety Culture Improvement Tool (PSCIT) was developed to provide the organisation with a straightforward and structured process to implement a positive safety culture (Fleming & Wentzell, 2008). The tool was adopted from the Hudson's (2001) model in determining the level of safety maturity and using leading indicators to assess the safety maturity level. The maturity level in this assessment describes how organisations at different levels of maturity approach safety culture improvement (Fleming & Wentzell, 2008). PSCIT provides organisations for reviewing the extent to which current systems promote a positive safety culture. Improvement actions are identified by comparing current systems with the practices associated with the next level of maturity.

However, the main weakness of the study is the failure to identify the influence of societal culture on safety culture. The studies failed to consider the differing categories of criteria and indicators that influenced the level of maturity in different environment. There is also lack of empirical researches on diagnostic tools for safety managers to easily identify certain organisational characteristics. This research, thus, focused on answering the following question: Is safety culture model (Hudson, 2001) suitable for adaptation for a country like Malaysia in developing the safety practice framework level, indicators, and criteria to measure the safety culture?

2.7.2 Performance Assessment and Index Matrix

In providing data and information to decision makers normally in the top management of the organisation, management and time consumed are very crucial. The data presented need to be more concise, clear, well-understood, and transparency. Risk-informing to the decision makers is somehow important to ensure that safety and health of the process or plant will get high priority. The performance index would be a better indicator to prioritise and measure the potential risk and hazard of the process.

Insufficiency in leading indicators, such as cost reduction, downsizing personnel, decrease in training, miscommunication between operators and management, management of change failures, lack of supervision, operator fatigue, inadequate instrumentation, deferred maintenance, and improper equipment maintenance, is always a recipe for disaster (Srinivasan & Natarajan, 2012). These measures also show the contribution towards safer plant operation. These factors need to be assessed and considered during decision-making, since increasing complexity of process industry is consistent with the emerging new technologies.

In order to motivate the application of RIDM in the hazardous or high risk industries, the systematic approach needs to be developed. A risk metric serves two important functions: it enables us to talk about risk; to communicate and discuss the results of risk analysis and the aspects of risk that are important to us, and it facilitates decision-making by providing a quantitative measure for risk evaluation (Johansen & Rausand, 2014). 17 risk metrics were introduced based on 11 risk criteria in the petrochemical industries (Al-Sharrah et al., 2007). The study is further delimited to major accidental events and does not cover continuous exposure to hazardous substances or occupational incidents.

In the nuclear power industry, a systematic reassessment of the safety of an existing nuclear power plant, such as a periodic safety review (PSR), can be useful in checking and confirming the long term success of the IRIDM process (International Atomic Energy Agency, 2011). A PSR might be the safety performance indicators in monitoring and evaluating the effectiveness of the decisions to control hazards and risks.

Performance indicators are important means for performance monitoring of the nuclear power plants. The consequences of decisions affecting safety should be monitored and feedback provided on their effectiveness. Thus, performance measures should be developed and monitored (International Atomic Energy Agency, 2011). Soysa et al., (2016) has developed the nine performance measurement (PM) dimensions: mission, strategy, organisational capabilities, infrastructure and people development, financial, processes and stakeholder satisfaction for performance monitoring of non-profit organisations (NPOs) in Australasia involved in healthcare.

One of the main ways to describe and communicate the level of risk is through risk indices, which summarises risk using numbers or categories, such as words, letters or colours. These indices are used to communicate risks to the public, understand how risk is changing over time, compare among different risks, and support decision-making (MacKenzie, 2014).

There are many approaches of safety performance indicators to be used to provide transparent, concise, and well-understood information on risk assessment. The indicators may be in the form of risk matrix, (International Atomic Energy Agency, 2011) and risk index (Li et al., 2009). While, to assess the strategic performance of an organisation, overall performance index (OPI) was empirically developed.(Soysa et al., 2018).

This indicator is used in plant safety performance management to communicate, as well as to inform decision makers and all stakeholders regarding the risks and hazards of the plant or processes. The indicators and metrics would be applied in RIDM to further improve the safety and health management system.

2.8 The Lessons Learnt and the Strategies to Strengthen Safety Practices

Taken a lesson learnt from the world's worst accidents of Bhopal Chemical Accident in 1984 (Broughton, 2005), Chernobyl Nuclear Accident in 1985 (Anspaugh, 1988), the Piper Alpha Rig Explosion 1988 (Pate-Cornell, 1993), the Fukushima Nuclear Accident in 2011, and other major industrial accidents, safety practices, especially in major hazard industry that need to be improved and strengthened. Technical and managerial issues of organisation safety are the highest priority.

For example, in March 11, 2011, an earthquake measuring 9.0 on the Richter scale hit Northeast Japan. It triggered a tsunami at 43–49 feet high, which struck the Fukushima Dai-ichi nuclear power plant. The IAEA assessed the severity of the Fukushima accident as Level 7, based on the International Nuclear and Radiological Event Scale (INES). This accident happened 26 years after the Chernobyl nuclear accident. (Yang, 2014) had identified that technical issues, as well as human and organisation errors, were two main key issues of the accidents. Technical issues of the hazard, combined hazards, explosion and multi-unit feature of the accident were underestimated. Meanwhile, human and organisation errors included: highly unstable human societies, miscommunication in operation, a harsh working environment, a lack of safety practices, and emergency preparedness. The accident became uncontrolled due to multiunit accidents and unexpected combined hazard of tsunami, as well as radiological and chemical hazards. There was also insufficient and ineffective information sharing among major players during emergency preparedness.

The accident changed several world perspectives of nuclear power plant. Some countries announced a halt in the reactor operation, affirmed the policy and reviewed the safety program of the plant (Anthony et al., 2014). Attitudes towards nuclear power decreased and people lost trust in nuclear safety and regulation (Tsujikawa et al., 2016). From the perspective of safety, there is a need to develop a more systematic approach to enhance the safety of nuclear installations (Wachter & Yorio, 2014). Malaysia, if wishes to embark on nuclear power plant, the aspect of risk assessment and risk management should be improved to include a systematic risk screening process, extend the scope of the risk, prepare mitigation systems for extreme conditions, and implement the risk-informed approach.

The accident that occurred on board the offshore platform Piper Alpha in July 1988 killed 167 people and cost billions of dollars in property damage. It was caused by a massive fire, an accumulation of errors, and questionable decisions. Most of them were rooted in the organisation, its structure, procedures, and culture. The report of the investigation revealed that there was inadequate management oversight and follow-up of safety matters (Center for Chemical Process Safety, 2005). This accident required organisational factors to be analysed and to include improvements to management practices in the organisation. (Kim et al., 2008) described that the organisational characteristics provide information that is important for optimisation of performance and settlement of a safety culture for safer operation of nuclear power plants.

The fire and explosion at a PETRONAS Gas Processing Plant in Kerteh in May 2012, occurred in the Storm Water Drain (SWD) in a gas processing plant, and resulted in one fatality, 32 workers hospitalised and damage to the SWD structure. Fire occurred while a worker was testing his welding equipment (amperage test) on a working platform about 6 meters above the SWD. From the investigation, the lessons learnt from the accident were that the identification of hazards and risk must be done thoroughly, to include the SWD; periodic maintenance work should be carried out, and effective communication within the organisation upheld during the implementation of the safety management system (DOSH, 2012). Ammonia gas cylinder explosions in March 2011 at the ammonia gas plant in Malacca also highlighted the importance of worker training and written guidelines and information on safe procedure for handling ammonia gas cylinders. Fortunately, there was no injury or death in this incident (DOSH, 2011).

In Malaysia, the issues of nuclear and radiation sector of ARE has had an impact on the public acceptance of nuclear technology (Malaysia, 2010). ARE is a Japanese-Malaysian joint venture company established in 1982. The factory was set up at Bukit Merah, near Ipoh in Perak, Malaysia, to manufacture rare earth mineral, a process involving the generation of radioactive by-products. After the discovery of the mishandling of nuclear waste in 1984 and fear of irradiation and lead poisoning, on 14 October 1985, the High Court in Ipoh ordered ARE to stop 'producing, storing and keeping radioactive wastes on their land in such a manner as to cause the escape of radioactive gases and wastes'; the injunction also imposed specific requirements for the storage of waste (Harding, 1995). Lack of preparation, including laws and regulation, enforcement, safety precautions, and technical expertise were the most severe challenges for Malaysia to handle in the management of the process related to nuclear material and wastes during that time. With poor experience of radioactive waste from ARE, public trust in the radiological and nuclear technology decreased. The lesson learnt from the incident has been to highly prioritise those industries dealing with nuclear, radioactive, and other harmful substances. Recently, in 2012, the operation of LYNAS, the rare earth separation plant with thorium as a by-product of the process, has been approved and licenced under the Malaysian Atomic Act (Act 304) with the supervision and monitoring by the AELB after several demonstrations (AELB, 2014). The public still has fear and distrust of the management of the risks of the operation, especially after major nuclear accidents happened (Nagai & Hayashi, 2000).

Radiological and chemical hazards have been classified as Hazardous Material, Substance and Radiation in the annual report of SOSCO. Industries that are involved directly with radiological and chemical hazards are licensed under the Atomic Energy Act (ACT 304). In 2014, there were 4959 licensed organisations that used nuclear and radiation techniques (AELB, 2014). Some of the industries were exposed to chemical hazard. Fortunately, the number of injuries and deaths caused by the hazardous material, substance, and radiation remained low (SOSCO, 2014). On 14 April 2014, fire incident in a factory providing a full range of sterilisation technologies, including gamma irradiation, electron and ion beam treatments, and ethylene oxide sterilisation in Rawang Selangor, created a shocking situation among the residents area as the fire incidents were reported to have occurred and involving gamma rays. Fortunately, with the effective safety control system, the incident did not cause any radiation leakage or exposure to the workers and public (Malaysia, 2014)[A12].[H13] Nevertheless, RM14.8 million was estimated on the rebuild of the damaged facility. The loss of the facility confirmed that the lesson learnt and outcomes from the incident were reviewed and actions identified to further enhance business continuity planning (Health, 2015).

Several lessons from the major accidents and incidents that should be learnt in managing radiation risks in Malaysia. Although risk analysis and risk assessment system may have been practiced for decades, accidents still can occur. The effective safety system is deemed to be in place if employees display fast responses to any risk and hazard in cases of accidents or emergency situations (Wachter & Yorio, 2014). The integrated risk management systems that include probabilistic and deterministic factors are the possible practice to implement improvised risk and hazard assessment approaches. The safety culture that comprises of physiological, situational and safety behaviour must be measured and monitored as well.

It was observed that there are several best practices and lessons learnt as an outcome from the accidents and incidents. Donovan et al. (2017) demonstrated the usefulness of applying systems-thinking methods to examine and learn from incidents in terms of what 'went right'. Most of the accidents show that lacking of leading factors of human and organisation errors including highly unstable human societies, miscommunication in operation, harsh working environment, lack of safety practices, and emergency preparedness led to the high impact accidents involving a huge number of fatalities. In controlling the risk and in reducing the impact, regulatory framework and safety culture of regulators are important (Fleming et al., 2017). Enforcement, inspection, and monitoring are not for licensing documentation alone. Unfortunately, the best practices and lessons learnt were not communicated and shared with other organisations. There is still lacking in benchmarking activities between sectors and industries in Malaysia. The young workers were also impacted with the lack of information and best practices of safety in the facility. The compilation of the best practices and lessons learnt might be applied as a framework and guideline for other workers, especially the young generation in managing radiation risk in the country.

2.9 Defining the Gap

This section defines the gap that provides the focus for this study. According to Cooper and Phillips (2004), and Mearns and Flin (1999), safety climate is defined as a summary of molar perceptions, attitudes, and belief to safety, which is often seen as a reflection of an organisation's current underlying culture. Evidences of successful investigation in safety climate instruments are available (see Mearns & Flin, 1999; Marín et al., 2017; Flin, 2000; Smith et al., 2006), but they have been mostly drawn from specific industries and country. Therefore, a comparison across industries and country is lacking, whereas the current assessment tool is focused more on the level of policy and managerial commitments rather than individual commitments in monitoring their individual response. Exploring the safety climate factor in Malaysian radiation safety culture through managerial, policy, and individual response would illuminate the safety culture by measuring the process and the factors that contribute to the safety practices.

Studies by Arezes (2008), Neal (2006), Vinodkumar and Bhasi (2009), and Ramli (2014) provide insightful understanding on the relationship of safety climate factors with safety performance and safety management system associated with lower accident rates and fewer respondents reporting accidents. The previous study showed that the safety climate was correlated with safety practices that were implemented (Varonen & Mattila, 2000). Nevertheless, the review of previous studies on the relationships on safety practices, decision-making attitude, risk control, and risk estimate on the radiation hazard is lacking and the relationship of safety climate validity and reliability is scarce. The conventional hazard and risk analysis through HIRARC assessment tool is not being informed to all the workers and not being used in the decision-making of organisation's top management. The information from the risk assessment provides information, understanding, and experience of the risk that affect the decision-making process (Mearns et al., 2004).

What are the indicators that have been used in assessing the safety practices in the organisation? To date, safety performance refers to the main indicators to show the safety culture and practices of organisation that uses lagging indicators. The analysis on the past event has been reported. In Malaysia, especially in radiation industry, the safety assessment report (SAR) is prepared to comply with the licensing process. There is still lack of leading indicators reported either to the management or the regulators. Similarly, Shipping (2012) provided an interesting guideline on the measurement of leading indicators that encourages organisations to improve future performance and to take further action to avoid unwanted event or accident from occurring. Currently, there are less leading indicators and criteria framework used to assess safety practices. By contrast, a great deal of, increasingly mandatory, advice and practice are provided for high risk industries, such as radiation facilities, especially the first development of nuclear power plant.

As for the assessment process, it is strongly associated with the framework assessment matrix that will provide guideline and clear information on the level of safety practices. Hudson's (2001) framework of safety culture maturity model, with some leading indicators, has been applied in petrochemical, oil and health care companies in mostly western countries. The application of the framework matrix assessment for nuclear and radiation in Asian countries is limited. The development of safety practice assessment matrix that comprises of nation socio-culture, leading indicators, and level of safety practices deserves further exploration. This study is an attempt to bridge this research gap.

On a similar note, my review of the prior studies is that there is a need to have integrated information especially on lagging and leading indicators, as well as probabilistic and deterministic aspects that complement each other to provide effective safety assessment in organisation. The best practices and lessons learnt shared through benchmarking with other organization will improve the networking and interagency collaboration. This suggestion implies that the safety practices level assessment using safety practice assessment matrix encourages the development of safety culture, controls risks, and minimises the impact of radiation exposure and accidents. The good and high level safety practices will regain trust on the nuclear technology application.

2.10 Summary of the Chapter

This chapter elaborated on the significance of the factors of safety climate and practice the evaluation of the safety culture. It also highlighted the methods used for the evaluation of the reliability and validity of the association between safety practice and the estimation of the degree of risk control measures and decision-making conducts. Furthermore, it described the assessment matrix, primary indicators which determine the degree of safety practice level, and the lessons applied regarding the practices of safety for the enhancement of safety performance. This was followed by an explanation of the management of hazard and risk of radiation, the practices of safety implemented in the safety culture of the organisation, and the safety climate which required evaluation and monitoring. Following this chapter is Chapter 3, which will draw on this research methodology.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Methodology

This chapter is composed of five main sections that cover the research methods of this study within three phases. Section one describes the introduction followed by section two discussing the initial phase of the study. It identifies the factors that affect the safety practices and their correlations with potential risk of radiation hazard. Next, section three deliberates the phase two of the study on the development of safety practices level assessment matrix. The fourth section elaborates on the third phase of the study, which focused on the verification and practicability of the assessment matrix of safety practice level. These aspects are focused on to implement methods of safety culture strategies and the most recommended operations for the control of radiation hazard in Malaysia's radiation facilities. Lastly, the final section describes the summary of methodology chapter. Figure 3.1 illustrates the research flowchart and the methodology employed in this study. The mixed method approach was selected for this study mainly because this method has been widely applied in social sciences and safety culture researches by incorporating both quantitative and qualitative approaches. The combination of quantitative and qualitative data explores an investigation from a different stance, apart from providing in-depth understanding regarding the issues concerned (Maxwell, 2016).

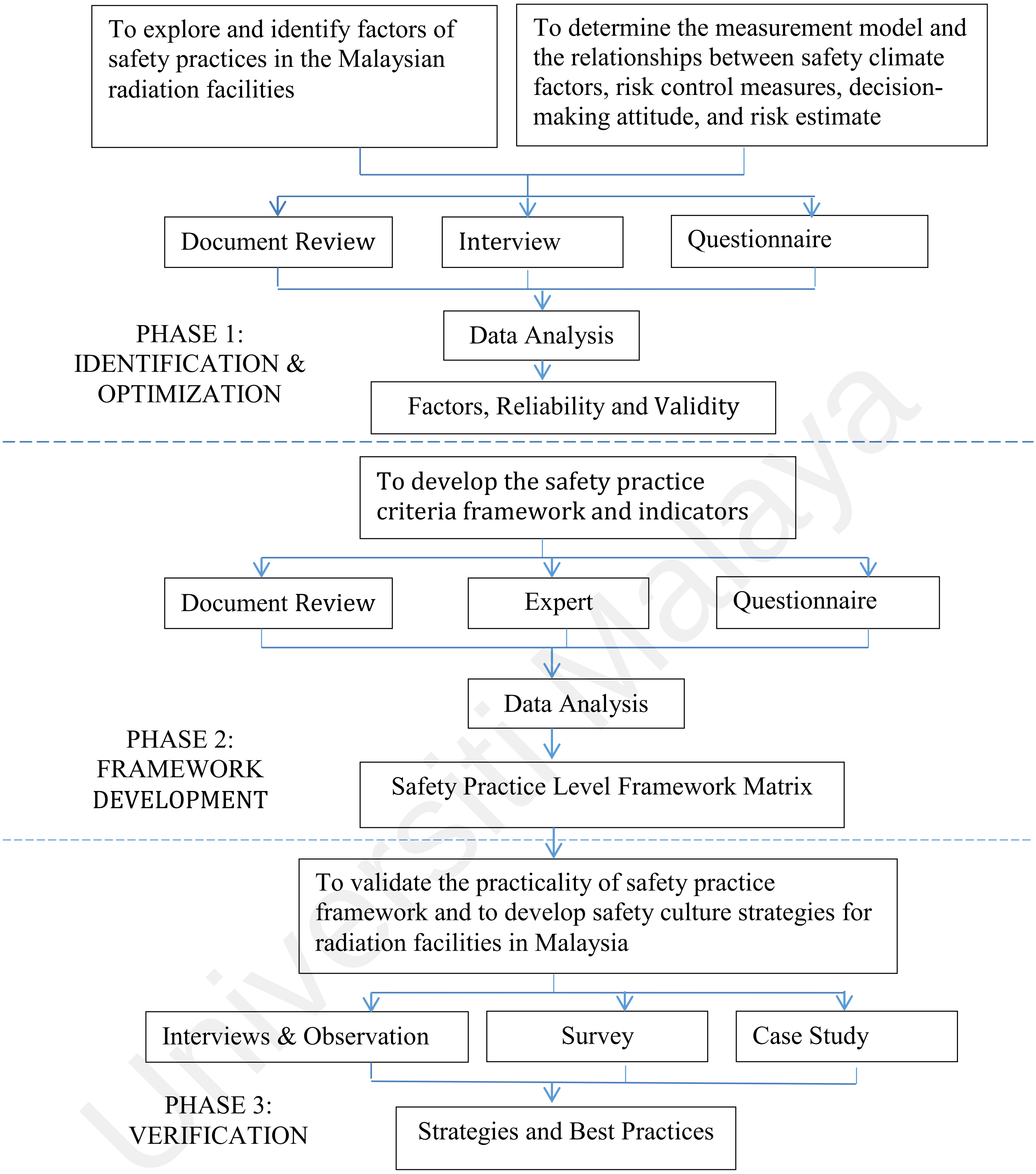

Figure 3.1: Research flowchart

The quantitative data gathered in the first phase of this study resulted in major findings in the second and third phase. The quantitative data were gathered from a questionnaire survey involving random respondents and a quantitative instrument that guided the selection of criteria and determined the correlations that stimulate further interview questions. Next, the contributing factors of the practices of safety identified in the first phase of this study resulted in the integration of the set of Delphi methods. This integration was according to the experts' perceptions and the agreement among the interviewees (n=16). Furthermore, the assessment matrix of the level of safety practices was established in the research second phase. Lastly, the third phase emphasised on verifying the assessment matrix of safety practice degree through interviews, site observations, and survey on perspectives. It also focused on multiple case studies (n=5) which identified the degree of practices of safety, the most recommended practices, and the practical methods for the reinforcement and improvement in the practices of radiation safety in Malaysia. A descriptive analysis of the quantitative data is presented in the final report, which is combined with and complements the interview data gathered from phases two and three of this study.

3.2 Phase One

In this phase, the quantitative approach was employed by performing a questionnaire survey to develop and to employ mathematical models, theories, and/or hypotheses pertaining to natural phenomena. A quantitative research requires accurate numerical data to be analysed using various statistical methods. It refers to the appropriate use of statistics to infer the presumed independent and dependent variables (Srinivasan & Rethinaraj, 2013).

In this study, the questionnaires are considered as one of the most widely instruments for collecting data in survey research, similar to the study conducted by (Isha, 2012). It is defined as a set of focused questions to obtain information from the targeted respondents. It also reduces time and cost since respondents are able to complete the questionnaires at their own time (Awang, 2012).

Various types of safety climate and safety attitude questionnaire surveys have been carried out as instruments to determine the safety culture. The questionnaires are varied based on the differing measurement levels. This is because; measurements made at one level cannot be employed at other levels unless certain conditions are met. In this study, safety climate (attitudes) and safety culture are not separate entities, but rather, they refer to different approaches towards the same goal of determining the importance of safety within an organisation (Guldenmund, 2007). The questionnaire used in this study combined a number of measures, some of which were adapted from the existing measures of MSTK studied in Occupational Health and Safety Practices in the Petrochemical Industries of Malaysia, since they share similar variables.

3.2.1 Instruments

The instrument utilised in this study consisted of four sections: demographic, safety climate factors (further divided into nine subheadings), risk measurement and control measures, and decision-making attitude. The items measured for all constructs were calculated to determine their frequencies, the measures of central tendency, and dispersion of the scores, which will be further discussed in the next chapter.

The items for safety climate factors adopted in this study were composed of a number of measures. Some measures utilised in the petrochemical industry were adopted from MSTK and adapted from the IAEA Guideline for individual response construct (IAEA, 1991) as the Malaysian Nuclear and Radiation Safety Tool Kit (MRSTK). The questionnaire applied a 7-point Likert scale that ranged from 1 (strongly disagree) to 7 (strongly agree) that indicated the respondents' agreement with each item. The items for section 3 of risk management were adopted from the HIRARC guideline developed by Malaysia's (DOSH, 2008). These questions assessed the hazard and risk levels.

Meanwhile, the questionnaire also employed the 4-point Likert scale to gather responses from the respondents within the range of 1 (never and may happen) until 4 (happens multiple times). The items for section 4 were adopted from the Decision-Making Questionnaire (DMQ) (French DJ, 1993) and used 6-point Likert scale that ranged from 1 (never) until 6 (always). The items were translated from the English language into Malay language by language translators (Appendix A).

In this study, the internal consistency reliability of the questionnaire was tested using the Cronbach's alpha technique. High alpha (0.80 or higher) denotes that all the items are reliable and the entire test is internally consistent (Ho, 2006). As suggested by Taber (2017), indications of alpha with a threshold or cut-off as an acceptable, sufficient or satisfactory level are as given in Table 3.1.

Table 3.1: Cronbach's alpha values and internal reliability (Taber, 2017)

Cronbach's Alpha Value	Internal Reliability
0.93–0.94	Excellent
0.91–0.93	strong
0.84–0.90	reliable
0.81	robust
0.76–0.95	fairly high
0.73–0.95	high
0.71–0.91	good
0.70–0.77	relatively high
0.68	slightly low
0.67–0.87	reasonable
0.64–0.85	adequate
0.61–0.65	moderate
0.58–0.97	satisfactory
0.45–0.98	acceptable
0.45–0.96	sufficient
0.4–0.55	not satisfactory

The values for Cronbach's alpha can be influenced by several factors, such as scale or instrument, different constructs or aspects, its application to a particular sample of respondents on a particular occasion, and the management of the instruments. This is typically observed as ≥0.70 (five instances) or >0.70 (three instances)[A14] [H15]although more vaguely referred to as 'the acceptable values of 0.7 or 0.6' (van Griethuijsen et al., 2014).

3.2.2 Sampling Technique

Sampling is part of the research strategy and it is a crucial process for a statistical analysis. In sampling, a representative sample of observations is taken from a larger population (Singh, 2006). In this study, the simple random sampling technique had been selected to gather maximum information to ascertain generalizability of the research data.

3.2.2.1 Population and sample size

The respondents for this study comprised of employees from the Malaysian-based nuclear and radiation facilities of three main sectors, which are: industrial and manufacturing, non-destructive testing, as well as R&D. Permission to participate was obtained from each company representative via training centre managers, who assisted in administrating the survey questionnaires. Overall, a total of 5254 employees had been determined to deal with nuclear and radiation with 1123 non-medical organisations licensed under ACT 304.

Study sample is defined as a set of respondents selected from a larger population for the purpose of a survey (Salant & Dillman 1994). The findings generate from the sample can be generalised on the whole population. Out of the 5254 radiation workers, 357 were selected as respondents and representatives of this study with 5.0% confidence interval. As proposed by Krejcie and Morgan (1970), this number is adequate for data analysis as it represents a cross-section of the population (Krejcie & Morgan, 1970).

The actual sample size of 330 samples was calculated by using 95% confidence level, which displayed a confidence interval of 5.38% when the following formula was applied:

$$\text{Sample size} = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal (.5 used for sample size needed)

c = confidence interval, expressed as decimal (e.g. .04 = ±4)

3.2.2.2 Sampling procedure

The sample of this study included employees who worked in the operation or production department at 104 facilities and installations that applied nuclear and radiation technique operated in three main sectors, namely industrial and manufacturing, non-destructive testing, as well as R&D. The survey questionnaires were distributed to the respondents by employing the simple random sampling technique. The advantage of this approach is its fairness and objectivity considering that every single person in the population has an equal chance of being selected (Hsu et al., 2008; Fernandez et al., 2007). A number of respondents were also selected from each region in the states located in Peninsular Malaysia, as well as some employees from the related companies. Region A refers to the central region, Region B is the northern region, Region C is the East Coast, and Region D is the Southern Region with a total of 450[H16] respondents[A17].

3.2.3 Data Collection

A total of 450 questionnaires were distributed directly to the respondents during the training series organised by the Nuclear Malaysia Training Centre. Additionally, electronic questionnaires were distributed via email to 100 selected respondents listed as those who worked involving radiation. Each respondent was given a questionnaire, instructions, consent form, and a token of appreciation, in which they were required to respond to the questionnaires anonymously. The explanation was made regarding the letter of agreement on the study and information privacy to the participants, as seen in Appendix B and Appendix C .On a similar note, the respondents who received the questionnaires via email were requested to complete the online questionnaire.

3.2.4 Pilot Study

The questionnaire pre-test was carried out to ensure the validity of the questionnaire, determine the safety climate factors and radiation risk baseline knowledge or preparedness for improving the safety practices; and understanding to the questions. In this study, five safety experts from the Malaysian Nuclear Agency discussed each discrepant item and verified its clarity to resolve any emerging discrepancy. At the initial stage of this study, a pilot test was carried out to determine the reliability of the research process. Requirement of a pilot test has been highlighted by (Zikmund, 2003). A pilot study is always carried out in quantitative research to test the relevance of the questionnaire, the suitability of the scales used, as well as the duration and the cost of the study. This serves as the guide to the actual study (Ayob, 1992).

Next, all 52 items in the safety climate questionnaire with 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) were pilot tested (along with other questions concerning respondents' background). This pilot study involved 30 employees from selected nuclear and radiation facilities of the industrial sector, wherein all respondents were informed about the confidentiality of their responses and all data during the process. All respondents returned their questionnaires within 2 weeks, which yielded a 100% response rate.

The collected data were analysed by using SPSS Software. All independent and dependent variables scored values between 0.6 and 0.88 for Cronbach's alpha, which exceed 0.6, as suggested by (Nunnally, 1978). This outcome suggests that all the items in the questionnaire are indeed reliable and the entire test is internally consistent.

Responses from all the respondents were reviewed and minor changes were made where necessary, for instance, the section entitled "Security Threat" was discarded, as suggested by several senior members of the company who assisted in the study and reviewed the responses from the pilot study, since the associated variables need to be studied separately. In the case to improve the internal reliability, 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) will be used in the questionnaire. With the responses from the respondents, the questionnaire was translated into the Malay language to ensure that all the respondents did understand and felt comfortable in providing responses.

3.2.5 Language Translation

In the present study, the questionnaire was originally developed in the English language and was later translated into Malay language by a certified translator using the back translation technique. The back-translation method refers to translation of a translated text back into the language of the original text, made without reference to the original text. This technique validates that the translation is accurate and relevant to every item and the whole concept (construct validity) of each scale (Fisher, 2004). Traditionally, this technique requires the translation of the questionnaire by a native speaker and its back translation to the original language. The two versions were then reviewed for inconsistencies, wherein changes were made in some of the items.

3.2.6 Questionnaire Validation

Finally, 3 experts, who comprised of officers in the radiation sector, were selected to evaluate the translated measurements and to validate the version that appeared to be the most appropriate for this study.

3.2.7 Data Analysis

As for statistical analysis, both descriptive and inferential statistics were applied in this study. The data were cleaned and analysed using descriptive statistics. Descriptive statistics presents the gathered data in a convenient, usable, and understandable form. In this study, the descriptive analysis incorporated internal reliability analysis, descriptive sample analysis, descriptive main variable analysis, exploratory factor analysis, and repeated analysis of variance (Repeated ANOVA[A18])[H19]. This study used the statistical package for social sciences (SPSS) version 22.0 for windows to perform the descriptive statistical analysis.

Inferential statistics addresses the problem of making broader generalisations or inferences from the sample data to the general population (Ho, 2006). In this study, inferential statistics was performed to measure construct, convergence, and discriminant validity of the measurement model, including the relationships and the direct effect of the nine safety practices (management commitment, personal involvement, personal view on safety, supportive environment, priority to safety, working environment, communicative information, prudent approach, and questioning attitude), three determinants of individual risk estimate (chemical, radiological, and organisation effect), three components of control measure (awareness, training, and administrative), and decision-making attitude.

The structural equation modelling (SEM) method was employed to measure the path analyses to test the hypotheses and the Goodness-of-Fit (GFI) of the various models applied in this study. SPSS AMOS-21 software package was utilised for confirmatory factor analysis (CFA) and path analysis of the structural models.

3.2.7.1 Factor analysis (FA)

Each factor was computed and statistical analysis was subjected to normality test in order to ascertain if the data were normally distributed. Internal reliability was also performed to determine the reliability of the items. Next, descriptive statistics was conducted after the data were gathered to calculate the frequency, the measures of central tendency (means, median, and mode), as well as the dispersion of the scores (variances and standard deviations).

Factor analysis (FA) was employed to deliberate the aspect of variability among the observed and correlated variables in terms of potentially lower number of unobserved variables called factors. For that purpose, the principal component factor analysis (PCA) was selected to minimise the dimensionality of the original dataset. This statistical technique can linearly transform the original set of variables into substantially smaller set of uncorrelated variables, which represents most of the data in the original set of variables. A small set of uncorrelated variables is easier to comprehend and applied in further analysis (Dunteman, 1989).

Two separate FAs were carried out in this study. The first FA had a total of six factors that comprised of 25 items taken directly from the MSTK. The MSTK was adapted after an expert in the radiation field was consulted and due to the similar safety practices shared between petrochemical plant and radiation facilities as high risk facility. The second FA consisted of 40 items composed of a combination of items developed based on the several selected items from MSTK and IAEA Safety Series: Safety Culture (INSAG 4). This combination of items is termed as the "Malaysian Radiation Safety Tool Kit (MRSTK)". The rationale behind performing two separate analyses is to determine which of the two sets of items presents the most reliable factors for interpretation, as well as to further explore the contributing factors to the overall safety climate in the organisations (Frazier et al., 2013). In this study, the ability of MSTK to function as a tool to assess the safety culture in radiation sector was determined. The factors that contributed to radiation facilities from the first FA were compared with the factors derived from the petrochemical industry.

3.2.7.2 Repeated ANOVA

In this study, a one way repeated measure method was carried out to evaluate the presence of mean differences between the nine observed variables. A repeated measured ANOVA is deemed more appropriate when the measurements are made more than twice repeatedly for the same dependent variable (Grice et al., 2015). This technique, hence, is appropriate for this study to determine the dependency of each of the nine components to be an influential factor to the safety culture of employees in an organisation.

The level of mean factors was compared by computing the mean score of the related items for each factor, first, by employing a statistical analysis called normality test. The outcomes from this analysis indicated that the data were normally distributed.

3.2.7.3 Evaluation of the measurement model: Confirmatory factor analysis (CFA)

The inferential statistics was carried out in this study to evaluate the measurement model. Hence, the CFA was adopted to assess the construct validity of the measurement model using SPSS AMOS-21. The CFA was performed for all latent constructs embedded in this study prior to modelling their inter-relationship and further proceeding with path analysis in SEM (Awang, 2012). Several GFI indices, as recommended in past studies were utilised to examine measurement adequacy (Awang, 2012). Table 3.2 presents the level of acceptance recommended for the index.

Table 3.2: The three categories of model fit and their level of acceptance (Awang, 2012)

Name of Category	Name of Fitness Index	Level of Acceptance
Absolute Fit	**Chi-square (χ2)**	p-value >0.05
	Root-mean-squared error of approximation (RMSEA)	RMSEA < 0.08
	Goodness of Fit (GFI)	GFI > 0.90
Incremental Fit	Adjusted Goodness of Fit (AGFI)	AGFI > 0.90
	Comparative Fit Index (CFI)	CFI > 0.90
	Tucker-Lewis Index (TLI)	TLI > 0.90
	Normed Fit Index (NFI)	NFI > 0.90
Parsimonious Fit	**Chi-square/ Degrees of Freedom (Chisq/df)**	Chisq/df < 3.0

3.2.7.4 Convergence and discriminant validity

After determining the CFA for every measurement model of the construct, the validity and reliability aspects of the measurement model were assessed. The types of validity and reliability measures, along with their requirements, are displayed in Table 3.3.

Table 3.3: Requirements to assess validity and reliability of the measurement models

Validity and Reliability	Requirement
Convergent Validity	The convergent validity for a measurement model is achieved when all the values of AVE exceed 0.50
Construct Validity	The construct validity for a measurement model is achieved when all the fitness indices meet the required level (see Table 3.2)
Discriminant Validity	The discriminant validity is attained when all redundant items are deleted or constrained as "free parameter" and when the value of square root of AVE (diagonal value) exceeds the values of AVE and CR for all constructs.
Average Variance Extracted (AVE)	AVE values that exceed 0.50 indicate the reliability of a measurement model in measuring the construct
Composite Reliability (CR)	CR is achieved when the value exceeds 0.60

Convergent validity is attained when all items in a measurement model are statistically significant (MacKinnon, 2008). In order to verify convergence validity, the Average Variance Extracted (AVE) for all constructs had been determined. The value of AVE should be 0.5 or higher.

Discriminant Validity is attained if the measurement model of the construct is free from redundant items. With AMOS, the redundant items can be identified via Modification Index (MI). The highest MI indicates redundant items, which must be deleted before running the measurement model.

Composite Reliability (CR) and AVE can be used to assess discriminant validity. CR value shows the reliability and the internal consistency of a latent construct, which should be 0.6 or higher.

In the attempt to prove that the constructs were discriminant towards each other, the square root of AVE for the construct was calculated. Discriminant validity is attained when the value of square root of AVE exceeds the value of AVE and CR of the entire construct.

The values of AVE and CR can be calculated by using the given formula (Awang, 2012):

$$AVE = \frac{\sum K^2}{n}$$

K= factor loading of every item

$$CR = \frac{(\sum K^2)^2}{[(\sum K^2)^2 + (\sum 1 - K^2)]}$$

n = number of items in a model

3.2.7.5 Structural equation model (SEM)

In this study, each factor was computed and was found to be normally distributed, cleaned, and analysed by using descriptive statistics. The inferential statistics was performed to measure the construct validity and reliability of the measurement model. Next, SEM was employed to measure the GFI for all different models in the relationships and the path analyses to test the hypotheses.

In this study, the correlations and the direct significant effect for safety practices, risk estimate, control measure, and decision-making attitude were analysed. SEM was selected to estimate and to test the theoretical correlations between latent and observed variables to combine regression with CFA (Tabachnick, & Fidell, 1996). Hair et al. (1992) described that SEM is a path analytical method that handles multiple relationships and assesses them from exploratory to confirmatory analyses.

One advantage of SEM is that the correlations among the latent variables are uncontaminated by measurement errors with CFA. In SEM, more than one exogenous and endogenous variable can be estimated simultaneously, thus enabling a researcher to display the direct, indirect, and total effects. The correlations between exogenous variables can also be considered and presented in a single model (Jeon, 2015).

3.2.7.6 Path analysis

After confirming the aspects of validity and reliability for the measurement model, the modified measurement models were verified. The SEM was used to examine hypothetical relationships between the variables. The fit of the structural path model (with correlated error terms) was assessed as well (Ho, 2006). The factor structure confirmed in the measurement model can be used as the foundation for the path model. Path analysis is used to determine the direct and indirect effects of a relationship. Path analysis allows one to analyse the relationship between dependent variables, as well as between independent and dependent variables from one time analysis. Path coefficient is calculated in the path model analysis. The direct effect of the correlations can be determined through the significant path coefficient of the path model based on p-value < 0.05. This signifies that the direct effect of a variable hypothesised as a cause of a variable taken as an effect (Jeon, 2015). The fit indices indicate that the model is accepted and fits the data adequately, as shown in Table 3.2.

3.3 Phase Two of the Study

The third objective of this study is to develop a safety practice assessment framework matrix that is inclusive of the level, the significant criteria, and the indicators, which is undertaken in phase two of this study. This study carried out the qualitative approach via document review and Delphi technique. Document review was used to understand and to identify the background information of the safety framework criteria and the matrix design. In the Delphi technique, opinions and reviews provided by experts in the field were evaluated to get consensus on the framework to be employed in the facilities. In this study, the lists of safety level, criteria, and indicators were selected from relevant documents. Next, the prepared list was proposed to a panel of experts to gain their feedback.

The Delphi technique was mainly suitable to generate criteria and indicators. Barzekar et al. (2011) generated both criteria and indicators to monitor ecotourism sustainability, while Vantamay (2015) developed effectiveness indicators of social communication to minimise health-behaviour among youth using the Delphi technique.

3.3.1 Document Review

Document review and analysis is a qualitative method used in this study. Data were gathered by reviewing and analysing several relevant documents. The documents, regardless of hard or soft copy, include annual reports, minutes of meeting, newsletter, safety manual and procedures, as well as regulations. These documents are available in the company websites and at the site of the facilities. In this study, the document review and analysis had been selected to gather background information regarding safety culture and safety practices. Documented reports of company performance, safety, and quality system may reveal the data of the implemented safety culture program. The background data contributed as baseline input to develop the assessment matrix. In this review, all relevant documents were compiled based on the theme of analysis and the confidentiality of the documents provided by the facilities was assured. The documents reviewed to develop the safety practices assessment matrix are listed in Table 3.4.

Table 3.4: Types of reviewed documents

Document Type	Document Title
Malaysian Act, Regulation and Guideline	• Act 304 : Atomic Energy Licensing Act 1984 • Radiation Protection (Basic Safety Standards) Regulation1988 • Code Of Practice On Radiation Protection In Industrial Radiography • Radiation Protection (Licensing) Regulations 1986 • Radiation Protection (Transportation) Regulations 1989 • Radiation Protection (Appeal) Regulations 1990 • Import & Export Guidance for Radioactive Material (Categories 1 and 2), including online permit • Act 514 : OSHA 1994 • OSH (Control Of Industrial Major Accident Hazards) Regulations 1996 • Pelan Induk keselamatan dan Kesihatan Pekerjaan • Guidelines for HIRARC • Guidelines on OSH Management System • OSH (Safety and Health Officer) Regulations 1997 • OSH (Use and Standards of Exposure of Chemical

Table 3.4, continued

Document Type	Document Title
	Hazardous to Health) Regulation 2000
Annual Report	Annual Report 2010 – 2016 • PERKESO • MALAYSIAN NUCLEAR AGENCY • AELB • DOSH • PETRONAS
International Standard	Application of the Management System for Facilities and Activities Series No. GS-G-3.1 The Management System for the Processing, Handling and Storage of Radioactive Waste Series No. GS-G-3.3 The Management System for Nuclear Installations Series No. GS-G-3.5 **Leadership and Management for Safety** Series No. GSR Part 2 **Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards** Series No. GSR Part 3
International Standard	Safety Assessment for Facilities and Activities Series No. GSR Part 4 (Rev. 1) Severe Accident Management Programmes for Nuclear Power Plants Series No. NS-G-2.15 Fundamental Safety Principles Series No. SF-1 Safety of Research Reactors Series No. SSR-3 Safety Assessment for Facilities and Activities, A Framework for an Integrated RIDM Process INSAG-25

Table 3.4, continued

Document Type	Document Title
International Reports on Safety And Accident	Chernobyl Three Miles Island Fukushima Piper Alpha Bhopal

From the document review process, a preliminary list of safety level definition, criteria description, and indicators was developed.

3.3.2 Delphi Technique

Delphi study was successfully designed to solicit the insights of expert supervisors and to add to the base of research knowledge concerning counsellor supervision (Magnuson, 2012), in order to document the experience by using a visitor use planning framework (Fefer, 2016) and to unearth information of health and safety [H20](H&S[A21]) performance measurement indicators to construct Small and Medium Enterprises[H22] (SME)s[A23] (Agumba, 2015).

In this study, the Delphi techniques design was employed to fulfil the research goal of obtaining information from experts to document their experiences on safety culture and safety practices, comprehending the criteria that describe the leading indicators of safety practices level, and in reaching the consensus that suits the Malaysian culture. This research used the Delphi technique as a method that ensured the reliability of the systematic processes of data collection, in line with the experts.

3.3.2.1 Population and expert selection

The literature recommends 10–15 experts (Vantamay, (2015), Magnuson, (2012). The indicators and criteria had been based on the literature review and experiences shared by a panel of 16 experts who served as radiation protection officer (RPO) and safety auditor for the Malaysian Government with more than 15 years of professional experience. The panel of experts were selected from the list of registered RPOs. The nomination letters were sent to the respective RPOs and subject to approval from the facility management. Table 3.5 shows the expert qualification, working experience and job scope

Table: 3.5 The number of the experts, their qualification, working experience and job scope

Area (subject matter area)/ sector	**No of experts**	**Qualification**	**Working experience**	**Job scope / role**
Irradiation facility - Manufacturing - Research	 4 2	Higher education: PhD, Bachelor Degree	More than 20 years	RPO/ Safety officers/ Auditor
NDT Facility - Research - Inspection	 1 3	Higher education: PhD, Bachelor Degree	15 to 20 years	RPO/ Safety officers/ Auditor
Regulator	3	Higher education: MSc	More than 20 years	Inspectors / Safety officers/ Auditor
Policy Maker	3	Higher education: PhD	More than 20 years	RPO/ Safety officers/ Auditor/ consultants
Total	16			

3.3.2.2 Delphi study

The safety practice level framework describes how each one of the five dimensions is treated in each level of the revised model. The process of Delphi study consist three rounds of interviews as shown in Figure 3.2.

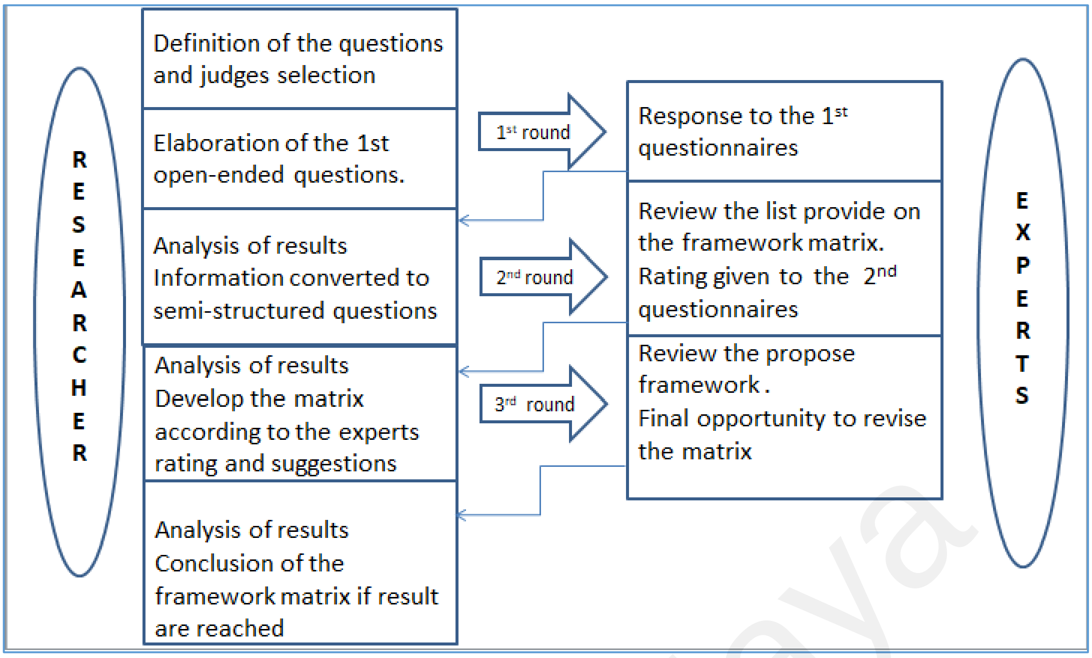

Figure 3.2: The process of Delphi technique

Round 1: the process began with an open-ended questionnaire. After receiving responses from the respondents, the gathered information was converted into a semi-structured questionnaire (Appendix D).

Round 2: each expert received the revised questionnaire and was asked to review the items summarised based on the information provided in the first round. Each panellist received a questionnaire that included the items and ratings summarised in the previous round and had been asked to revise his/her judgment or "to specify the reasons for remaining outside the consensus"(Appendix E).

Round 3: a list of remaining items, their ratings, minority opinions, and items achieving consensus were distributed to the panellists. This is the final round for the respondents to revise their judgements (Appendix F).

3.3.3 Data Collection and Analysis

In this study, the qualitative approach was used to gather data via in-depth interview with a panel of experts using open-ended and structured questions. Three rounds of interviews intertwined the data pertaining to the safety practices. Data generated from the series of interviews were analysed via content analysis through word-based method, along with some analytical strategies.

3.3.3.1 Content analysis

Content analysis refers to the method of analysing qualitative data that derived from interviews, written open questions, and pictures expressed in words. Consequently, one is unable to use statistical analysis to give meaning to such data and therefore, has to apply other analysis methods (Vaismoradi, 2013). The four steps of content analysis in this study are coding, categorising, identifying emerging themes, and determining the frequency of the themes from the interview data.

The method of content analysis can be of quantitative or qualitative, depending on the approach selected. In the quantitative content analysis, the free-flowing text is segmented into several basic meaningful components that are useful in discovering the patterns of ideas in the body of the text (Tobi, 2016). This is divided into two categories: word-based and coded-based analyses.

The word-based analysis weighs in data generated from unstructured, semi-structured, and open-ended questionnaires to identify the correlations between the main concepts and the emerging themes (Tobi, 2016). According to Silverman (2006), performing content analysis by examining the frequency of words is an accepted method of textual investigation to establish a set of categories and later, to count the number of instances that fall into the categories.

The second category in content analysis refers to the code-based method. The development and definition of the codes can be obtained from literature reviews and experiences. In addition, the text itself generates concepts, categories, and codes. Codes can be identified before, during or after date collection (Ryan & Bernard, 2003). Data generated from interview text can be categorised into codes that have been developed.

As for this study, the word-based analysis was selected because the questionnaire used during the interview was open-ended and semi-structured. The categories and themes were identified from the words that derived from the interview text. The frequency of the words that appears from the interview text denoted the selected category and the framework concept. Instead of counting the frequency of the word emerging, this approach can be applied to find similar cognition under the same concept (Swan, 1997).

In round one, data gathered from the interview were analysed using word-based method. Categories and themes were identified after counting the frequency of words that appeared from the text. Based on these concepts and themes, semi-structured questions were constructed to be used in round 2. In round 2, the experts allocated score rating for the proposed level, criteria and indicators. The mean values were calculated; wherein level and indicators with mean values less than 2.0 and criteria exceeding 3.0 were embedded into the safety practice level assessment matrix. After that, the matrix was submitted to the panel of experts to receive feedback. Lastly, in round 3, the mean and frequency values of expert acceptance pertaining to the assessment matrix were calculated.

3.4 Phase Three of the Study

Phase three of this study verifies the practicality of safety practice level assessment matrix and develops the safety practices strategies. In this phase, triangulation served as the validation method. Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding regarding the phenomena studied (Patton, 1999). Triangulation is also viewed as a qualitative research strategy that evaluates validity by converging information from varied sources. Denzin (1978) and Patton (1999) in Tobi (2016) listed four types of triangulation methods: (a) Method triangulation, (b) Investigator triangulation, (c) Theory triangulation, and (d) Data source triangulation.

The method triangulation was selected for this study to validate the responses about safety practice level. This indicates the accuracy of the study outcomes so as to enhance study credibility, stimulate the inventive methods, validate new ways of capturing a problem to balance with conventional data-collection methods , lead to synthesis or integration of theories, and finally, serve as a critical test, by virtue of its comprehensiveness, for competing theories (Jick, 1979; Hussein, 2015).

In assessing the safety practice level using the developed assessment matrix, three validation methods were applied in this study. The first method refers to the perception survey among RPOs. The second method is site observations and interviews with selected RPOs and managers of the facilities regarding the implementation of safety practice and its practising level. Finally, the case study method was performed to assess the safety practices level in selected cases, apart from determining the best practices and lessons learnt to be included as mitigation strategies in strengthening the safety practices.

The multi-method used in this study ascertained the validity of the proposed assessment matrix. The level of safety practice does indicate the current safety culture of the facilities in controlling and managing risks and hazard. The mitigating strategy can be implemented in facilities that have yet to adopt a high level of safety culture in their facilities.

3.4.1 Perception Survey

Perception survey identifies the gap between the value intended for safety in the organisation and the perceived value safety achieved from the stance of the employees (Weightman, 2017). In this study, a set of statements was derived from the developed

assessment matrix. Each statement represents the items for each level of safety practice and criteria. The respondents who were employed as radiation safety officer were asked to select the statement that best resembled their perceptions and practices in the facility. Each item of the framework was used as a statement to develop a question to investigate how each one of the five dimensions was treated in the organisations studied (Appendix G). The respondents were composed of 24 RPOs and managers who worked for the radiation facilities for more than 5 years. All the respondents answered the questionnaires and returned them to the researcher. Next, data analysis was performed and the frequency of the level and the percentage for each level were calculated.

3.4.2 Observation & Facilities Visit

The visit revealed the actual facility management, process, and safety practices implemented in the organisations, along with several best practices. Site visits to 14 facilities that use radiation technique presented a great opportunity to closely observe the culture of safety in these organisations.

The developed safety practice assessment matrix with template can serve as a guide to indicate the level of safety practices in the facilities. Thus, radiation safety officers and the manager of the facility were interviewed to gain clarification regarding the developed assessment matrix. Data gathered from both observation and interviews during the site visits were analysed. The frequency and the percentage of the level for each facility were determined.

3.4.3 Case Study

The case study, which is a qualitative approach, was employed in this study to comprehend the safety practice at radiation facilities. Case study is an empirical enquiry that helps to understand complex phenomena within the real-life context by undertaking in-depth data collection that involves multiple sources of information (Tobi, 2016). Case study enables one to determine and to explain the best practices, including experiences in practicing safety culture at the facilities. Accordingly, the case study approach contributes to the exploratory phase and elaborates the causal process to clarify ways of thinking linked to the certain issue or phenomenon (Johannessen, 1997).

3.4.3.1 Case study selection

In this study, the multiple case studies had been adopted. The multiple case studies are a practical way to understand the phenomena of safety practices. Selecting the multiple case studies enables one to study the issues at hand comprehensively with multiple sources of evidence and replication of findings. The findings are considered as robust and worthy for further investigation (Herriot & Firestone, 1983). A single case study is more appropriate for that unique case and one of its kinds. Safety culture and practices share similar characteristics with a few cases, hence selecting multiple case studies seems more appropriate (Thomas, 2015).

Five radiation facilities were selected based on the type of organisation, number of workers, and rate of accidents. Interviews were conducted at negotiated sites to maximise privacy, focus, and comfort for the respondents. The interview questions were based on issues, concepts, safety practice levels, criteria, and indicators proposed in the safety culture assessment matrix. Some questions probed into the best practices and lessons learn (Appendix[A24] H). [H25]The duration to complete the initial interviews was 140 to 160 minutes. Contact was made via email to clarify responses. Additionally, annual reports, as well as facility pamphlets and brochures, were reviewed during the site visits.

3.5 Summary of the Chapter

This study adopted the mix-method approach. The advantages and the disadvantages of this approach are complemented by each other to offer the best study outcomes. The mixed method approach enables one to comprehend gathered data in an in-depth manner, apart from providing the opportunity of learn from experiences and real practices to answer the research questions. The in-depth understanding on safety practices and the exploration of the best practices and lesson in implementation provide more robust data in developing the assessment matrix. This mix-method refers to one way to unravel creative and reliable research methods in formulating the sets of criteria and indicators to conceive and implement evaluation in safety practices. The next chapter presents a detailed analysis of phase one study including the data gathered from the questionnaire survey and analysed using SPSS version 22.0.

CHAPTER 4: FACTORS OF SAFETY PRACTICES IN THE MALAYSIAN RADIATION FACILITIES

4.1 Introduction

This chapter is divided into five major sections to include the findings retrieved from phase one of this study. In the first and second sections, the introduction and demographic profiles of the respondents were presented. In the third section, the survey findings outputs on safety climate are described and a summary of estimate risk of chemical and radiation hazard is presented. Next, sections four depict the statistical analysis of both descriptive and interferential analyses, including path analysis. Finally, the chapter ends with a summary of the phase one study in section five.

4.2 Demographic Profiles of the Respondents

A total of 312 respondents participated in this study; wherein 59% were from industrial processing, 15% linked to industrial testing, and 26% in other related fields, such as research and education. The response rate was 60% (n = 330) and the respondents were comprised of majority males with 78.2%, and followed by females, 21.8 %. Majority of the respondents are male due to the less numbers of female supervisors in the overall Malaysian nuclear industry. Basically, the selected respondents dealt with chemicals and radiation as average once in every 3 months. They were selected based on various categories of position, work experience, age, and academic qualification. The demographic profiles of the respondents are given in Table 4.1 as follows:

Table 4.1: Demographic Profiles of Respondents

Profile		Frequency	Per cent
Job Position	Other	58	18.6
	Operator	90	28.8
	Manager	57	18.3
	Supervisor	107	34.3
	Total	**312**	**100.0**
Working Experience	Less than 5 years	110	35.3
	5-10 years	87	27.9
	More than 10 years	115	36.9
	Total	**312**	**100.0**
Age	Less than 30 years	84	26.9
	31 - 40 years	135	43.3
	41 - 55 years	89	28.5
	More than 56 years	4	1.3
	Total	**312**	**100.0**
Education Level	SPM and below	44	14.1
	Certificate/Diploma	116	37.2
	Bachelor Degree	117	37.5
	Master Degree	29	9.3
	PhD	6	1.9
	Total	**312**	**100.0**
Gender	Male	244	78.2
	Female	68	21.8
	Total	**312**	**100.0**

Job positions included operators (28.8%), supervisors (34.3%), managers (18.3%), and others (18.6%). Hence, the proportion of the respondents seemed rather balanced, in which supervisors made up the largest group involved in this study.

Work experience was divided into three groups. The first group refers to those who has worked for at least 5 years (35.3%), while the second group is for those with 6 to 10 years of working experience (27.9%), and the third group is for those who has been working for more than 10 years (36.9%).

In terms of age, the respondents were segregated into four groups. The first age group refers to those below 30 years old (26.9%), while the second age group is between 31 and 40 years old (43.3%), making the largest age group. The third group of respondents are of age between 41 and 55 (28.5%), whereas the fourth group reflects those above 55 years old, with the lowest percentage of 1.3%.

Another variable of personal profile in question was the education level of the respondents. In this section, the respondents displayed colourful academic background. 14.1% of the respondents had SPM qualification and below, whereas 37.2% of them were diploma holders with technical certificates and 37.5% held degrees. Meanwhile, 11.2% were master's and PhD degree holders. In terms of education level, the respondents were balanced for diploma and degree levels.

The demographic data displayed that the proportion of respondents in this study is fairly balanced. The respondents were well experienced, in young age and educated. In this survey, the supervisor group appeared to be the largest group.

4.3 Findings of the Safety Climate Assessment and Estimated Risk

The survey outcomes retrieved from the three main sectors of the radiation field are presented. They are divided into two parts: 1) Safety Climate Factors, and 2) Risk Estimate of Chemical and Radiation Hazard.

4.3.1 Safety Climate Factors

The nine variables of safety climate factors incorporated in this study are management commitment, communication, involvement, environmental support, safety priority, working environment, questioning attitude, prudent approach, and information.

4.3.1.1 Management commitment

The results show that the data were normally distributed. Figure 4.1 illustrates that approximately 10% of the respondents agreed, while 80% chose to moderately agree on the items related to management commitment and leadership. Meanwhile, less than 5% of the respondents opted to moderately disagree with management commitment. These results indicated that the respondents from inspection and industrial process moderately agreed and were moderately satisfied with the commitment displayed by the management team towards the aspect of safety at the facilities.

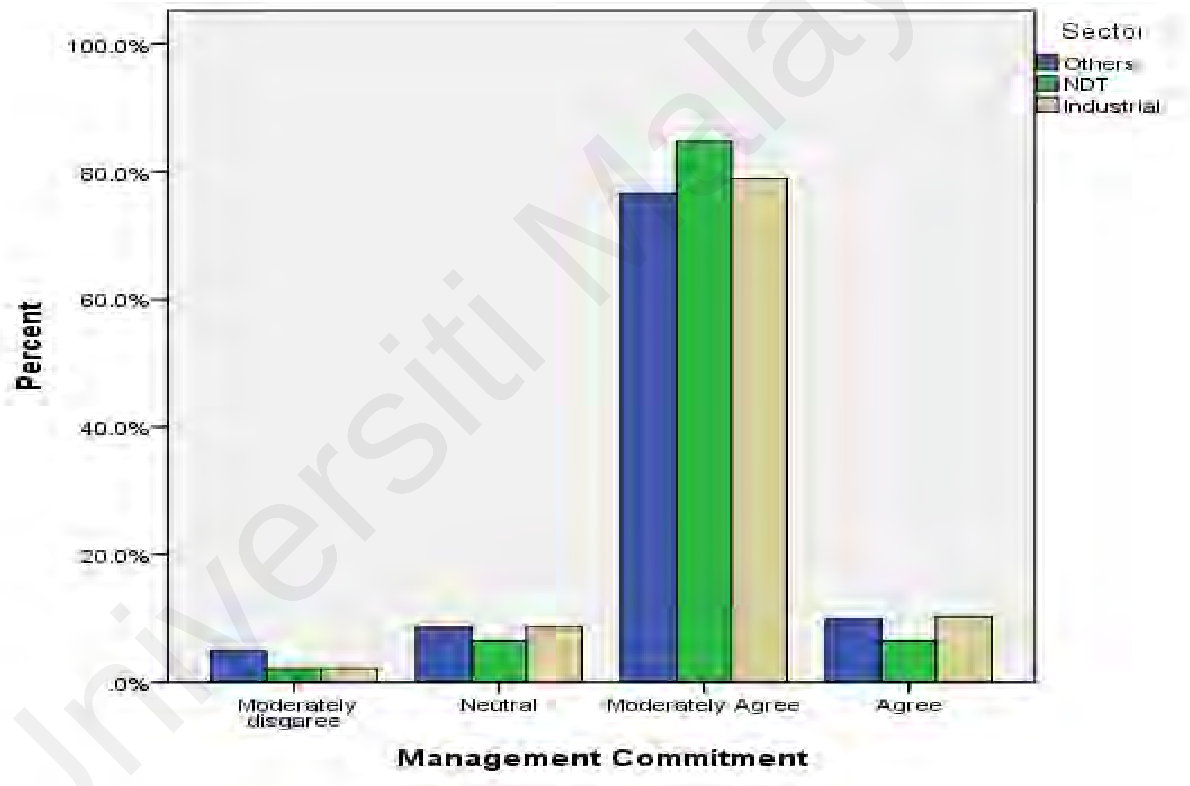

Figure 4.1: Management commitment

4.3.1.2 Communication

Figure 4.2 portrays the responses to the communication in safety issues at the facilities. About 70% of the respondents for all sectors seemed to moderately agree with items related to communication. Meanwhile, 17%-18% of the respondents agreed with the statements given. Generally, this indicates that most of the respondents did agree with the communication strategies on safety issues at the facilities.

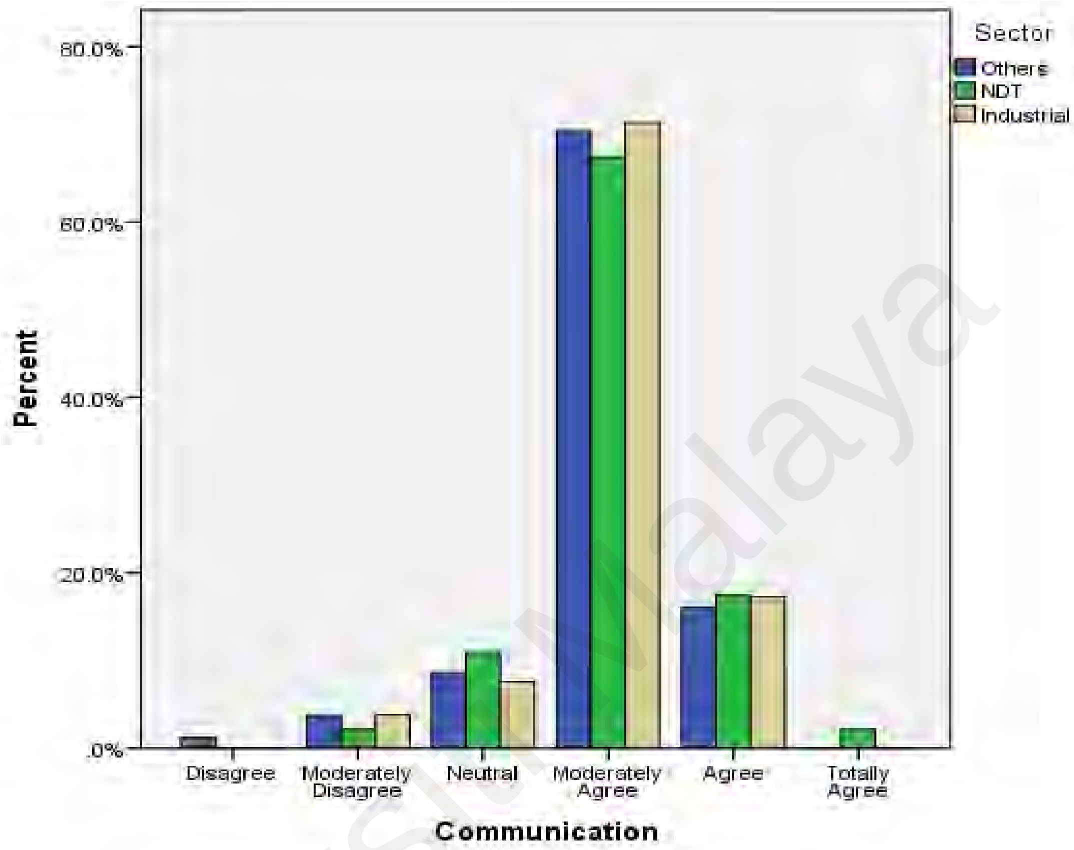

Figure 4.2: Communication

4.3.1.3 Involvement

The results exhibited in Figure 4.3 show the responses to the involvement of workers in safety concerns. Approximately 49% to 50% respondents of inspection and industrial process sector agreed to the related items, while 38% to 45% chose to moderately agree, and only 1% to 2% totally agreed with the activities to display their involvement in safety. The results, however, did not show any significant disagreement on the involvement of the workers in safety aspect.

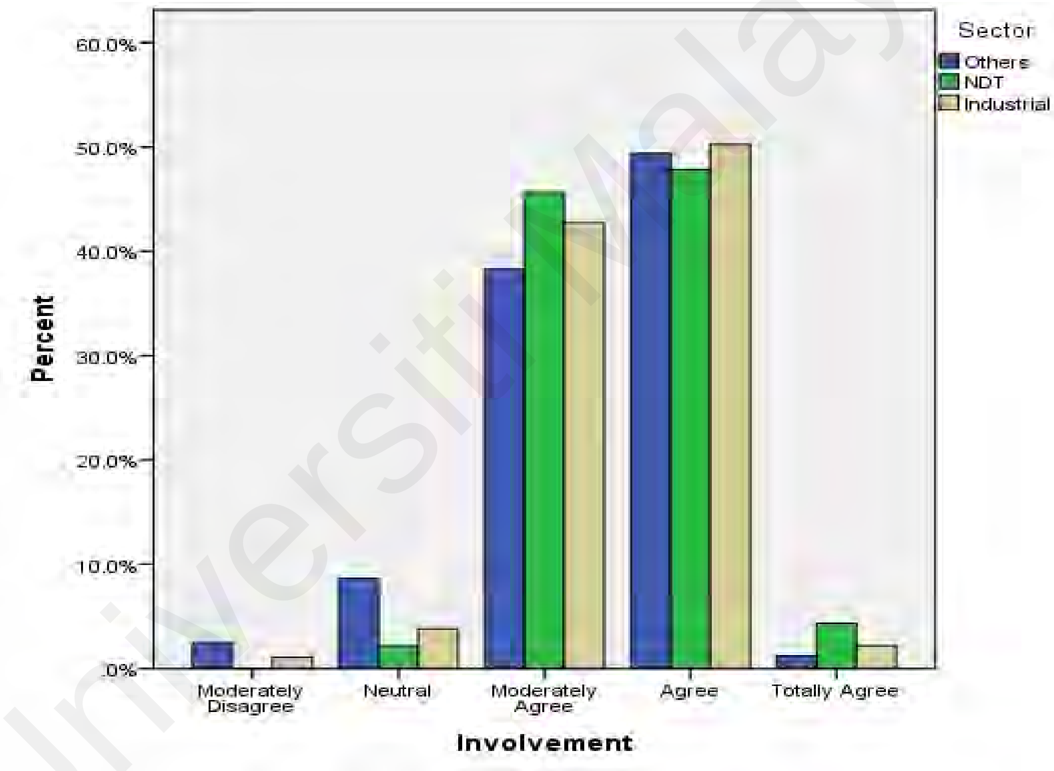

Figure 4.3: Involvement

4.3.1.4 Environmental Support

Figure 4.4 presents that most of the respondents agreed with the environmental support initiatives. In precise, 18% to 21% of them moderately agreed, 59% to 65% agreed, and 18% to 22% totally agreed with the given statements. Generally, these results show that the respondents agreed with the safety procedures and guideline, the provided safety monitoring system, and complied with the safety procedures at the facilities.

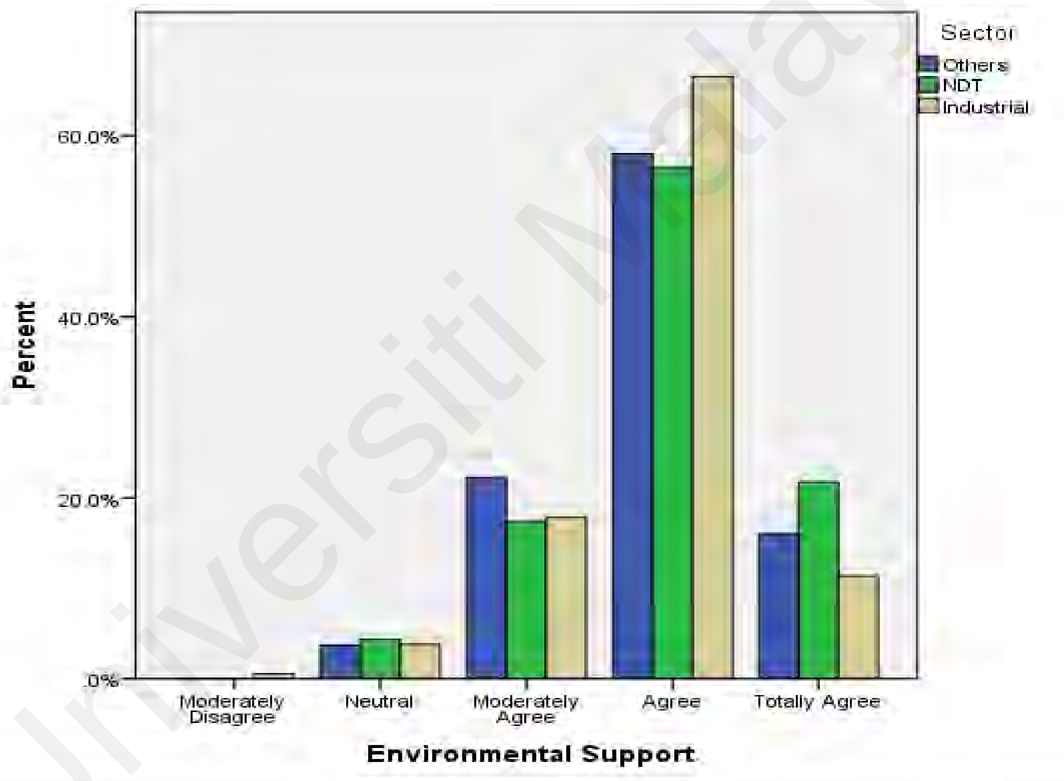

Figure 4.4: Environmental support

4.3.1.5 Safety priority

The responses to safety priority are shown in Figure 4.5. About 2%-3% of respondents from inspection and industrial process chose to totally agree with the given statements. In fact, a majority of the respondents, including those from the other sectors, moderately agreed and agreed. The results show that 30%-38% of respondents chose to moderately agree, while 58%-65% agreed to the given statements. This indicates that the respondents agreed in giving high priority to safety at workplace.

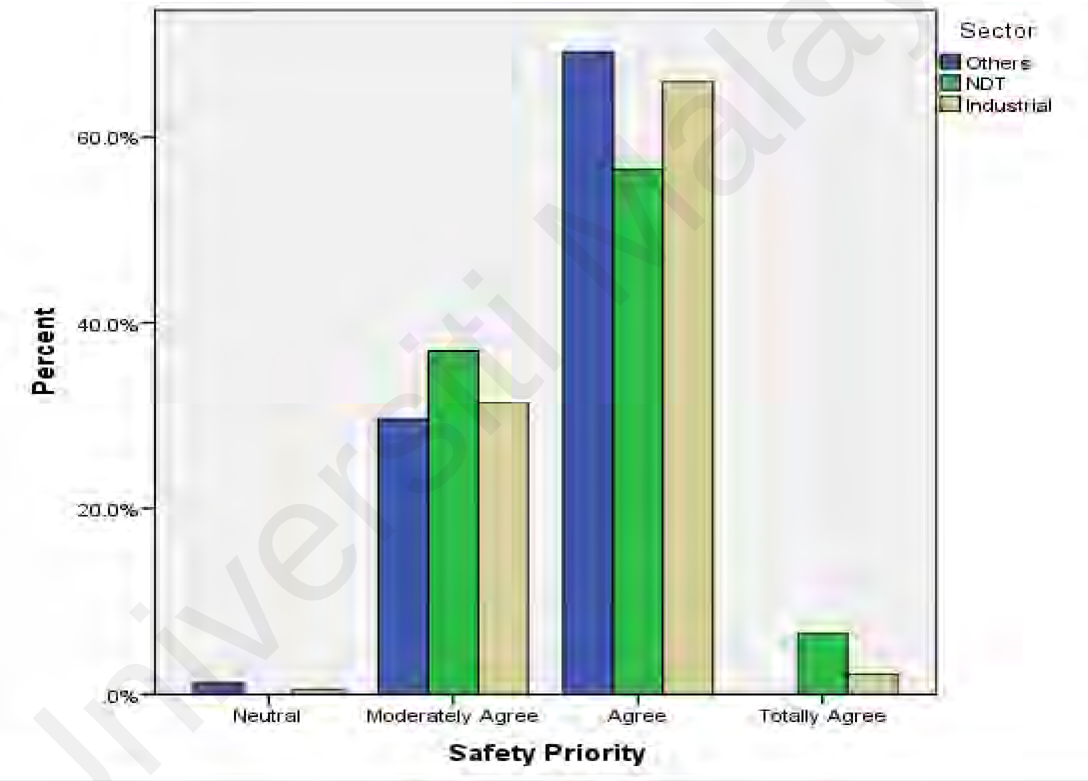

Figure 4.5: Safety priority

4.3.1.6 Working environment

Figure 4.6 illustrates the responses regarding working environment at the facilities. More than 50% of the respondents from the three sectors moderately disagreed with the given statements. Nonetheless, 10% of the respondents from other sectors, 18% from the inspection sector, and 25% from the industrial sector moderately agreed with their working environment. These results indicate that most of the respondents disagreed with their working environment that did not prioritise and failed to emphasise safety concerns amongst the workers at the facilities.

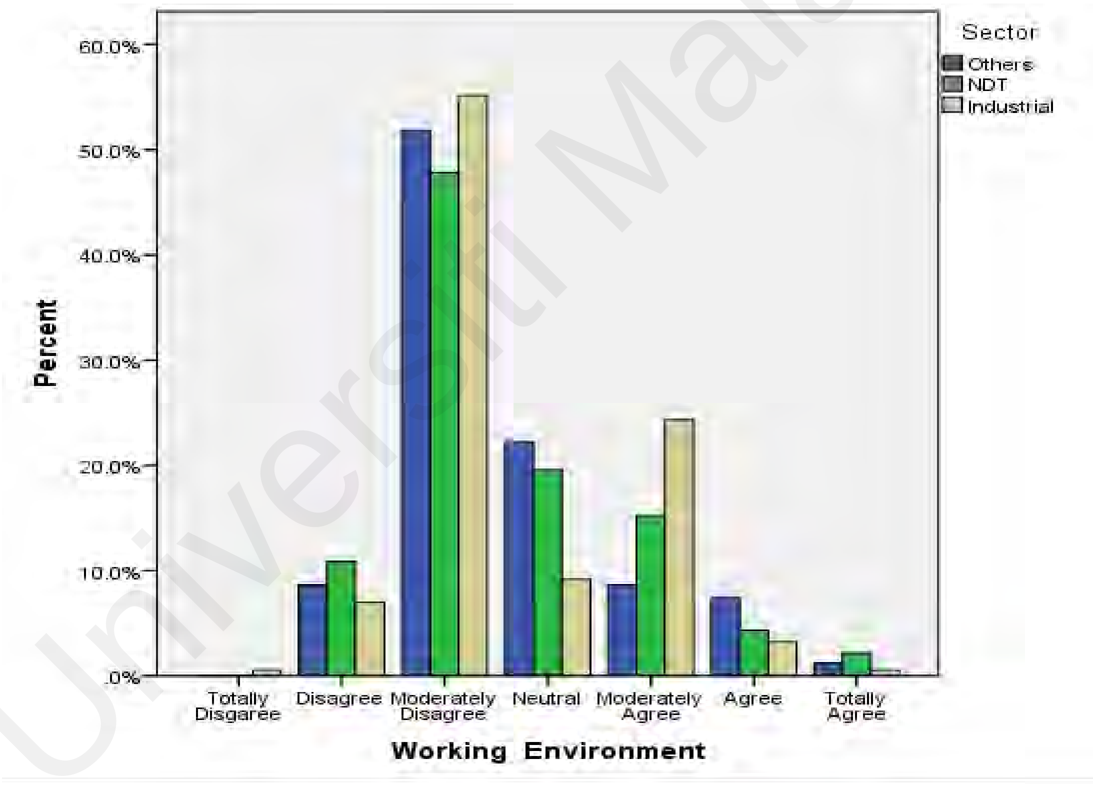

Figure 4.6: Working environment

4.3.1.7 Questioning attitude

Responses[A26] to the questioning [H27]attitude are given in Figure 4.7. The results show that 45% to 60% of the respondents moderately agreed with the given statements, whereas 20%-25% chose to moderately disagree and gave neutral response to the questioning attitude. The outcomes indicate that the questioning attitude of workers is still new to the respondents. In fact, some respondents did question about the safety aspect at the workplace, while some moderately practised the questioning attitude.

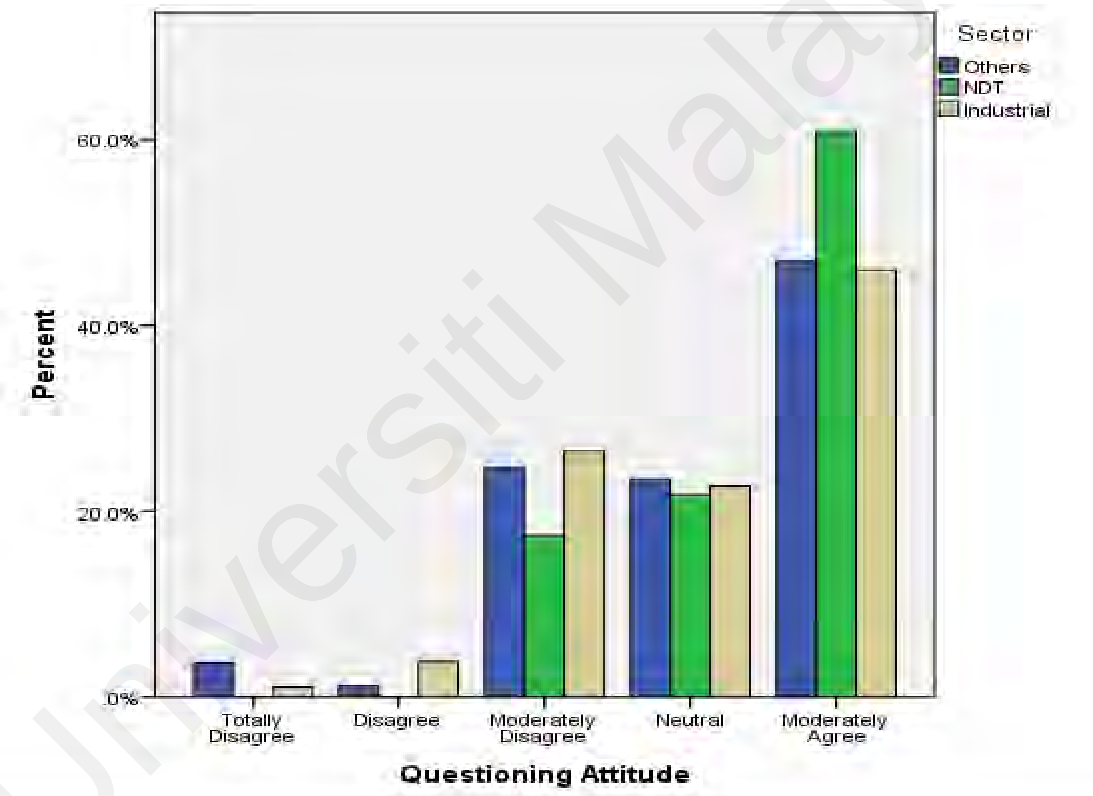

Figure 4.7: Questioning attitude

4.3.1.8 Prudent approach

Most respondents agreed and were satisfied with prudent approach. Figure 4.8 illustrates that 30% to 38% respondents moderately agreed with the given statements, while 55% to 60% agreed, and more than 10% totally agreed to statements related to prudent approach. This indicates that the respondents did agree with practising the proper and standard approach at job that requires safety precaution.

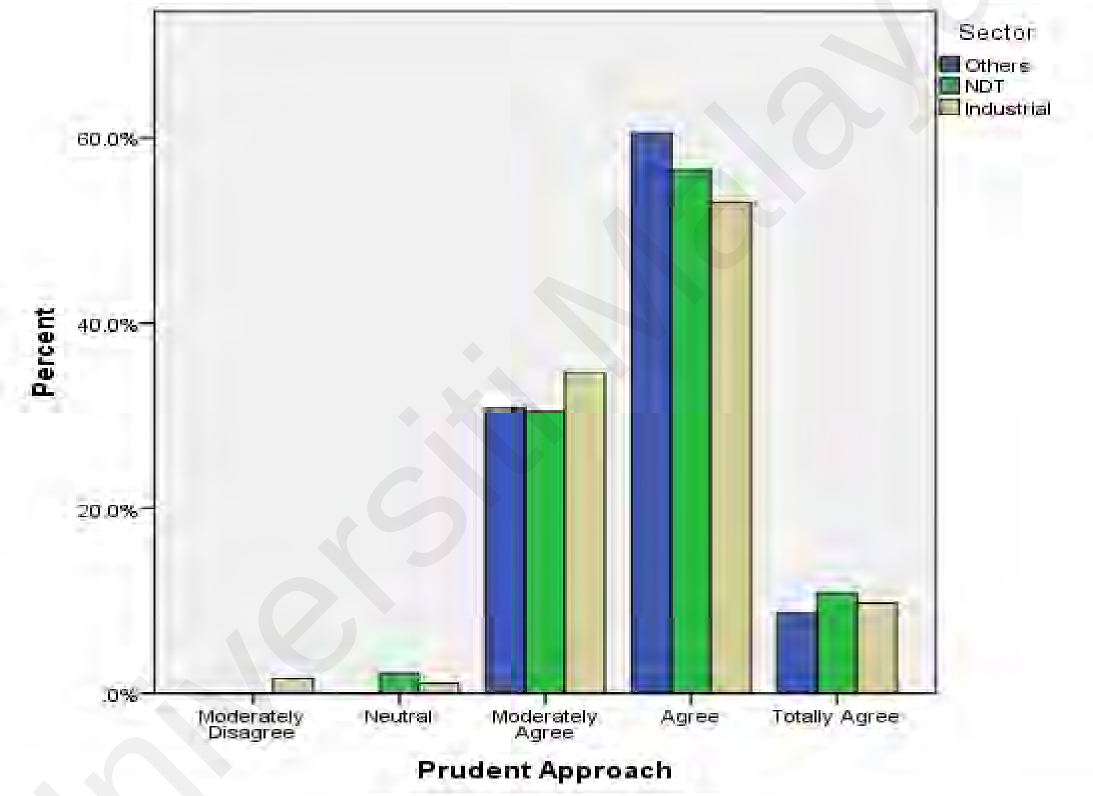

Figure 4.8: Prudent approach

4.3.1.9 Information

Figure 4.9 displays responses for information in safety issues. Most respondents agreed that they had to find and communicate accurate information for the sake of their safety while at work in the facilities. About 20% of them moderately agreed with the items stated, while 50%-60% agreed, and more than 20% totally agreed with the use of information in managing safety and risk at workplace. Generally, these results indicate that communicative information activities through reporting, sharing, and disseminating safety information are practised at the facilities.

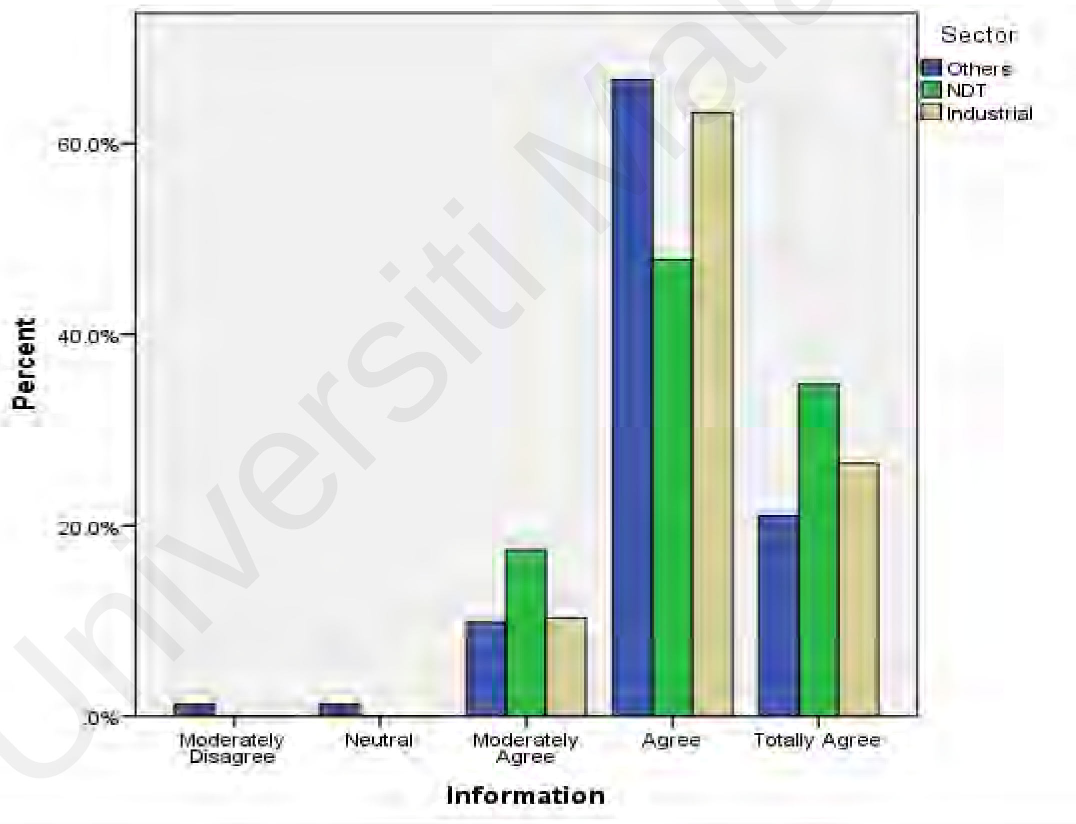

Figure 4.9: Information

4.3.2 The Estimate Risk of Chemical and Radiation Hazard

The risk level of hazard can be estimated based on the probability of risk occurrence and consequences of the hazard to the workers at the facilities. Hazard reflects chemical and radiation hazards.

4.3.2.1 Chemical exposure

Figure 4.10 illustrates the chemical exposure level. Most of the respondents estimated that the risk of chemical exposure was at a low level. About 80% to 95% respondents perceived low risk, while 5% to 10% estimated medium and high risks. The results show that chemical exposure was at low risk due to the low frequency and consequences of the hazard. This indicates excellent risk management at the facilities.

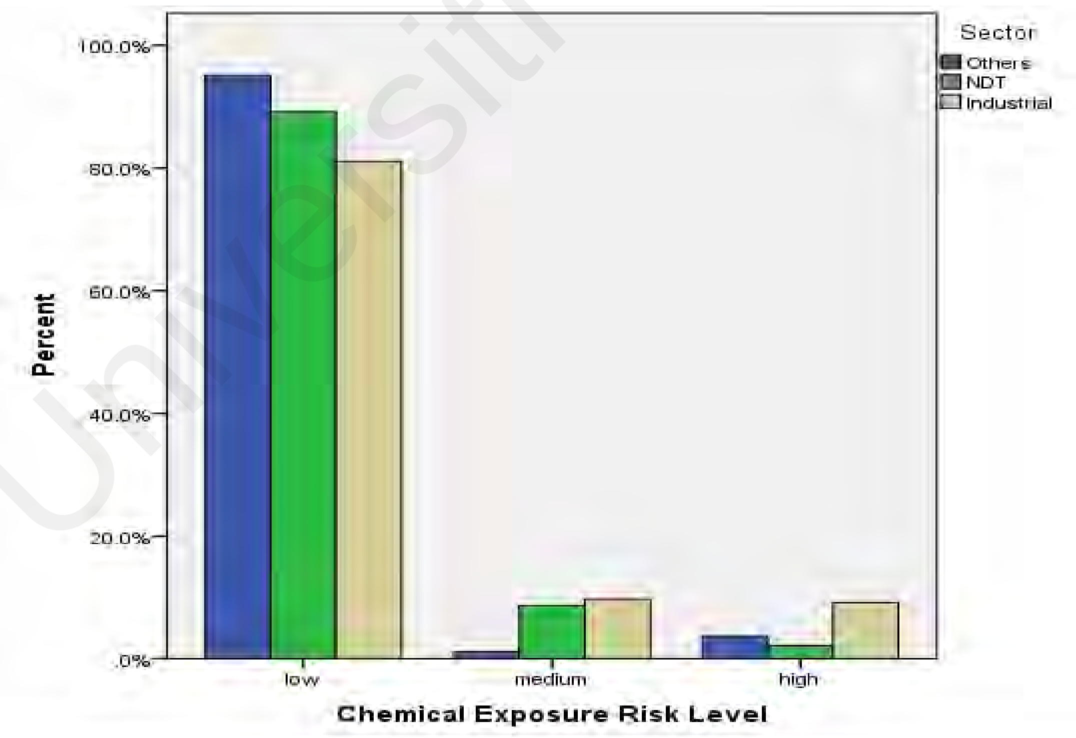

Figure 4.10: Chemical exposure

4.3.2.2 Chemical spillage

The results indicate the estimated risk level of chemical spillage hazard. Figure 4.11 exhibits that 85% to 95% of the respondents had perceived low risk of chemical spillage, while 5% to 10% estimated medium and high risks. The responses from the inspection sector estimated that chemical did not pose high risk in their operations. This indicates that the occurrence of chemical spillage and its consequences to the workers were low and did not cause any death or fatal accident.

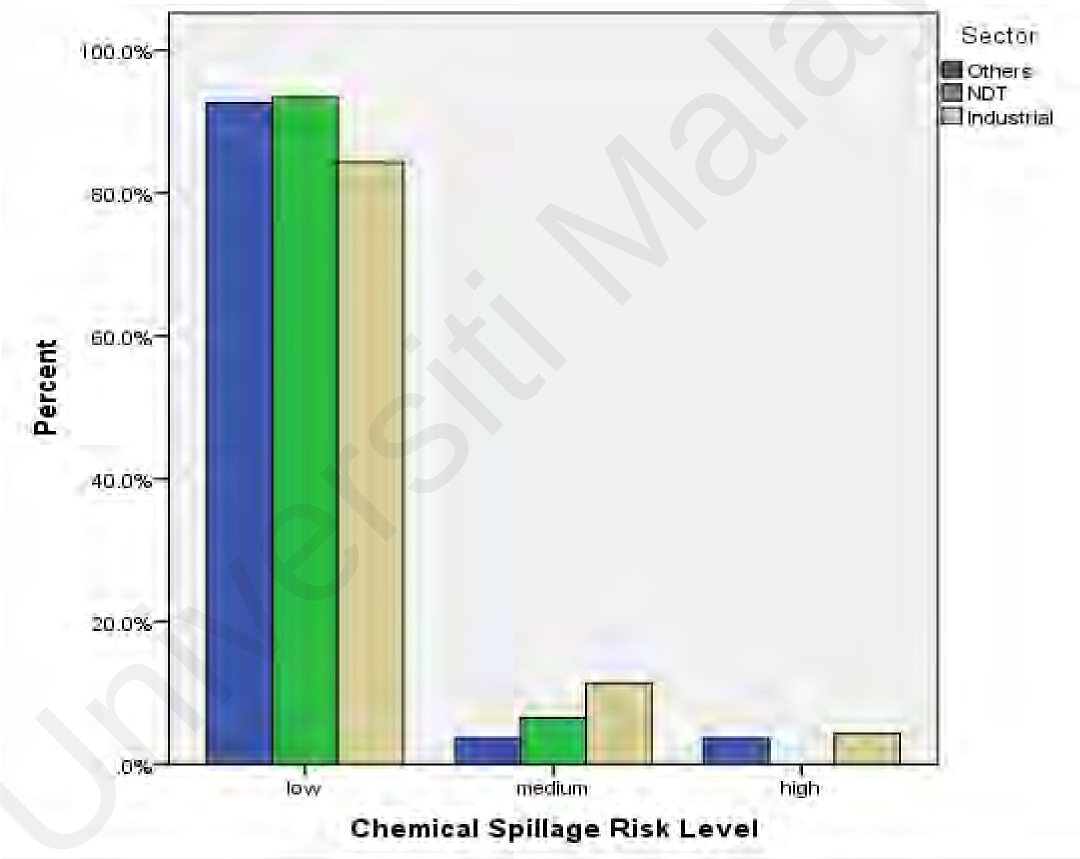

Figure 4.11: Chemical spillage

4.3.2.3 Chemical leakage

Chemical leakage was estimated to be at a low level risk by almost all the respondents, as portrayed in Figure 4.12. About 90% to 98% perceived low risk, while only 2% to 10% estimated medium and high level risks. Generally, the results display the probability of chemical leakage that had never happened, but it may occur if uncontrolled and cause minor injuries.

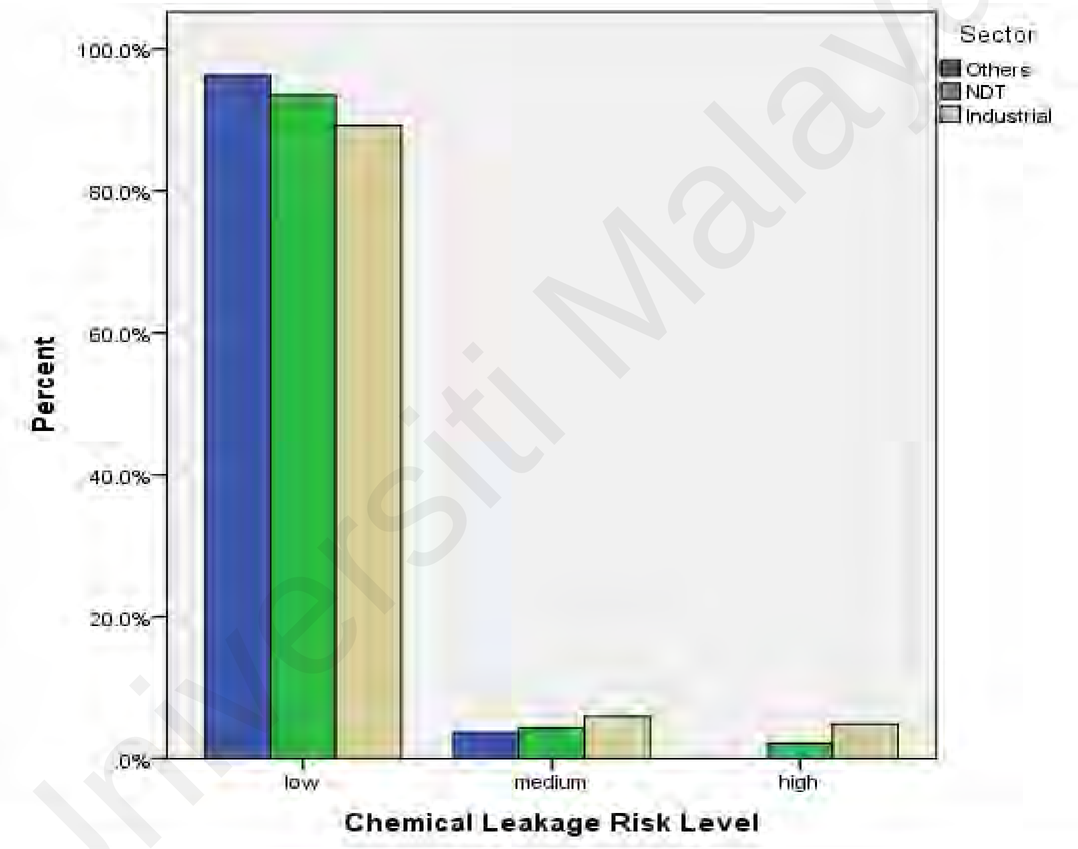

Figure 4.12: Chemical leakage

4.3.2.4 Radiation exposure

Figure 4.13 illustrates the results of estimated risk level for radiation exposure. Approximately 85% to 95% of the respondents perceived low risk, while 5% to 15% estimated medium and high level risks. This indicates that radiation exposure rarely happened and did not cause any major accident involving death at the facilities. The case was classified as remote and it did not have much impact on the workers.

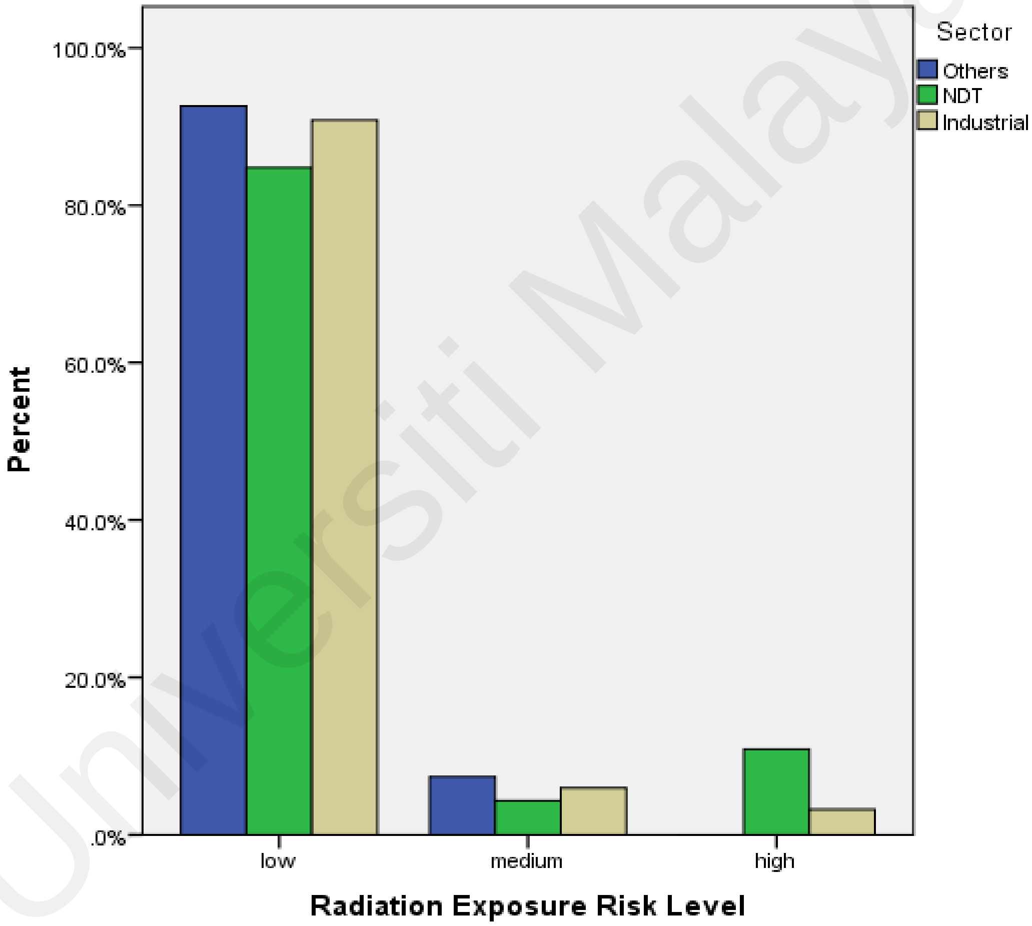

Figure 4.13: Radiation exposure

4.3.2.5 Radiation contamination

The results of radiation contamination risk level estimation are shown in Figure 4.14. More than 90% of the respondents estimated that the radiation contamination has low level risk. The probability of contamination to occur was very low and no major accident has been reported due to the risk. However, less than 10% of the respondents perceived medium and high level risk. The results indicate low probability of accidents that might have occurred due to radiation contamination.

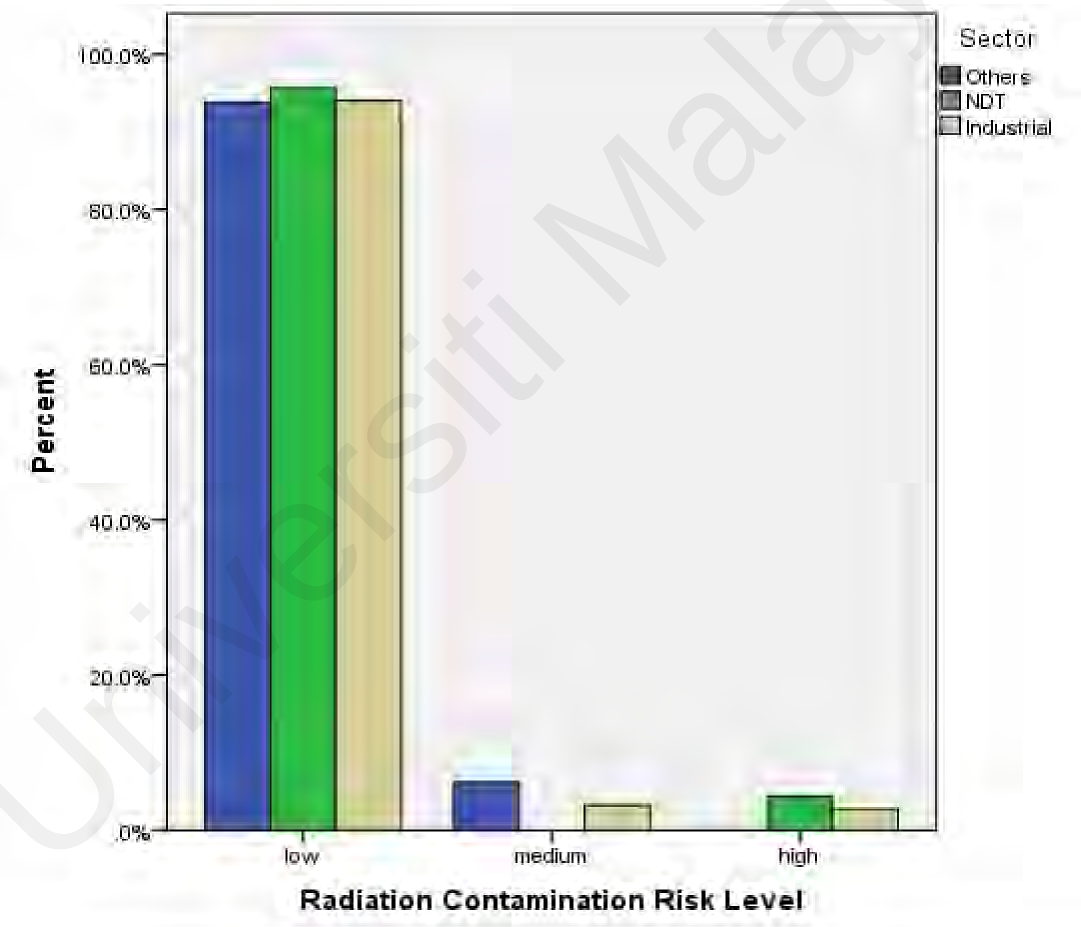

Figure 4.14: Radiation contamination

4.3.2.6 Radioactive spillage

Figure 4.15 illustrates the results of the estimated risk level of radioactive spillage. Most of the respondents (95%) perceived low risk, whereas 5% estimated medium and high level risk. The results indicate that radioactive spillage very rarely happened and had never caused major accident involving death at the facilities. The probability of the accidents caused by radioactive spillage seemed to be lower, when compared to radiation exposure and radiation contamination.

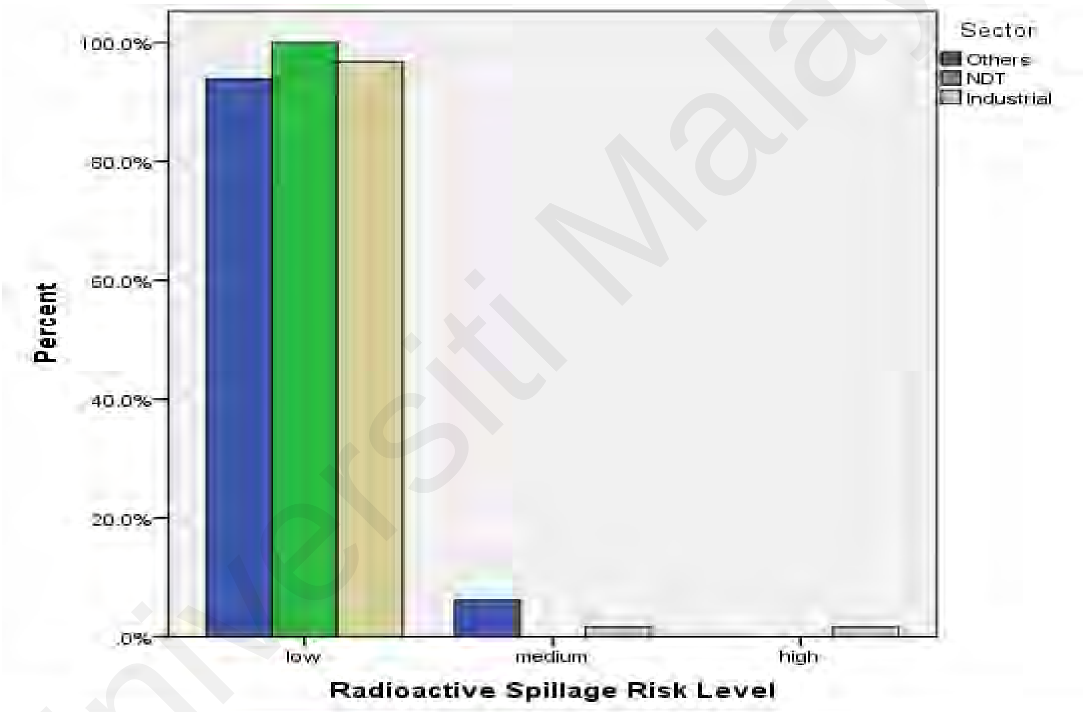

Figure 4.15: Radioactive spillage

4.3.3 Summary of the Survey Findings

The results depict the data pertaining to safety climate factors of management commitment, communication, involvement, environmental support, safety priority, working environment, questioning attitude, prudent approach, and information; as well as risk level estimates of chemical and radiation hazards were normally distributed (see

Appendix I). [A28][H29]The normal distribution of the variables had been tested by using the Kolmogorov-Smirnov test. Hence, the data gathered from the survey qualified to be used in this study. The statistical analysis in this study required the data to be normally distributed, and this requirement had been fulfilled.

The respondents from the three main radiation sectors displayed the highest percentage of consent in the factors of the safety climate in their facilities, as seen in Figure 4.16. These scores indicated that they moderately agreed (MA) with the commitment of leadership and management, the methods of communication at the facilities, and the actions of questioning. Furthermore, they mostly agreed (A) with their participation in safety initiatives and programmes, the prioritisation of safety in the assigned duties, well-advised method to complement the standard of safety, the provision of the support of environment by the top management and facilities, and distribution of information related to concerns of safety at the facilities. Meanwhile, there were participants who moderately disagreed (MD) regarding the mismanagement of the working environment at the facilities.

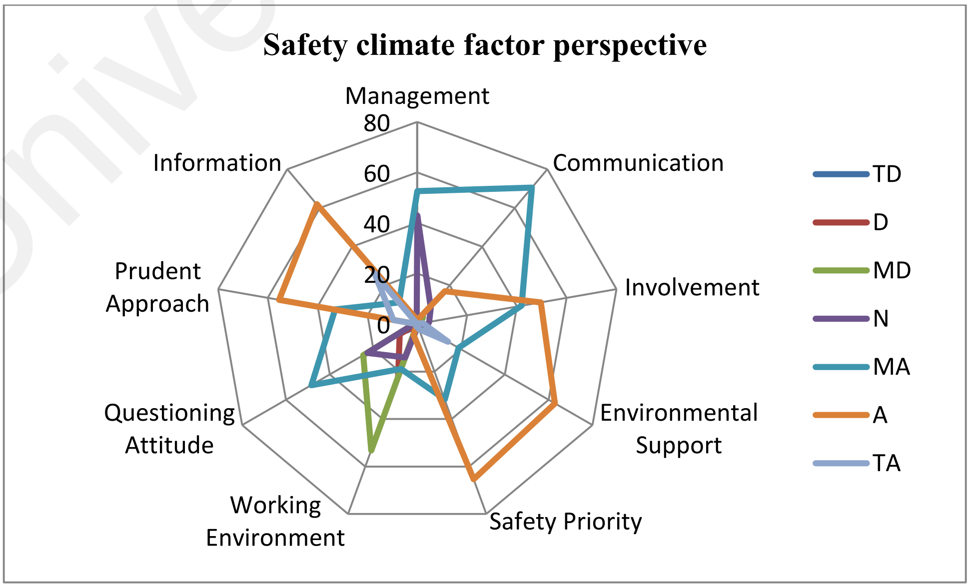

Figure 4.16: Safety climate factor perspective

It was viewed by most participants that radiation and chemical hazards in each of their facilities were categorised under “low-level risk”, as seen in Figure 4.17. Based on this figure, the participants determined that radiation spill, contamination of radiation, exposure to radiation, chemical leaks, chemical spill, and exposure to chemical had the low level of risk. The risk level assessed based on the probability of occurrence and consequences of the hazard towards the workers and in the facilities.

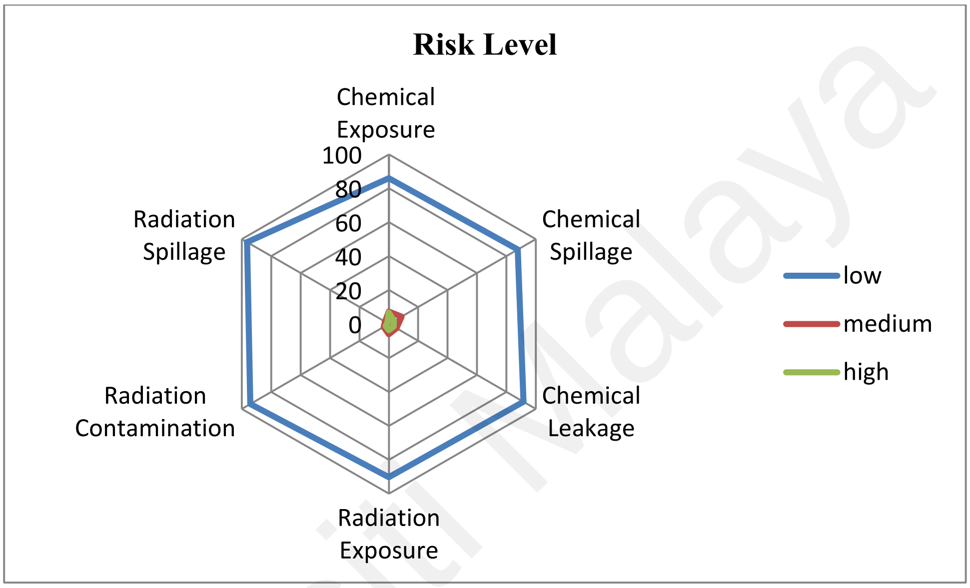

Figure 4.17: Risk level

4.4 Statistical Analysis

This section presents the analysis of quantitative data using statistical analysis. The internal reliability of the questionnaire for the entire test was verified using Cronbach’s alpha method. Both descriptive and inferential statistics are presented in this section to describe the basic features of the data, to estimate the correlations between the parameters, and to assess both reliability and validity of the measurement model in testing the research hypotheses.

4.4.1 Internal Reliability

Table 4.2 shows the variables and the values of Cronbach's alpha for internal reliability. The values of Cronbach's alpha for each factor exceeded 0.6, which signified the adequacy of internal consistency reliability of the questionnaire. According to Taber (2017), it was implied from the results that the items' reliability, which was set in the questionnaires as Cronbach's Alpha value ranging from 0.46 to 0.90, was accepted. Despite the alpha value is lower than 0.6 for the prudent approach, its acceptance was due to the possibility of the alpha being influenced by the length of scale (Ferguson & Daniel, 1995). Additionally, the Cronbach's Alpha values could be influenced by questionnaire item numbers, as the Cronbach's alpha values would be accepted due to a slight increase in the item numbers (Taber, 2017).

Table 4.2: Variables description and Cronbach's alpha values

Construct	Number of items	Cronbach's Alpha value
Safety Climate Factors		
Management & Communication	5	0.83
Personal Involvement in Health and Safety	2	0.74
Personal view	2	0.65
Supportive Environment	3	0.72
Personal Priorities and Need for Safety	4	0.86
Work environment	5	0.81
Questioning Attitude	5	0.88
Communicative Information	4	0.86
Prudent Approach	2	0.46
Risk Control		
Administration control measure	6	0.84
Accident Awareness	2	0.78
Training	6	0.84
Individual Risk estimate		
Chemical Hazard	3	0.88
Radiological Hazard	3	0.90
Organisational Effect	6	0.82
Decision-making attitude	8	0.60

4.4.2 Descriptive Statistics

Descriptive statistics is used to describe the basic features of the data in a study. It gives simple summaries regarding the sample and the measures. In this section, the analyses of mean values, factor analysis, and repeated ANOVA are presented. Each factor was computed and statistical analysis was subjected to normality test, wherein the results indicated that data were normally distributed.

Table 4.3 presents the mean values, standard deviations, and mid of scales for all the measures. The highest mean of safety climate factors value was 6.06 for communicative information, while the lowest mean value was 1.54 for organisation effect of risk level estimate. The mean value for safety climate factors were the highest among all the components studied. All components displayed higher mean value than the mid of scale component, except for organisation effect. The descriptive results portrayed that the score of standard deviation was low for safety climate factors, risk control, and decision-making. The score was high for the risk level estimate. The results indicated that the dispersion of the scores from the mean value was low for safety climate factors, risk control, and decision-making.

Table 4.3: Mean and standard deviation values of all measurements

Variable	Construct	Mean	SD	Mid of Scales
Safety Climate Factors	L.M	4.96	.47	3.5
	C.M	4.96	.57	3.5
	I.M	5.26	.55	3.5
	EM.M	5.74	.66	3.5
	PP.M	5.58	.42	3.5
	WE.M	3.77	1.02	3.5
	Q.M	4.15	.76	3.5
	A.M	5.58	.60	3.5
	IC.M	6.06	.61	3.5
	Total	5.12	.32	3.5
Risk Control	AA.M	5.94	.75	3.5
	RC.M	4.08	.64	2.5
	T.M	3.35	.99	3.0
	Total	4.46	.51	3.0

Table 4.3, continued

Variable	Construct	Mean	SD	Mid of Scales
Risk Level Estimate	RCE.M	2.59	2.09	2.0
	RRA.M	2.16	1.73	2.0
	RE.M	1.54	. 62	2.0
	Total	2.04	1.23	2.0
Decision-Making	DM.M	3.76	.64	3.0
Abbreviations: LM – Management, C.M- Communication , I.M- Involvement, EM.M- Environment Support, PP.M – Personal Priority, WE.M- Work environment, Q.M – Questioning Attitude, A.M –Prudent Approach, I.C.M – communicative information. AAM- Accident Awareness, RC.M – Risk Control, T.M – Training, RCE.M- Chemical Risk , RRA.M- Radiation hazard, RE.M – Organisation effect DM.M- Decision-Making Attitude				

4.4.2.1 Exploratory factor analysis

Factor analysis is used to describe the aspect of variability among observed and correlated variables in terms of a potentially lower number of unobserved variables called factors. Table 4.4 displays the retained items in the final solution. The number of factors retained was determined by Kaiser Criterion that selects factors with eigenvalues exceeding 1 (Bryman & Cramer, 2001). As a result, nine factors with eigenvalues greater than 1 emerged accounting for 67.81 % of the total variance. Factor 1, which included 5 items with a loading factor, ranged from 0.76 to 0.85 and termed as questioning attitude (QA). Factor 2 of 5 items with a loading factor ranging from 0.63 to 0.86 and termed as Work Environment (WE). Factor 3 included 5 items with a loading factor that ranged from 0.62 to 0.77 and termed as Management & Communication (MC). Factors 4 and 5 included 4 items with loading factors that ranged from 0.72 to 0.78 and from 0.67 to 0.83 and termed as Safety Priorities (SP) and Communicative Information (CI), respectively. Factor 6 included 3 items with a loading factor, ranging from 0.64 to 0.70 was Supportive Environment (SE). Factors 7 until 9 included 2 items with loading factors that ranged from 0.55 to 0.74, 0.79 to 0.81, and 0.82 to 0.74; termed as Personal View (PV), Prudent Approach (PA), and Involvement (I), respectively.

Table 4.4: Results of factor analysis of MRSTK based on PCA with Varimax rotation

Rotated Component Matrix[a]									
Item	Component								
	QA	WE	MC	SP	CI	SE	PV	PA	I
Q3	.851								
Q2	.843								
Q1	.829								
Q4	.791								
Q5	.760								
WE3		.856							
WE2		.822							
WE5		.732							
WE1		.713							
WE6		.626							
L3			.765						
L4			.757						
C4			.684						
L1			.632						
C6			.618						
PP6				.782					
PP3				.763					
PP1				.750					
PP4				.724					
IC2					.829				
IC1					.825				
IC3					.790				
IC4					.686				
A4						.700			
E3						.683			
E5						.643			
C2							.746		
L5							.548		
A5								.808	
A6								.785	
I3									.741
I4									.582
Percentage of variance	23.410	10.570	8.555	5.556	4.622	4.505	3.860	3.572	3.157
Eigenvalues	7.491	3.382	2.738	1.778	1.479	1.442	1.235	1.143	1.010
Cronbach α	0.875	0.814	0.830	0.858	0.864	0.72	0.651	0.464	0.741
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.[a]									

The factor analysis showed that the questioning attitude, as individual's response to safety, emerged as the strongest factor of MRSTK. This finding is in line with that depicted by (Madalina Tronea, 2014), who revealed that self-assessment was towards the individual risk and hazard through questioning attitude. Martinez et al., (2014) described that positive individual response contributes to a strong safety culture of nuclear and radiation hazard.

Based on the factor analysis comparison with petrochemical sector, all the six factors of MSTK (Factors 1 until 6) listed in Table 4.5 that contributed to the safety practices culture in petrochemical sectors also contributed to the safety practice in the radiation sectors in Malaysia. In this study, the radiation facilities were involved the radiation and chemical hazard. In the petrochemical sectors, the management factors were independent, while in radiation sector, items for management were loaded in the communication factor. Items in communication of petrochemical sectors seemed to be loaded in supportive environment. However, the factors differed in loading factors and the total percentage of variance. This is related to awareness, training, and practice towards safety and health of the workplace (Hui-Nee, 2014). Furthermore, safety climate in the organisation also influences the factors that contribute to the safety practices of workers (Kouabenan et al., 2015). Safety management and work environment as organisational commitment were affected by safety practice more than individual commitment in petrochemical facilities.

Table 4.5: Comparison and list of factors that contribute to the safety practise of petrochemical and radiation sectors using MSTK and MRSTK

Contribute Factor	MSTK (Isha, 2012) (Petrochemical)	MRSTK (Radiation)
Total % of Variance	61.74%	67.81%
Factor 1	Work Environment (28.94%)	Questioning Attitude (10.969)
Factor 2	Personal Safety Priorities (10.09%)	Work Environment (9.88%)
Factor 3	Involvement (6.78%)	Management & Communication (9.43%)
Factor 4	Management (5.77%)	Personal Safety Priorities (9.42%)
Factor 5	Supportive Environment and Communication (5.52%)	Communicative Information (9.17%)
Factor 6	Personal View (4.62%)	Supportive Environment (5.22%)
Factor 7	-	Personal view (4.70 %)
Factor 8	-	Prudent Approach (4.53%)
Factor 9	-	Involvement (4.48%)

4.4.2.2 Repeated measured ANOVA

In this study, the repeated ANOVA was conducted to assess the presence of mean differences for F1-F9. The repeated measured of ANOVA is more appropriate as the measurements are made more than twice repeatedly for the same dependent variable. It has been acknowledged as appropriate in this study to determine the dependency of the nine components to be factors that affected the safety culture of workers in the facilities.

The level of mean factors was compared by computing the mean score of related items for each factor first, and followed by statistical analysis of normality test. The results indicated that the data were indeed normally distributed.

The repeated measure of ANOVA with Greenhouse-Geisser correction and Bonferroni post-hoc test determined the significant mean difference among the variables and the highest mean of the variables (Singh et al., 2013). The results of Mauchly's test illustrated that the sphericity assumption was violated (χ^2= 655.328, p =0.000), thus the degree of freedom had to be adjusted via Greenhouse-Geisser estimation of sphericity. The results of repeated ANOVA showed that the variance among these nine factors was statistically significant ($F(4.58, 1423.46)$= 480.610, $p <$ 0.005, $\eta 2$=0.607), hence to evaluate the mean differences of these nine factors, post-hoc test (Bonferroni) was applied to compare the mean scores.

Table 4.6 presents the pairwise comparison analysis that elicited insignificant mean difference for pair of Factors 1 and 2 (4.9606 ± 0.473 and 4.9693 ± 0.570, p > .005.), as well as Factors 5 and 8 (5.582 ± −0.428 and 0.583 ± −0.602,p > .005)). A significant difference was noted for components 6, 7, 3, 4, and 9 (3.779 ± −1.028 to 6.066 ± −0.610,p < .005).

Table 4.6: Pairwise comparison between mean scores of safety climate factors

(I) Factor	(J) Factor	Mean Difference (I-J)	SE	P Value
F1 (Management)	2	-.009	.032	1.000
	3	-.309*	.036	<.001
	4	-.787*	.037	<.001
	5	-.622*	.032	<.001
	6	1.181*	.064	<.001
	7	.809*	.050	<.001
	8	-.623*	.040	<.001
	9	-1.106*	.039	<.001
F2 (Personal View)	3	-.300*	.039	<.001
	4	-.778*	.041	<.001
	5	-.613*	.035	<.001
	6	1.189*	.065	<.001
	7	.818*	.052	<.001
	8	-.615*	.040	<.001
	9	-1.097*	.041	<.001
F3 (Involvement)	4	-.478*	.041	<.001
	5	-.314*	.033	<.001
	6	1.489*	.064	<.001
	7	1.118*	.051	<.001
	8	-.315*	.042	<.001
	9	-.797*	.039	<.001
F4 (Environmental Support)	5	.165*	.036	<.001
	6	1.967*	.076	<.001
	7	1.596*	.050	<.001
	8	.163*	.040	.002
	9	-.319*	.037	<.001
F5(Safety Priority)	6	1.803*	.063	<.001
	7	1.432*	.049	<.001
	8	-.001	.033	1.000
	9	-.484*	.033	<.001
F6(Work Environment)	7	-.371*	.074	<.001
	8	-1.804*	.067	<.001
	9	-2.287*	.072	<.001
F7 Questioning Attitude)	8	-1.433*	.052	<.001
	9	-1.915*	.049	<.001
F8(Prudent Approach)	9	-.483*	.038	<.001
F9 (Communicative Information)				

The results showed that the nine factors; questioning attitude, communicative information, work environment, management commitment, communication, safety priority, involvement, prudent approach and personal view, contributed to the safety practices. The repeated ANOVA with Greenhouse-Geisser correction and Bonferroni post-hoc test determined statistically significant mean differences between the nine safety practices factors identified in this study.

Figure 4.18 displays the mean difference between the factors that contributed to safety practice, with the communicative information being the highest mean level. On the contrary, the lowest mean level was work environment.

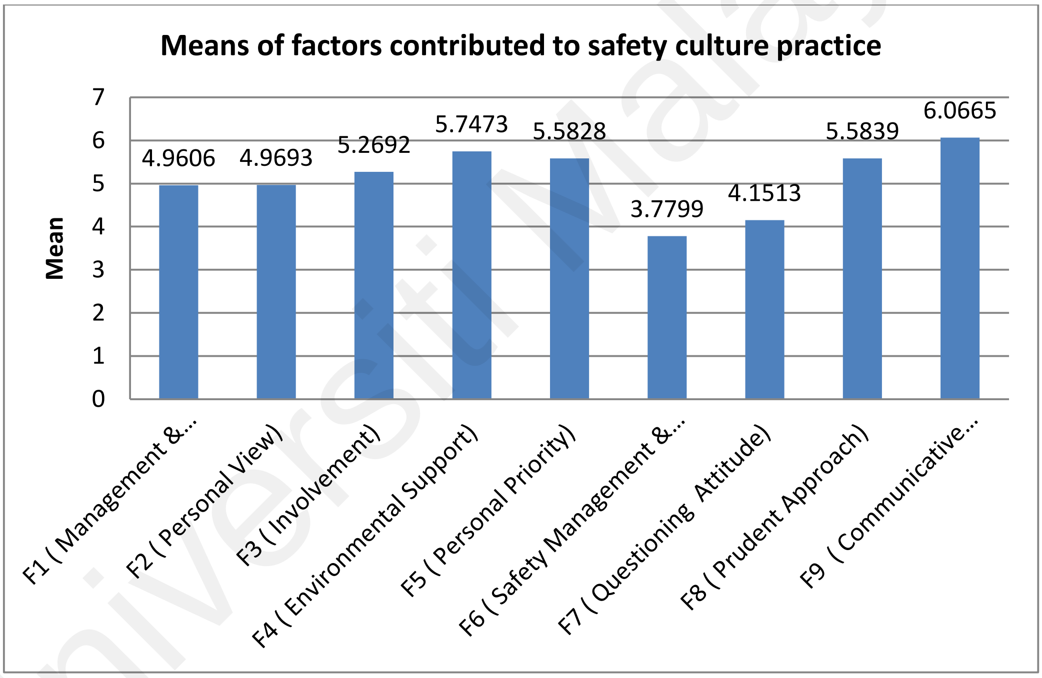

Figure 4.18: Mean differences between factors

4.4.3 Inferential Statistics

Inferential statistics are used to predict parameter(s) and test statistical hypotheses. In this study, both aspects of validity and reliability of the constructs, significant direct effect of the relationship, and hypotheses testing are presented. CFA was used to assess the reliability and validity aspects of the measurement model for all the constructs.

Construct, Convergence, and Discriminant Validity were employed, along with AVE and CR. Once the validity and the reliability of the measurement model had been accepted, the SEM was used to test the relationships of direct effect and moderator effect; and path analysis was used to evaluate the research hypotheses. The assessment for validity and reliability of the measurement models are required prior to developing the SEM (Awang, 2012).

4.4.3.1 Construct validity

The CFA was performed to examine the construct validity of the measurement model by using SPSS AMOS-21. Several GFI indices recommended by past researchers to evaluate measurement adequacy were adopted, as listed in Table 3.2 (Awang, 2012): Chi-square ($\chi 2$), CFI, GFI, and RMSEA. Joreskog and Sorbom (1993) recommends CFI, GFI of .90 or greater to indicate acceptable data fit. A RMSEA value of .08 or less indicates a reasonable model fit, while a value greater than .10 indicates poor model fit. In summary, the test results indicated that the construct validity of safety practices, individual risk estimate, control measure, and decision-making attitude were adequate. The required minimum level displayed in Table 4.7 can be claimed to have been achieved.

Table 4.7: Fitness index for measurements model

Measurement Measures	No of construct	No of items	RMSEA	GFI	CFI	Chisq/df	P-value
* DM	1	4	0.118	0.990	0.948	5.355	0.005
**SF	7	24	0.047	0.904	0.953	1.702	<0.001
**RC	2	7	0.054	0.978	0.986	1.894	0.026
**RA	3	11	0.079	0.941	0.966	2.922	<0.001
**Integrated / Overall Model	4	14	0.077	0.929	0.947	2.860	<0.001
- Measurement model** *- Second order CFA**							

4.4.3.2 Convergence and discriminant validity

The assessments of validity and reliability for measurement models are required prior to SEM. The AVE indicates the average percentage of variation explained by the measuring items for a latent construct. An AVE > 0.5 is required for every construct for convergence validity. However, AVE > 0.4 is still accepted for the first time study if the CR exceeds 0.6, and if the convergent validity of the construct is still adequate and does not generate major discriminant validity issues (Huang et al., 2013). AVE was computed using the formula shown in Section 3.2.7.4. Table 4.7 reveals that seven safety practices, two determinants of risk control measure, and three components of risk level estimate had achieved convergence validity, suggesting that the survey items were appropriate indicators of their respective constructs.

Based on the Fornell & Larcker's technique, the diagonal value (in bold) is the square root of AVE, while the other values are the correlation between the respective constructs (Larcker, 1981). Table 4.8 displays that the diagonal value (in bold) is higher than the values in its row and column. The constructs in the model proved to be discriminant of each other.

Table 4.8: Convergence and discriminant validity values for the main research constructs

Construct	AVE	Analysis	Control	SF	dec
analysis	0.487	**0.698**			
control	0.669	-0.083	**0.818**		
SF	0.558	-0.144	0.698	**0.747**	
dec	0.471	0.029	0.405	0.400	**0.686**

4.4.3.3 Composite reliability (CR)

In this study, the reliability of the measurement model was analysed to ensure that all the constructs were indeed reliable. CR indicates the reliability and the internal consistency of a latent construct. Table 4.9 shows that the CR values for all the constructs were > 0.60. These results indicate that the measurement models of all the constructs are reliable and have successfully achieved internal consistency. Besides, the Cronbach's alpha value of each factor that exceeded 0.6 also reflected internal consistency.

Table 4.9: The value of composite reliability and average variance extracted for all constructs

Construct	CR	AVE
analysis	0.726	0.487
control	0.800	0.669
SF	0.877	0.558
dec	0.721	0.471

4.4.4 Structural Equation Model (SEM)

SEM was carried out to test the hypotheses of the structural model illustrated in Figure [A30]2.2[H31]. The present study used a set of different types of fit measures (Hair et al., 1998) to determine the GFI of the models. The recommended values for CFI and GFI are higher than 0.9, while the RMSEA value should be less than or equal to 0.08 for a good model fit (Awang, 2012). Table 4.10 shows the fit indices of the hypothesised and the modified models. The required level was attained and the structural models were accepted.

Table 4.10: The fitness index for path model of safety climate factors and risk estimate level

Model	RMSEA	GFI	CFI	Chisq/df	P-Value
With Mediator	0.059	0.934	0.950	2.082	<0.001
Without Mediator	0.068	0.962	0.970	2.430	<0.001

4.4.5 Path Analysis and Hypotheses Testing

The mediating roles of risk control measure and decision-making attitude in the relationships of safety practices with individual risk estimate were tested. Figure 4.19 portrays the model with the selected mediator. In Figure 4.19, a significant direct path relation exists between safety practices and individual risk estimate, while insignificant direct paths between risks control measure, decision-making attitude, and individual risk estimate. In addition, a significant direct path correlation was established between safety practices and risk control measure; and safety practices with decision-making attitude. Model modification was made using model trimming procedure by deleting the paths linked to insignificant path coefficients, one at a time.

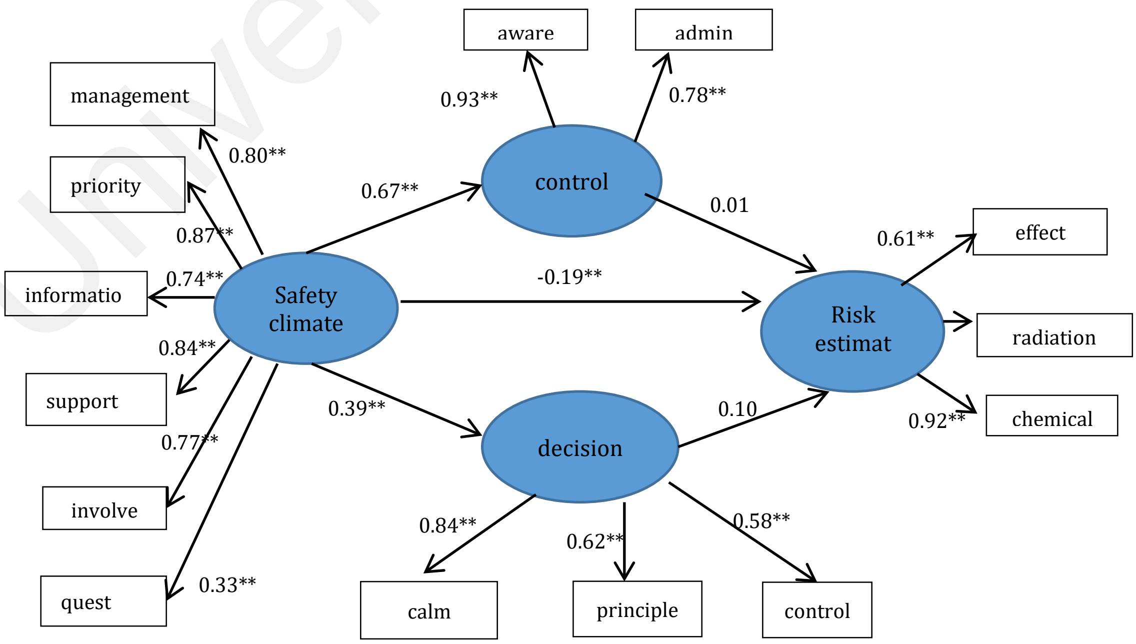

Figure 4.19: Model with mediator

Figure 4.19 shows that out of the nine safety climate factors, six comprised of management commitment, priority to safety, communicative information, personal involvement, supportive environment, and questioning attitude had impact upon individual risk estimate. Table 4.11 shows the regression path coefficients and p-value of the relations. The p-value of the path relating safety climate (SF) and individual risk estimated (analysis) was < 0.05. Kock (2015) asserted that if p-value ≤ 0.05, the hypothesis is accepted and the hypothesis statement is supported and significant, otherwise rejected. Thus, hypothesis H1 of this study is supported. Table 4.11 presents that paths related to safety climate and management commitment, priority to safety, communicative information, personal involvement, supportive environment, and questioning attitude appeared to be significant with p-value < 0.05. This indicates that safety climate was influenced by those factors. This finding is in line with the observations made by Mearns (2003) and Kapp (2012).

Table 4.11: Regression path coefficients and p-value

	Estimate	S.E.	C.R.	P-value	Result
control ← SF	.851	.075	11.289	***	Significant
dec ← SF	.530	.101	5.245	***	Significant
analysis ← dec	.052	.038	1.355	.175	Not Significant
analysis ← control	.007	.047	.156	.876	Not significant
analysis ← SF	-.131	.065	-2.027	.043	Significant
aware ← control	1.000				
involve1 ← SF	1.000				
support ← SF	.898	.058	15.612	***	Significant
info ← SF	.771	.069	11.163	***	Significant
mgmt ← SF	.879	.059	14.839	***	Significant
priority ← SF	.982	.060	16.447	***	Significant
admin ← control	.629	.054	11.601	***	Significant

Table 4.11, continued

	Estimate	S.E.	C.R.	P-value	Result
effect ← analysis	1.000				
rad ← analysis	2.375	.324	7.332	***	Significant
chem ← analysis	4.570	.699	6.535	***	Significant
DMA2 ← dec	1.000				
DMA4 ← dec	1.041	.131	7.974	***	Significant
DMA5 ← dec	.889	.151	5.891	***	Significant
DMA6 ← dec	1.448	.174	8.341	***	Significant
Quest ← SF	.330	.058	5.725	***	Significant

The safety climate factors predicted both risk control measure and decision-making attitude. Table 4.11 displays the p-value of the path of safety climate and control measure, as well as safety climate and decision-making attitude, was < 0.05. Hence, H2 and H3 are supported. In this study, the significant direct paths from both awareness and administrative with risk control measures also indicated that awareness on accidents and administrative control predicted the risk control measure for chemical and radiological hazards, as well as organisation effect. In addition, the safety climate factors were predicted good decision-making attitude with a significant direct path with calm, principle, and controlling attitude.

This study highlights the role of informative communication and questioning attitude to influence safety practices. Table 4.11 portrays the p-value of the path relating safety climate and informative communication and safety climate with questioning attitude was < 0.05. These results indicated that informative communication and questioning attitude influenced risk control measure, decision-making attitude, as well as risk level estimate of the chemical and radiological hazard.

Table 4.11 shows that the p-values of the path relating risk control measure and individual risk estimate; and the path relating decision-making attitude and individual risk estimate were > 0.05. However, there was no significant direct path between risk control measure and individual risk estimate, which suggests that risk control measure is not a mediator between safety practice and individual risk level estimate. Hence, H4 is not supported. Similarly, the absence of a significant direct path from decision-making attitude and individual risk estimate indicated that decision-making attitude does not mediate the relationship between safety practice and individual risk level estimate. Hence, H5 is also not supported as shown in Table 4.12

Table 4.12 shows the hypotheses statements for every path and its decision. Hence, from the path analysis of this study, three hypotheses H1, H2 and H3 were supported and H4 and H5 were rejected.

Table 4.12: The hypotheses statements for every path and its decision

Hypothesis Statement		**Decision**
H1	Safety climate factors influence the individual risk level estimate on the chemical, radiation hazard and organisation effect	Supported
H2	Safety climate factors influence the risk control measure to reduce the impact of the hazard	Supported
H3	Safety climate factors influence the good decision-making attitude of the workers in managing the risk of chemical and radiological hazard	Supported
H4	Safety climate factors influence the risk level estimate through risk control measure implementation as mediator	Not Supported
H5	Safety climate factors influence the individual risk level estimate through decision-making attitude as mediator	Not Supported

The model without mediator illustrated in Figure 4.20 was obtained by deleting the insignificant paths. The fit indices indicated that the model does fit the data adequately, and the model is accepted. The results showed that management commitment, priority to safety, communicative information, personal involvement, supportive environment, and questioning attitude estimated the safety practices and predicted individual risk estimate on chemical and radiological hazard.

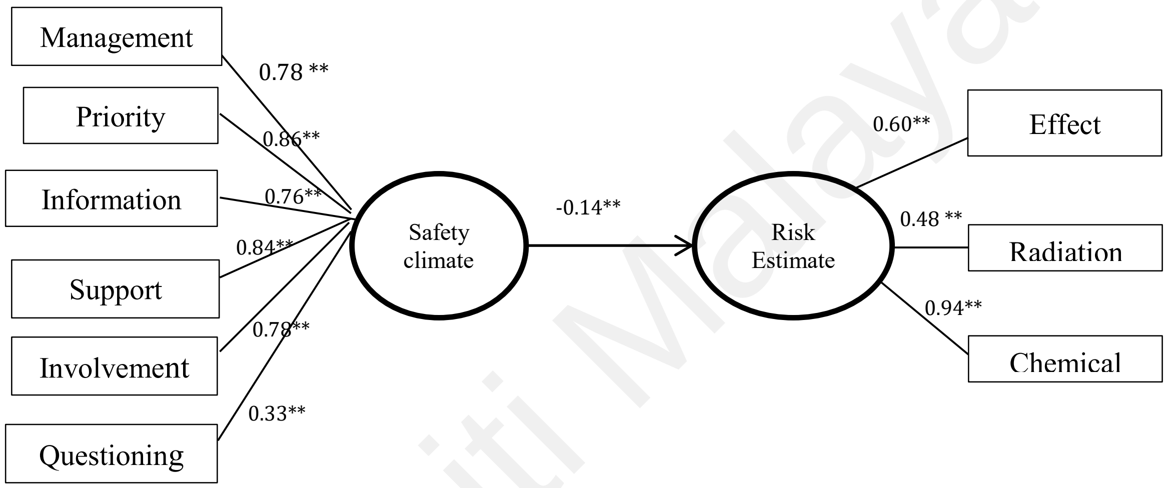

Figure 4.20: Model without mediator

Incorporating assessments of safety practices, risk control measure, and decision-making attitude, along with risk level estimation into the safety monitoring systems, generates a more integrated risk assessment, in terms of the effectiveness of managing risks and hazards, including their operations. The outcomes can be used to convince the public that high risk operation, such as nuclear power program, can be developed with the strength of safety practices and intervention of safety climate factors. The findings being significant indicate that employees' safety practices awareness and priority for managing risk in Malaysia are reasonably good, hence opening avenues for more researches in the field of safety, especially if Malaysia wished to embark in nuclear power program.

4.5 Summary of the Phase One of the Study

This section presents the findings derived from phase one of this study. Being quantitative in nature, the data gathered from the survey were analysed using statistical analysis. The demographic profiles of the respondents, the survey outcomes, as well as descriptive and inferential analyses, are presented. This study has attempted to determine the safety climate factors that significantly affected the safety practice assessment on radiation hazard for Malaysian industrial workers. This has been achieved by developing MRSTK consisting of 32 items, encompassing: questioning attitude, communicative information, work environment, management commitment, communication, safety priority, personal view, involvement and prudent approach. The findings of the SEM proposed strong empirical support for the theoretical model that is closely associated with the components of safety climate factors. This study also demonstrated the validity and reliability of the six perceived safety climate factors, three components of risk control measures, three components of decision making attitude, and three components of risk estimate. The hypotheses for the relationships were tested. The direct significant paths of the relationships between safety climate factors and risk estimate on chemical and radiation risk are elaborated. On top of that, the first and the second objectives of this study are met. The quantitative findings obtained from those objectives will be contributed to the next phase of this study.

The next section of this chapter presents the findings retrieved from phase two of this study on the qualitative study in developing the safety practice level assessment matrix, including their levels, criteria, and indicators.

CHAPTER 5: THE DEVELOPMENT OF SAFETY PRACTICE LEVEL ASSESSMENT MATRIX: MALAYSIAN RADIATION FACILITIES

5.1 Introduction

This chapter consists of five primary sections which elaborate the results obtained from the second phase of this study through the Delphi method. In this study, experts' perceptions, stance, and information regarding radiation safety in the aspect of legislations, culture, and evaluation of safety practice were collected when the assessment matrix was established. The introduction is presented in the first section. The experts were involved in three interview rounds. The second section presents the first round of the interview, which focused on the current framework of legislation and practice of safety. Meanwhile, the second and third rounds of interview collected experts' stance and agreement regarding the level of safety practice, attributes, and the indicators which were set into the assessment matrix of the level of safety practice. These subjects are elaborated in the third and fourth sections of this chapter. This chapter is concluded with the fifth section, which presents a summary of the second phase of the study.

For the initial review of expert responses, comments were reviewed and organised according to each of the four open-ended questions in Round One. The responses initially were categorised into personal issues, safety system, and organisation. Based on the content analysis performed by experts, the themes that emerged from the responses to strengthen the safety practices in radiation facility were decided. Content validity for qualitative analysis of the identified themes and subsequent questions with Likert-scale for Rounds Two and Three had been verified for reliability in consultation with the qualitative analysis experts.

5.2 Interview Round 1: Safety Practices Assessment in Radiation Industries

In the first round, the interview took about 1.0 hour for each session with the selected panel of experts. The interviews were divided into four general sections discussing the expert background, radiation safety practices in radiation facilities, current safety practice level and the importance of safety practice assessment in the radiation facilities.

5.2.1 Background and Working Experience

Most of the experts selected for the study were involved in radiation technology, such as radioisotope techniques, Non- Destructive Testing (NDT) in petrochemical industries, NDT for aviation industries, sterilisation and irradiation process in manufacturing, as well as transportation of radioactive materials. They were also involved in the auditing process of the safety and quality management system. Most of the experts were in service for more than two decades in radiation technique and more than a decade in auditing of management system. Most of them contributed to organisations that have been certified ISO 9001, ISO/IEC 17025, ISO14001, and OHSAS 18001. The panel of expert are knowledgeable and competent in Act 304, apart from being familiar with the IAEA safety guideline. Some experts were trainers and consultants for the radiation protection programme at the radiation facilities. The experts also were given an opportunity to contribute their comments and opinions on the safety practices issues in Malaysia during the interview sessions.

5.2.2 Radiation safety practices in radiation facilities

The experts were required to discuss the issues associated to radiation safety practices and indicators employed to assess the level of safety practices in Malaysian radiation facilities.

5.2.2.1 Number of accidents

A majority of the respondents monitored the number of accidents in the facility as their main safety practice indicator. Higher occurrence of accidents reflects poor culture of safety practices. The number of accidents signifies the overall safety performance at the facilities. Many radiation facilities assess their safety practices by using the lagging indicator. Lagging indicators are used to determine safety performance that is traditionally measured using 'after the loss' type of measurements, such as accident and injury rates, incidents, and dollar costs (Shipping, 2012). The leading indicators refer to the prospective or leading safety performance evaluation methods (i.e. safety inspections/audits, behavioural observations, and safety climate/culture surveys) to provide information that lacks from incident-based measurement and keeps up-to-date with the cutting-edge organisational and safety management trends (Sgourou et al., 2009).

The Atomic Energy Licensing Act 1984 (Act 304) prescribes several indicators for safety performance on radiation protection, as listed in the following:

a) conditions of exposure,
b) dose limitation,
c) occupational exposure,
d) medical exposure,
e) exposure of members of the public and persons other than workers, excluding medical exposure,
f) accidental exposure,
g) emergency exposure, and
h) exposure other than any of those specified in paragraphs (a) to (g).

Most of the respondents agreed that these indicators were elements that need to be reported in the SAR. Most of the facilities have carried out programs to tackle part of the medical exposure of the workers. Medical assessment and monitoring determine the internal exposure of radiation to the exposed workers. According to a respondent, the top management has given full commitment either in financial or time requirement to ensure all related workers implement the routine medical check-up on the radiation exposure level. The management team is aware that the safety and health of workers is the most important aspect and needs to be controlled. These indicators seem to be lagging indicator in monitoring the safety performance in the facilities with a lack in leading indicators.

5.2.2.2 Radiation Exposure Level

The exposure level of radiation to workers, public, and environment is the most important indicator used to monitor and control radiation safety at the facilities. In fact, different accepted levels are based on the categories of workers and public, as presented in Table 5.1.

Table 5.1 : Annual Dose Limit for occupational and public exposure (Basic Safety Standard, 1998)

Occupational exposure	Application	Annual Dose Limit (mSv)
	Annual dose limit for the whole body exposure of workers	20
	Female pregnant workers: dose to the foetus accumulated over the period of time between confirmation of pregnancy and the date of birth	<1
	Partial body exposure of a worker : 1) Limit for effective dose – equivalent 2) Limit on average dose in each organ or tissue 3) Limit for lens of the eyes 4) Limit on equivalent dose for hands and feet	 50 500 150 500
Public	Dose limit for the whole body exposure	1
	Average dose for lens of the eyes	15
	Average dose for lens for the skin	50
	Effective dose limit for a person who knowingly assists is a support of a patient during the period of diagnostic examination or treatment of patient	<5
	Effective dose limit for a person who is below the age of 16 visiting patients undergoing treatment or diagnostic examination	<1

Many respondents agreed that the exposure level is the main indicator and has been used to monitor the safety of workers and public based on the international standard practice. The exposure level for workers is measured using film batch or dosimeter personal. Most of the respondents are aware about the exposure level and the importance of film batch. One respondent claimed that some workers did not wear the film batch. It is a standard practice and mentioned in the safety procedure, but attitude and behaviour of human is difficult to manage. There is a need for the RPO to constantly remind the workers to always wear their film batch, especially within the control working area.

One respondent explained that the film batch and the dosimeter personal need to be calibrated and the dose reading has to be recorded. The main issue is in the process of film batch calibration and dose analysis that is time consuming and may be misled by a faulty regulator, in which the facility management team has to address. If the film batch reading displays high exposure and exceeds the exposure limit, the dose record should be reported to the regulator immediately. This indicates that the exposure dose requires an effective management control system.

As for environmental exposure, the radiation facility would analyse the radiation impact assessment (RIA), which is mandatory to be reported in the Safety Analysis Report (SAR) for all facilities. Most of the respondents have implemented the RIA in their facilities, although not all facilities exhibit back ground exposure level in their premises, as recorded in the report. One respondent explained that the back ground exposure level of the facility has to be shown openly to the public. This aspect refers to transparency of the data for public awareness and to have trust on the safety operation of the facilities.

5.2.2.3 Safety Analysis Report

SAR is an annual report and it is a mandatory requirement in licensing process, reviewed by an atomic regulator. This report adheres to the international practice and guideline. However, there is no specific report concerning the national radiation safety culture and indicators. A respondent mentioned that this report is the main reference about radiation safety at the facilities. The performance safety indicator would be collected, analysed, and documented in this report. A safety assessment shall be carried out for all applications of technology that give rise to radiation risks for all types of facilities and activities.

One respondent highlighted that the SAR is a good practice to monitor the safety performance at the facility. Based on experience in radiation safety management, the report is prepared and reviewed by the radiation safety team and RPO. Nevertheless, the report and the information is not communicated and not understood by all workers. This is because; the main reason to produce the report is to fulfil licensing and regulatory requirements.

From this interview session, the respondents agreed that most of the radiation techniques in Malaysia compliment and support the conventional methods in the process. Some manufacturing companies apply radiation technology as part of their industrial process. Hence, radiation hazard from the process is combined with other hazard. The RPO mainly manages radiation hazard and SHO for other types of hazards. However, some respondents mentioned that the safety assessment on radiation hazard has to be done separately. Two respondents agreed that safety assessment on radiation can be integrated with other occupational hazard in the facility, but the separated report on radiation hazard is sent to the atomic regulator. It was observed that facilities with ISO certification have integrated the entire hazard and a good connection exists between SHO and RPO in the facility.

A respondent described that the facility uses a graded approach based on the organisation's specific circumstances and needs in safety assessment. After the safety assessment has been reported, the needs of safety culture would be determined and strategized, wherein internal experts shall review the safety culture initiatives.

All the respondents agreed that the implemented assessment on safety practices lack details. This assessment is performed as part of overall safety assessment and safety performance evaluation.

5.2.3 Current radiation safety practice assessment

During this interview, experts invited to identify issues related to current safety practice assessment level in monitoring the safety practices at their facilities. Most of the respondents agreed that the facilities do provide the SAR as a complimentary in the licensing process. The radiation safety practices are included as part of the report. The safety practices assessment is based on the facility initiatives and programs.

5.2.3.1 Compliance to international practice and national regulation

In order to determine if an adequate level of safety has been achieved for a facility or activity and if the basic safety objectives and safety criteria are established by the management, most of the respondents described that they need to comply with and fulfil the requirements for protection and safety, as established in Radiation Protection and Safety of Radiation Sources: **International Basic Safety Standards**, IAEA Safety Standards Series No. GSR Part 3.

The IAEA safety standards establish fundamental safety principles, requirements, and measures to control radiation exposure amongst people and the release of radioactive material into the environment, to restrict the likelihood of events that might lead to loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, as well as to mitigate the consequences of such events in case if they occur.

As for the question on how the safety practice is assessed, a majority of the respondents provided similar responses: (a) The Atomic Energy Licensing Act 1984 (Act 304), (b) The Radiation Protection (Licensing) Regulations 1986 (P.U.(A) 149), (c) The Radiation Protection (Basic Safety Standards) Regulations 1988 (P.U.(A) 61), and (d) OSHA (1994), which are the primary references in assessing the safety practice in the radiation facilities. RPOs of each facility have to prepare a SAR as a requirement for the licencing process, including the observation of general safety culture and practices.

5.2.3.2 Inspection and auditing in compliance to regulatory requirement

During the interview, all respondents agreed that regulator inspection on the facilities does improvise the safety practices. Inspection means, the regulator body visits the facilities to verify the report prepared by the RPO. Nonetheless, the workers should comply with the safety procedure and the standards only during the inspection process. According to one of the respondents, there is good effort if the inspector of the regulatory body visits the facility without any notification. Some workers tend to comply with the procedure and standard only during RPO supervision.

Some of the facilities have been certified by the ISO certification, thus they implement the auditing process; internal and third party audits, without fail. Most of the respondents have been involved in the certification auditing. Most of them agreed that although the audit content does not specify safety culture, the culture to comply with the standard and procedure has been growing among the workers. Indirectly, these practices encourage workers to comply with all radiation safety requirements and further improve the safety performance.

The interview sessions disclosed that the facilities are aware about issues related to leading indicators, such as number of audits, training, and safety programs. Many companies have indirectly carried out programs to promote organisational culture and to address issues related to human errors in their organisations. According to a respondent, the facility would be reviewed thoroughly on its safety practices by an international third party reviewer. The reviews are made using graded approaches based on culture, country, and operation of the facilities. After the review, the facilities are given recommendations, suggestions, good practices, and lessons learnt in improving their safety culture and practices. For facilities that do not have international reviewers, the safety practices assessment will be reviewed in various circumstances, for example, the ISO or OSHA audits that indirectly detect the compliance of safety practices in the organisations.

5.2.3.3 Working experience

The competent and experienced supervisors have the power to observe the safety culture and practices. Most respondents believe that the experienced workers have good performance and attitude in terms of safety aspect. Based on work experience and routine, a task can be assured to be in safe operation. Many respondents are concerned about the new employees as they lack experience in handing hazards. New employees require more training and supervision, as compared to those experienced. Most of the respondents agreed that even though the facility and workers have gained working experience, monitoring and management of radiation risk still need to be implemented.

5.2.3.4 Licensing of Radiation Facilities

The licensing purpose requires a facility to ensure the safety of nuclear and radiation source. Licensing also controls the application of nuclear technology. The regulatory framework through licencing approach is a success in Malaysia. All the respondents agreed that the licencing requirement has contributed to radiation safety management. In order to sustain radiation safety, some modifications on licensing have to be made. After a while, the licensing requirements narrowed its focus on the system and process, while it is still lacking in the assessment of safety practices. Human behaviour and the attitude of workers are the most difficult aspects to control and monitor. However, there is no specific framework to assess the safety practices at the facilities. One of the respondents suggested developing a mechanism to manage the safety culture within the organisations.

Another issue refers to the personal relationship between the inspector and the RPO. A respondent mentioned that good personal relationship between the inspection and the RPO eases the processes related to licensing. The RPO knows the criteria and complies with the requirements. Besides, the respondents agreed that some inspectors are too rigid and upon detection of non-conformance of the facility leads to suspension of licence and a fine. In order to avoid these, the facility and its employees would opt to comply with all requirements only during the inspection and hide all errors and non–compliance elements. Hence, safety is far from being a culture, but it only serves to satisfy the regulator. Most of the respondents agreed that in order to establish an effective management system of safety culture, employees' behaviour and attitude must be in control.

When inquired about the assessment tools or methods to assess the safety practice level that has been implemented, most of the respondents agreed that there is no specific tool, framework or criteria. Each facility has its own mechanism to observe the safety practice by referring to the regulations requirements and international standards.

5.2.4 The importance of safety practice level assessment framework

During this interview, experts invited to discuss the importance of safety practice level assessment framework in monitoring the safety practices at their facilities. Most of the respondents agreed that the assessment would benefit the radiation workers and the level of safety practices would be determined. This approach will probably continuously improve the facilities safety performance, controlling the attitude and behaviour of the workers and encouraging the self-assessment.

5.2.4.1 Continuously improve the facilities safety performance

Most of the respondents agreed that the safety practice level assessment need to be established. The culture of safety practices at the facility needs to be continuously improved and be consistent with the facility development. Every modification, addition, and new process in facility operation needs to undergo risk assessment analysis and hazard determination. The safety practices also need to be strengthened. Many respondents believed that the current practice of radiation safety is at satisfactory level. There is low probability on the death and fatality accidents caused by radiation hazard. Nevertheless, control measures and safety monitoring are always given the highest priority. If Malaysia is going to embark nuclear plant and to sustain the application of radiation technology, there is a pressing need to strengthen and monitor its safety practice strategy amongst facility operators and regulators to ensure the safety of its workers, the public, and the environment.

5.2.4.2 The practice relies on people's behaviour and attitude towards safety.

The IAEA, for example, performs safety culture assessments as an integral part of its Operational Safety Review Team Missions. Most of the respondents agreed that it is essential to reckon the present level of safety culture and practice. With the level determination, the facility and workers tend to analyse the improvement strategies, best practices, and lessons learnt. The continuous improvement in safety practices should encourage workers to work in a safe manner, improve their behaviour and attitude wherein risk can be controlled. Mohammad et al., (2010) described that improvement initiatives' refers herein to approaches, systems, tools and/or techniques and include, business process reengineering or benchmarking can be used to continually improve an organisation's performance. Such practice prevents accidents from happening. During the interview, most of the respondents claimed that there is no national framework on the level, indicators, and criteria for them to refer in assessing their safety practices, but it is important.

5.2.4.3 Self-assessment

Self- assessment is part of managing radiation risk. IAEA (1991) described that self-assessment means workers and facility need to assess their risks and consequences of the hazard in three phases: a) Before the operation; b) During the operation; and c) After the operation.

Most of the respondents were aware about the importance of self-assessment and they agreed that in order to perform the assessment, the workers and operators need to have adequate information, training, and knowledge. Besides, there is also lack of indicators and also assessment framework to be used to self-assess the safety practice at the facilities. From these responses, it shows that workers at the facilities are not familiar with self-assessment practice, but they need the tools and mechanism to implement the self-assessment. Respondents agreed that the safety practice level assessment framework will resolve the constraints on self-assessment.

5.2.5 Content Analysis

In round one interview, data gathered from the interview were analysed using word-based content analysis method. Eight categories and 3 themes were identified after counting the frequency of words that appeared from the text and note during the interviews sessions as shown in Table 5.2.

Table 5.2: Themes and frequency of content analysis

Merged finding (codes)/ Categories	**Cases (Frequency)**	**THEME**		
		1	**2**	**3**
Accidents, radiation level, dose exposure, safety	18	Indicator		
International practices	10		Assessment Practice	
Audit/ risk assessment/ observation	15		Assessment Practice	
Work experience	2		Assessment Practice	
Licensing	7		Assessment Practice	
Needs of Improvement	16			Improvement
Attitude and behaviour	9			Improvement
Assessment and Inspection	10			Improvement

Three themes from question one in the first round of the interview with the panel of experts were identified. These themes formed the development and selection of indicators, as well as the criteria for Rounds Two and Three, with the aim of developing the safety practices level assessment matrix.

From Round One interview, the analysis showed that all the respondents perceived the need to **strengthen and improve** the safety practices of radiation safety. The improvement needs to be a continuous process and monitoring should be implemented to ensure the safety of workers, public, and environment. At present, radiation safety is being managed properly to reduce the probability and consequences of risks.

The number of accidents and radiation exposure level appeared to be the main **indicators** used to identify the safety performance of radiation safety at the facilities. Indirectly, these types of indicators have been reported in the SAR that has been reviewed by the national atomic regulator. However, from the interviews, there is still lacking in leading safety indicators to determine the safety practices at the radiation facilities.

Both international standard and national regulation framework serve as the main references in managing radiation hazard. Indirectly, licensing requirement, safety inspection, and external audit from relevant bodies practically support the implementation of **safety assessment practices** at the facilities. However, the lack of assessment on the safety practices level relies on the attitude and behaviour of the employees at the facility. The safety practice assessment matrix developed in this study covers the level of safety practices, the significant criteria that influence risk estimate, and the leading indicators relate to human behaviour and attitude.

5.3 Interview Round 2: Development of Safety Practice Level Assessment Matrix

After the round one interview session and analysis, the proposed levels, criteria, and indicators to be embedded in the assessment matrix were determined. The level, criteria, and indicators were proposed with the intervention of the factors that may affect the safety practice, as elaborated in Chapter 4.4 and reviews from several documents. The Round Two of Delphi Technique in this study determined the consensus on the rating of these proposed levels, criteria, and indicators to be incorporated in the safety practice level assessment matrix.

Table 5.3 presents the list of proposed safety practice levels and their description, as adapted from the Hudson's Model. Such levels were selected because the Hudson's Model (2001) is practical for implementation, thus making it possible to identify the levels of safety culture maturity within the context of petrochemical industry (Filho et al, 2010).

Table 5.3: The safety practice levels and their description

Maturity Level	Description (Westrum 1993, Hudson 2000, Parker 1996)
Pathological	Safety is a problem caused by workers. The main drivers are the business and the desire not to get caught by the regulator. (Who are as long as we're not caught)
Reactive	Organisations starts to take safety seriously only after incidents happen. (Safety is important; we do a lot every time we have accident)
Calculative	Safety is driven by management systems, with much collection of data. Safety is still primarily driven by management and imposed rather than looked for by the workforce. (We have systems in place to manage all hazards)
Proactive	With improved performance, the unexpected is a challenge. Workforce involvement starts to move the initiative away from a purely top-down approach. (We work on the problems that we still find)
Generative	There is active participation at all levels. Safety is perceived to be an inherent part of the business. Organisations are characterised by chronic unease as a counter to complacency. (Safety is how we do business around here)

Table 5.4 presents the list of criteria proposed to be included in the framework. Based on the interview sessions, the lagging indicators have been well-assessed and reported in safety report assessment. The criteria for leading indicators have been selected as they can significantly minimise the radiation risk, as depicted in Chapter 4.4.

Table 5.4: The list of significant safety climate criteria

Criteria	Description (Mearn, 2000,2003; Cox 1998, 2000, 2006; Zohar 2000)
Management Commitment	Describe the support given by the organisation as far as Health and Safety is concerned, adequate timeframe to complete the job, number of people to perform the job, and compliance to the safety procedure.
Environmental Support	Management support, interest in safety system, and people's attitude about working in a safe environment.
Safety Priority	Describe the commitment to emphasis on safety by all parties, positive attitude about workplace, as well as knowledge and awareness about safety rules at work.
Information	Internal information sharing and dissemination of safety and accidents information among colleagues.
Involvement	Workers' involvement in safety issues, involvement in policy/procedures developments, as well as reviews and meeting.

Table 5.5 lists the proposed indicators that have been applied to assess safety performance at the facilities and also in international practices. These indicators, which were derived from IAEA (2000), can be implemented to monitor safety culture and practices at radiation facilities.

Table 5.5 : The list of indicators

Indicators	Description (IAEA TECDOC-1349, SAFETY SERIES No.75-INSAG-4, Teemu Reiman & Elina Pietikäinen)
Safety Planning	The extent to which the management system aligns with and contributes to the achievement of organisational goals. The clarity of the description of how work is to be prepared, reviewed, carried out, recorded, assessed, and improved. Management is actively committed to, and visibly involved in safety activities.
Safety Review	Corrective actions not completed within planned time-scale. The clarity of integration of the consideration of process safety. HSE (health, occupational safety, environment) and security issues.
Rewarding System	People are rewarded for obedience and results, regardless of long-term consequences. People are rewarded for improving processes, as well as results.
Training and awareness of OHS	Percentage of managers trained in root cause analysis. Extent to which the personnel is trained in accordance with the planned training programme. Extent to which the personnel have suitable skills, knowledge, and experience to carry out their tasks safely and effectively.

Table 5.5, continued

Dimension	**Description** **(IAEA TECDOC-1349, SAFETY SERIES No.75-INSAG-4, Teemu Reiman & Elina Pietikäinen)**
Radiation risk and hazard analysis	The extent to which the personnel understands the hazards that are connected to their work; The extent to which the personnel continuously seek to identify new risks and enhance their view on the hazards of their work.
Accident Analysis	There is a system for investigation and analysis of internal incidents that takes into account technical, human and organisational factors in equal degree.
Compliance to inspection and auditing	Internal and external safety assessments and audits are carried out to improve safety performance. The extent to which external audits provide results in accordance with the findings of internal audits or prevalent conceptions of the personnel.
Audit Planning	Number of safety audit recommendations implemented.
Self-monitoring and inspection	Number of safety inspections. Percentage of tasks having risk assessment in pre-work planning.
Reporting system	Frequency of reporting near misses.
Access to information	Information that is relevant for work is easily accessible.
Awareness to disseminate the information	Adequate exchange opportunities for safety-relevant information within and between units. Information flow in change of shifts situations is assured.
Employees engagement in radiation safety	The number of safety improvement teams.
Employees interest in radiation safety	The extent to which the personnel has the motivation to look into safety related issues.

In Round Two interview, referring to Figure 3.2 illustrated in Chapter 3 of this thesis, 16 experts that dealt with radiation and safety management system were requested to share their opinions pertaining to the safety practice level, criteria and indicators to be used in assessing safety practice level at radiation facilities.

5.3.1 Safety Practice Level

The panel of experts were required to rate based on 5-point Likert-Scale for the proposed safety practice level to develop the framework matrix, in which the rating score was scale 1 (most important) to scale 5 (less important).

From the interview sessions, most of the respondents accepted the levels embedded in the safety practices assessment matrix. However, none of them had experience in using the levels to determine their safety practices. There is no analysis or review on the status of safety culture and practices at the facilities, as nil death or fatal accident has been reported.

The five safety practice levels proposed in this study could be understood by all the respondents as long as the descriptive for each level is explained clearly in the framework. The score from the panel regarding the acceptance for level ranged from 1.12 until 1.81 (see Table 5.6). In this study, the acceptance score was less than 3.0, thus all the five suggested levels were accepted.

Due to some confusion and misunderstanding pertaining to the Pathological and Generative level during the interview, the level was amalgamated with another term. The scores showed that these two levels exceeded 1.5 and displayed huge variances with other levels. Furthermore, some respondents suggested that it would be better to identify the level with numbering index, thus represented by Level 1 until Level 5.

When the respondents were asked about the appropriateness of the levels to be applied in the safety practices assessment, all of them stated their agreement. A respondent clearly mentioned that it is indeed time to assess the safety practices so as to improve and to strengthen the safety perception on radiation in Malaysia.

Table 5.6: Rating scores on the safety practice level and criteria in the second round interview

No	Criteria	Rating given by each expert																Mean	Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
	Safety Practice Level																		
	Pathological	1	1	2	2	1	3	5	1	3	1	1	3	2	1	1	1	1.8125	**Accepted**
	Compulsive																		
	Reactive	1	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1	1.125	Accepted
	Calculative	1	3	1	2	1	3	3	1	1	1	1	1	2	1	1	1	1.5	Accepted
	Proactive	1	2	1	2	1	1	2	1	3	1	1	1	2	1	1	1	1.375	Accepted
	Generative	1	5	1	5	1	1	3	1	1	1	1	1	2	1	1	1	1.6875	Accepted
	Safety Climate Criteria																		
	Management Commitment	7	5	3	5	5	7	3	7	7	7	7	7	5	5	7	7	5.875	Accepted
	Env. Support	5	7	3	5	3	5	3	5	5	7	5	5	5	7	7	5	5.125	Accepted
	Safety Priority	5	5	7	5	5	7	5	3	7	5	7	7	3	7	5	7	5.625	Accepted
	Information	3	3	5	5	5	3	3	5	5	7	5	3	3	7	5	7	4.625	Accepted
	Involvement	3	3	3	3	5	5	3	5	7	3	5	5	3	7	5	7	4.5	Accepted

5.3.2 Safety Climate Criteria

In this section, the panel of experts were required to rate based on the rating score of -5 for low priority; 3 for medium priority; 5 for high priority; and 7 for top priority.

The listed safety climate criteria, which are significant to estimate the risk level, was reviewed and rated by the panel of experts. Most of them agreed that the criteria were familiar for them. They used the criteria in monitoring and planning the safety performance activities at the facilities. Although this list refers to important criteria in safety, most of the respondent had never used the criteria to assess the safety culture directly. The respondents were asked to rate the priority of the criteria in their safety practice. The retrieved scores are presented in Table 5.6.

Based on the scores given by the respondents, as presented in Table 5.6, all the safety climate criteria were accepted to be incorporated in this assessment matrix. The scores ranged between 4.5 and 5.8, which indicated medium to high priority. The findings appeared to be similar with the results obtained for the questionnaire survey (phase one) regarding safety climate factors that affected safety practices, apart from projecting that these five criteria were statistically significant to the safety culture and practice at their facilities.

In this study, the findings showed that the management commitment had the highest priority of the safety climate factor as shown in Figure 5.1. From the interview, most of the respondents agreed that management team plays an important role in practicing safety. Leader and supervisors who support safety activities and initiatives encourage high motivation amongst workers to implement safety initiatives at the facility. Management that provides adequate planning on safety, as well as sufficient funding and investment on safety, supports the implementation of safety initiatives.

Management review on safety performance encourages every personnel to develop safety culture. Most of the respondents were satisfied with the management of the facilities, although some perceived that the management did not give high priority to safety.

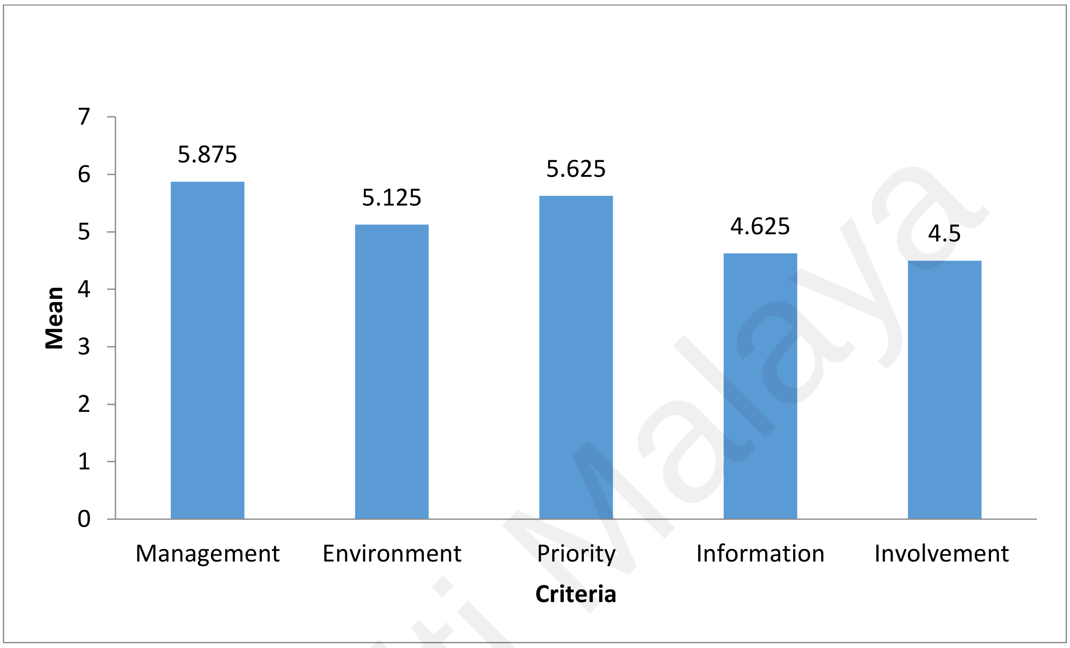

Figure 5.1: The mean values of safety practice criteria

Figure 5.1 shows that the safety priority was the second highest priority given by the panel of experts. From the interview, most of the respondents agreed that every personnel in the facility must prioritise safety at workplace. The experts believed that most employees involved in radiation hazard were aware about the risks and the consequences of the hazard. This criterion is essential in monitoring the safety practices of radiation hazard.

The third criterion rated important by the panel was environmental support. From the interview, most of the experts agreed that safe working environment promotes the safety culture among its workers. High-risk task can be managed and controlled with high-standard working environment. The management needs to provide conducive and safe environment, while the workers need to maintain the environment. Some respondents explained that they found it difficult to maintain a safe environment without audit or inspection. Workers would still need a third-party opinion, on top of internal inspection.

The fourth criterion is information on safety and risk assessments. Most of the respondents agreed that information is important in managing safety. Most of the respondents described that they have a communication toolbox and briefing for every task before it starts. Information concerning safety should be updated from time to time.

The last criterion refers to involvement. Most of the respondents described that it is compulsory for all workers at the facilities to attend safety programs initiated by the safety team and the management. They are also given an opportunity to suggest and being consulted on the safety initiative.

5.3.3 Indicators

For every criterion assessed, the indicator is needed. In this study, the leading indicators were used to determine the continuous improvement in safety practice to control radiation risk.

The panel of experts were required to rate based on 5-point Likert-Scale for the proposed indicators, in which the rating score was 1 (most important) to 5 (less important) [A32]. The mean scores of the indicators are tabulated in Table 5.7.

Table 5.7: Rating scores on the indicators in the second round interview

No	Indicators	Rating given by each expert																Mean	Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
	Criterion 1: Management																		
	Safety Planning	1	1	1	1	1	1	1	2	1	2	1	2	2	2	2	1	1.375	**Accepted**
	Safety Review	1	1	1	1	1	1	1	2	1	1	2	1	2	2	1	2	1.3125	**Accepted**
	Rewarding System	3	3	3	4	2	1	4	4	1	1	3	2	3	3	1	3	2.5625	
	Criterion 2: Safety Priority																		
	Training and awareness of OHS	1	1	1	1	2	1	1	1	2	1	1	1	1	2	1	1	1.1875	**Accepted**
	Radiation risk and hazard analysis	1	1	1	1	1	1	2	1	2	1	2	1	2	1	1	2	1.3125	**Accepted**
	Accident Analysis	3	3	4	4	2	1	2	5	1	1	2	2	1	2	1	2	2.25	
	Criterion 3: Env. Support																		
	Compliance to inspection and auditing	1	1	1	1	2	1	1	1	2	1	2	1	2	2	1	2	1.375	**Accepted**
	Audit Planning	2	1	1	1	2	3	2	1	1	3	1	3	3	3	3	3	2.0625	
	Self-monitoring and inspection	3	1	1	3	1	1	2	3	1	1	1	1	2	2	1	1	1.5625	**Accepted**
	Criterion 4: Information																		
	Reporting system	1	1	2	1	2	1	1	1	2	1	1	2	1	2	1	1	1.3125	Accepted
	Access to information	2	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1.1875	Accepted

Table 5.7, continued

No	Indicators	Rating given by each expert																Mean	Status
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**		
	Awareness to disseminate the information	**3**	**2**	**3**	**3**	**1**	**4**	**2**	**4**	**2**	**1**	**1**	**1**	**2**	**2**	**1**	**1**	2.0625	
	Criterion 5: Involvement																		
	Employees engagement in radiation safety	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**1**	**2**	**2**	**2**	**1**	1.3125	Accepted
	Employees interest in radiation safety	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**1**	**2**	**1**	**2**	**1**	**2**	**2**	**1**	**1**	1.375	Accepted

Table 5.7 shows that ten indicators were accepted to be used in developing the assessment matrix. Those indicators with mean scores exceeding 2.0 were rejected, while scores less than 2.0 were assumed as essential for this study and employed as the key indicator.

As for management commitment criterion, three indicators were listed. Two of them scored 1.31 and 1.37 to be accepted, while the rewarding initiative was rejected. Some respondents highlighted that safety cannot be compromised and it is not a good culture to reward workers who uphold safety. The two indicators for safety priority were accepted; out of three indicators suggested. The accident analysis scored more than 2.0; indicating that the indicator was less important in the safety priority criterion. Some respondents disagreed that accident analysis will increase safety priority. As for environment support criterion, the panel agreed to accept two indicators. Most of the respondents asserted that audit planning is compulsory for facilities that possess the international certification of ISO.

As for information criterion, two indicators were accepted. Awareness to disseminate information was rejected with a score of 2.06. In the present situation with influences of the social media, most of the respondents agreed that only right and accurate information has to be disseminated. The awareness to disseminate information internally amongst colleagues is a routine practice and every facility has implemented a suitable program for that purpose.

As for the involvement criterion, it is divided into two main indicators: involved and consulted. Most of the respondents agreed that safety issues and facility performance improvement have to be involved and consulted by all personal at the facility. One respondent mentioned that if some workers were not involved, they would be consulted about some safety matters.

Based on the interview outcomes from Round Two, most of the respondents agreed with the proposed levels, criteria, and indicators for each criterion with minor modifications. Therefore, some amendments were made to the framework so as to ensure that the assessment matrix is appropriate, clear, concise, and easily understood by all workers at the facilities. Some respondents suggested applying the result assessment of safety practice level to determine the risk level and the actions that have to be taken by the facilities. The modified framework was distributed to the panel of experts in the final round of Delphi. In Round Three, the consensus on the assessment matrix acceptance was decided as opined by the panel of experts.

5.4 Interview Round 3: Development of Radiation Safety Practice Assessment Matrix

The proposed assessment matrix was distributed to 16 experts via email and interviews were held via phone call and face-to-face interview sessions. The panel was requested to review the framework and to provide their personal opinion on the matrix. They were asked to choose three options of responses regarding the developed assessment matrix; accepted, rejected or accepted with amendment. From the 16 experts involved, only 14 responded to the assessment matrix. Two respondents failed to offer feedback about the assessment matrix due to time constraint. Table 5.8 shows the frequency of acceptance by the panel about the developed assessment matrix in this study.

Table 5.8: Frequency of acceptance

Framework	Codes	Frequency
Level (SCPL)	Accepted	10 (71 %)
	Rejected	0
	Accepted with Amendments	4 (29 %)
Criteria (SCC)	Accepted	14 (100 %)
	Rejected	0
	Accepted with Amendments	0
Indicators	Accepted	12 (86%)
	Rejected	0
	Accepted with Amendments	2 (14 %)

Table 5.8 shows that most of the respondents **accepted** the proposed assessment matrix with 71% agreeing with the safety practice level, 100% agreed with the safety climate criteria, and 86% had no qualms about the indicators. Hence, the assessment matrix can be used to assess the safety practice level at the facilities. Some respondents agreed that the information embedded in the assessment matrix is adequate and easy to understand by all the workers.

No respondent **rejected** the element or the criterion in the framework. All the respondents were clear and familiar with the terms used in the assessment matrix. Most of the respondents agreed that it is indeed time to have a framework matrix assessment with leading indicators to monitor and to strengthen the safety culture and practices at the facilities.

Table 5.8 shows that four respondents claimed that the assessment matrix would be accepted with minor changes at the proposed level. The respondents suggested changing the name of the safety practice level, as it was toughed to understand and remember. In fact, they preferred using numbering system on the level based on stages, as suggested by IAEA-TECDOC-1349. Meanwhile, 14% of the respondents accepted the framework with minor changes on the proposed indicators in the assessment matrix. The respondents suggested changing the indicators description to be shorter and clearer. They also suggested that the indicators would be suitable with the "SMART" principle of specific, measureable, achievable, realistic, and time-based.

As a result of the third round interview, the outcomes were reviewed by two volunteers from the field of study. The assessment matrix was reviewed and the outputs of Delphi study are given in Table 5.9.

Table 5.9 shows the output summary of the three rounds of interviews in the Delphi study that has been implemented in developing the Safety Practice Level Assessment Matrix in this study. The opinions, rating and suggestions from the experts has been analysed and contribute to the development of the matrix which consist five levels of safety practice, five criteria and ten indicators.

Table 5.9: Summary of the Delphi technique in developing safety practices assessment matrix

	Round 1	Round 2	Round 3
Instrument	Open-ended questions	Semi-structured questions	Structured Questions
Database to questionnaire	Document review	Results from Round 1 and Document Review	Results from Round 2 and Document Review
Duration	3 weeks	8 weeks	4 weeks
No of experts Selected	16	16	16
No of experts responded	16	16	14
Finding	a) Level (n=5) b) Criteria (n=5) c)Indicator (n=14)	a)Level (n=5), *amend to the numbering format* b) Criteria(n=5) c) Indicator (n=10)	a) Level (n=5) - Accepted (n= 10) - Rejected (n= 0) - Accept with changes (n= 4) b) Criteria (n=5) - Accepted (n= 14) c) Indicator (n=10) - Accepted (n= 12) - Rejected (n= 0) - Accept with changes (n= 2)
Data Analysis	Document review, Content Analysis	Percentage, mean, frequency	Percentage, mean, frequency

After a few series of interviews sessions with the experts, the modified safety practice level assessment matrix that has been developed in this study is presented in Table 5.10. The final assessment matrix emphasises the level, criteria and indicators of safety practices. From the second objective of this study, the safety climate factor that represent the safety practice criteria in this matrix shown the significant direct path with the risk estimated. As a result, this assessment matrix suggested the risk level that obtained from the safety practice level assessment. The risk level was synchronised with IAEA guideline. In this study, there is also suggestion on the "action to be taken for improvement" to be included in the assessment matrix to improve the safety culture and practice level at the facilities. As a result, this assessment matrix clearly emphasised the level determination, criteria assessed, leading indicators, radiation risk level, and action for improvement as shown in Table 5.10.

This safety practice level assessment matrix had successfully developed in this study. The assessment matrix developed to assess the safety practice level that has been implemented in the radiation facilities with regards to strengthen the safety culture and minimize the consequences from the radiation risk.

Table 5.10: Safety practice level assessment matrix

Criteria	Indicators	Level				
		1	2	3	4	5
Management	Safety planning	None	After Accident/ Emergency	Focus on existing and current risk	Not integrated with other areas	Scheduled meeting, Integrated with other issues
	Safety review	None	After Accident/ Serious injury	Focus on existing and current corrective actions and non-compliance	Corrective actions completed within planned	Structured corrective and preventive action review
Priority to safety	Training and awareness	None	After Accident/ Emergency	Adequate annually program	Effective program with individual responsibilities	Continuous program with the latest information, trend, and needs
	Risk and hazard analysis	None	After Accident/ Emergency	System for individual risk analysis provided and planned	Risk analysis is monitored regularly	Personnel is aware of the hazards and risks, and self-measures for every task
Environmental Support	Inspection and auditing	None	After Accident/ Emergency	Regular and scheduled audits	Noncompliance on safety & monitored by colleagues	Workers comply with all safety procedures even during non-schedule audit and inspection
	Self-assessment	None	After Accident/ Emergency	Regularly checked by supervisors/ RPO	Work team to assess safety for every task	Everyone is aware to assess for hazards and non-compliance looking out for themselves and others

Table 5.10, continued

Criteria	Indicators	Level				
		1	2	3	4	5
Information	Reporting system	None	After Accident/ Emergency	Annual reporting system on risk and hazard	Formal reporting system of unusual event	Formal reporting system on risk for every task and activities
	Access to information (Toolbox kit)	None	After Accident/ Emergency	The minority of the employees	The majority of the employees	Personnel is willing to share and gain access to the information
Involvement	Engagement	None	After Accident/ Emergency	The minority of the employees	The majority of the employees	Personnel is willing to engage in safety program
	Consultation	None	After Accident/ Emergency	The minority of the employees	The majority of the employees	Personnel is willing to consult with safety program
Risk Level		**Top**	**High**	**Medium**	**Low**	**Low**
Action for improvement		**Need Immediate action**	**Need specific action**	**Need to be managed**	**Continuous improvement**	**No immediate action**

The development of safety practices assessment matrix in this study provides a comprehensive assessment tool to identify the level of the safety practice in an organisation. This user-friendly, clear, informative, and reliable assessment matrix can facilitate organisations in executing the assessment in timely manner. The assessment matrix will facilitate the regulators, inspectors and auditors as a guideline in assessing the safety practice level, risk level and safety performance of the facilities.

5.5 Summary of Phase Two of the Study

The purpose of applying the Delphi techniques in this study was to acquire in-depth understanding, opinions, perspectives, and consensus from radiation safety experts pertaining to the development of five safety practice levels, five criteria, and ten leading indicators in monitoring and assessing the level of safety practice within the context of radiation facilities in Malaysia.

Sixteen experts responded to the open-ended and structured questions in three rounds of interviews concerning these areas and subsequently rated the important statements related to safety practice levels, criteria and indicators to develop the safety practice level assessment matrix.

This study emphasised that the developed assessment matrix described the safety climate criteria and leading indicators in assessing the level of safety practices in the facilities. The safety practice level obtained from the assessment matrix then suggested the risk level and action to be implemented to control the risk and strengthen their safety culture. This assessment matrix highlighted the level of safety practices on the safety climate with leading indicators of the workers and facilities regarding their risk level in easy and transparent way.

In the next section, the validity of the framework assessment matrix was tested with the perceived questions, observations and multiple case studies to determine the level of safety practice in Malaysian radiation facilities. The best practices and lessons learnt from the case studies in practising safety culture were also determined.

CHAPTER 6: VALIDATION OF THE SAFETY PRACTICE LEVEL ASSESSMENT MATRIX, BEST PRACTICES, AND LESSONS LEARNT

6.1 Introduction

This chapter is divided into four sections, which are introduction in the first section, validation of the assessment matrix in the second section, and third section depicts the outcomes from the case studies pertaining to safety practice level, best practices, and lessons learnt in five radiation facilities. Lastly, is the summary of the phase three of the study.

6.2 Validation of the Assessment Matrix

The triangulation method was used to validate the assessment matrix. In this study, two methods were employed to determine the safety practice level using the assessment matrix. The first method referred to perception survey amongst RPOs, whereas the second method involved interviews with RPOs and facility observation during site visit. The case studies were also embedded in the triangulation method, along with verification of the assessment matrix with real life experiences.

The idea is that one can be more confident with the outputs if different methods generate similar results in triangulation, thus supporting the findings. Outcomes obtained from varied methods offer new information to enhance and to clarify the results. The completeness of results is supported via triangulation, wherein new results and new information may complement the data (Ammenwerth et al.,2003; Greene, 1993a; Jick, 1979)

6.2.1 Perception survey

In this study, the perception survey was implemented to determine how the RPOs of the facilities understood and responded to the assessment matrix, which later determined the level of their safety practices culture. Each item of the developed assessment matrix was used as a basis statement to develop the questionnaire to measure the level of safety practices. The questions were reviewed by two experts via interview and email correspondence as in Appendix G.

In this study, the questionnaire was distributed to 24 RPOs who were employed at 24 facilities that applied radiation technology in Malaysia. Most of the respondents claimed to have been working for more than 5 years.

Table 6.1 presents the percentage score of answers from 25 questions for each one of the five dimensions from the 24 selected RPOs. It presents the characteristics from the lowest stage (Level 1) until the highest stage (Level 5).

Table 6.1: Maturity of safety practice scores for each dimension

Criteria	**Level 1 (%)**	**Level 2 (%)**	**Level 3 (%)**	**Level 4 (%)**	**Level 5 (%)**	**Total (%)**
Management	13 (3)	9 (2)	9 (2)	9 (2)	**60** (15)	100
Environmental Support	13	0	**70**	0	17	100
Safety Priority	0	4	**48**	13	35	100
Information	0	0	26	13	**61**	100
Involvement	0	0	0	**52**	48	100

The management commitment and environmental support dimensions present characteristic of the two extreme stages: Levels 1 and 5. Table 6.1 shows that 60% of the respondents determined that their facility management commitment and information strategies were at the highest level. 52% of the respondents claimed that involvement was at Level 4. Environmental support and safety priority were positioned at Level 3 by 70% and 48% of the respondents, respectively. Less than 13% of the respondents determined their safety practices to be at Levels 1 and 2. All the safety practices criteria seemed to be ranked at least three different levels of safety practice culture, except the involvement criterion. The management criterion exhibited five stages of safety practices level. These results indicate that the organisations can be at different levels with the similar set of criteria.

6.2.2 Site visit observation

In this study, 15 facilities were visited with the engagement of RPOs at the facilities. Some interviews and observations on the safety practice were performed during the site visit to identify the level of safety practices. The observations made and questions asked had been based on the statements developed in the safety practice level assessment matrix.

These selected facilities for site visit and observation were closely associated to radiation applications. Facilities that applied radiation technique in manufacturing, inspection, and calibration, including for research process in the industrial sector, had been selected. Basically, in these facilities, the radiation safety practices were always a mandatory amongst the workers and the management by adhering to the process standard and regulation requirements. The selected facilities have been licensed by the national AELB, certified to the ISO 9001:2015 or ISO/IEC 17025 and complied with OHSAS 18001. The certification and licensing requirements are deemed to improve the safety process and to provide adequate data concerning the safety practices at the facilities. Besides, the number of radiation workers and years of operation reflect the effectiveness of the safety practice at the facilities. Table 6.2 displays the number of facilities, the years of operation, the number of radiation workers, as well as the related certification and licensing.

Table 6.2: Information regarding the selected facilities

Sector	Number of facilities	Years of Operation	Number of radiation workers	Certification and Licensing
Manufacturing	9	20-30 years	10-36 workers	-ISO 9001 -ISO /IEC 17025 -OHSAS 18001 -ACT 304
Research	3	30 years	10-20 workers	-ISO 9001 -ISO /IEC 17025 -OHSAS 18001 -ACT 304
Inspection	3	15-20 years	10- 22 workers	-ISO 9001 -OHSAS 18001 -ACT 304

It could be seen from the site visit that safety practices were implemented in facilities due to their compliance with the certification and licensing requirements. Auditing to the facilities was one of the processes taken place during the observation and visit. The assessment matrix of safety practice level, which was present in Table 5.10 in Chapter 5, became a reference during the observation to identify the level of safety practices in accordance to the actual practices and proof in the facilities. Table 6.3 shows the safety practice levels determined during the site visit and observations made at the facilities.

Table 6.3: Safety practice levels determined during site visit and observations made

Criteria	**Level 1 (%)**	**Level 2(%)**	**Level 3 (%)**	**Level 4 (%)**	**Level 5 (%)**	**Total (%)**
Management	2 (13.3)	1 (6.6)	**4 (26.7)**	4 (26.7)	**4 (26.7)**	15 (100)
Environmental Support	0	1 (6.6)	**10 (66.7)**	2 (13.3)	2 (13.3)	15 (100)
Safety Priority	1 (6.6)	1 (6.6)	**5 (33.3)**	4 (26.7)	4 (26.7)	15 (100)
Information	2 (13.3)	1 (6.6)	**6 (40.0)**	3 (20.0)	3 (20.0)	15 (100)
Involvement	0	1 (6.6)	4 (26.7)	**8 (53.3)**	2 (13.3)	15 (100)

Table 6.3 shows that the level of safety practice culture differed for every criterion assessed. The highest percentages of the respondents for management, environmental support, safety priority, and information criteria were at Level 3. The involvement criterion fell at Level 4, as determined by 53.3% of the respondents. Besides, 13.3% to 26.7% of the respondents determine those five safety climate criteria to be at Level 5, whereas less than 13.3% of the respondents ranked the safety practice at Levels 1 and 2. The outcomes pointed out that the organisations can be at different levels on their safety practice culture for the same criteria. In this study, most of the facilities were ranked at Level 3 for most of the criteria. Based on the safety practice culture assessment matrix, the radiation risk was at a medium level, while the safety climate criteria need to be managed so as to reduce the risk level at the facilities.

6.3 Case Studies: Safety Practices Level of the Radiation Facilities

Multiple case studies had been selected for this study not only to explore the safety practice level that have been implemented at the facilities, but also to explore the best practices, the lessons learnt, and the strategies devised by the facilities in managing, improving, and strengthening both safety culture and safety performance. The benefits of multiple case studies are to illuminate the variance in each case study, especially from the contexts of problematic areas and significances of the safety practices. Each single case studied reflected a complex entity located at its own location. Background, history, cultural, and physical contexts were the main interest in the cases, including the phenomena in varied scenarios (Stake, 2013). During the case study investigation, the practices of safety were observed with reference to the safety practice level assessment matrix.

During the data collection process of the case studies, five sections were categorised. The first section was background of the facility, followed by second and third sections of risk analysis and safety practice level. Next, sections four and five were related to best practices, lessons learnt, and improvement to strengthen the safety culture performance. The information and data gathered from each case were analysed case by case for each of the facility.

After that, cross-case analysis was performed to determine the level of safety practices, the best practices, and the lessons learnt in this case study using the five safety practice level criteria matrix as the guideline. The best practices of and the lessons learnt from management, environmental support, safety priority, information, and involvement criteria that were implemented in the facilities had been studied and observed.

In this study, five case studies were analysed to determine the effectiveness of the framework in assessing the safety practices level. The best practices and the lessons learnt in managing radiation risk were investigated to enhance the safety practices and safety culture in the radiation facilities.

These facilities were selected for this study due to their varying facility genre. These facilities were either making profit (private) or non-profitable (government). Besides, the different facilities were selected based on the years of operation, mainly because more experienced facilities means more experience in terms of safety practices. The facilities involved in this study were also experienced in some major and minor accidents related to radiation during their operations. The practices in handling emergencies and radiation-related accidents provide valuable best practices and lessons learnt in managing radiation risks. The different background criteria of the facilities illustrate varied safety practices level, best practices, and lessons learnt. In this study, two facilities were non-profitable companies, while three were profit-based facilities.

6.3.1 Case study: Facility A

a) Background

Facility A refers to a radiation facility established in Malaysia. The facility is government-owned and does not reap profits. The facility used Cobalt-60 as its main source to produce radiation. The radiation technique was applied to irradiate the natural rubber latex and other agricultural products. Apart from radiation hazard, chemical hazard was the other main hazard as the process involved chemical materials. About 10 employees were involved directly in radiation risk at this facility. The interview was carried out with the manager of the facility, who was responsible for radiation protection and occupational health and safety.

b) Accidents / Risk analysis

Since the past decade of operation, no serious injury or death was reported, except for infrequent minor injuries due to chemical hazard, wherein an employee suffered from rashes due to chemical material reaction during operation.

Risks of radiation leakage, exposure, and spillage were estimated at Level 1 due to the low probability and consequences. The risk of chemical hazard was also recorded at Level 1 (low risk).

Upon inquiry about risk analysis, it was performed only to meet the OHSAS 18001 requirement. This was done only by the manager at the Safety, Health and Environment Management [H33]System (SHE-MS[A34]). The employees were not involved in the risk analysis and it completely relied on the safety officers and RPOs.

c) Safety Practices Level

In accordance with the assessment matrix of the level of safety practices in Table 5.10, identification of the level of five safety practice attributes was done.

i. Management - The management aspect in Facility A was at Level 1. The safety planning and the safety review were insufficient. Although the corrective actions were taken care, the production planning excluded safety planning. Thus, this facility requires immediate action to improvise its management commitment practice.

ii. Safety Priority - The safety priority for radiation risk and hazard was at Level 5. There are adequate training and awareness activities for radiation hazard. The safety procedure and requirements for radiation safety were adhered. The manager intended to rank chemical safety at Level 3 due to the low priority given by the employees. The employees obeyed the radiation safety procedure more than that for chemical safety. They believed that radiation hazard had worse consequences. Hence, the facility needs to manage the employees' safety attitude towards chemical safety.

iii. Environmental support - The safety monitoring program included inspection by regulators, auditing, and self- assessment. The environmental support was categorised at Level 5. The auditing and monitoring activities were recorded and scheduled. The radiation risk was at a low level.

iv. Information - The information system and its dissemination were adequate. The communication tool boxes, such as noticeboard, email, and internal group meetings, were practiced. There were two ways of communication practices due to the small group of workers involved in the process. This criterion was categorised at Level 5.

v. Involvement - All the employees and the manager were involved in safety concern and matters. They followed the safety requirements and procedures. Top-down approach was implemented. The employees were willing to comply with the rules, regulations, and procedures. The workers were also consulted to every new safety procedure and during emergency basis. A few dialogues and internal group meetings led this category to be ranked at Level 4.

d) Best Practices and Lessons Learnt

Several best practices were implemented that affected its safety culture and practices. ISO certification for health, environment, and management systems has impacted the practices on safety in the facility. The auditing process was inclusive of internal and external audits that were controlled and maintained. The audit findings were the most important aspect that determined the safety performance of the facility. In this facility, continuous training and awareness program on safety and health were provided to all employees. In the case of small group members in this facility, all employees were involved in the safety events. The two-way communication between the manager and the employees was practiced. With ease of communication amidst them, information or any abnormality at the facility was communicated and well disseminated.

In maintaining the radiation safety at this facility, the manager cum the radiation safety officer faced some challenges. Since its operation, no serious injury or accident was recorded due to radiation hazard. The experienced employees, however, took the regulations for granted and gave less priority to safety. Safety practice was implemented only during audit and regulatory inspection. Such culture promotes risks at the facility and monitor is required to ensure that the employees do practice safety at the facility.

e) Improvements

This facility implemented continuous improvement to strengthen its safety culture and practices. Safety engineering also always improved the facility. However, the fund for safety engineering and safety practices were inadequate. Safety planning that was excluded from the safety activities due to costing was not highlighted by the top management. This facility suggested having adequate fund to encourage safety related activities.

6.3.2 Case study: Facility B

a) Background

Facility B refers to a facility that processes radiations for various products in Malaysia. The plant uses ionising energy in the form of gamma radiation from Cobalt-60 source. The plant activities are diversified to offer services to the public for sterilisation of medical products and packaging materials; decontamination of food, pharmaceuticals, herbs, and animal feeds; disinfestations of insects in agricultural commodities; and for quarantine purposes.

The facility is government-owned and not a profit-based company. Aside from radiation hazard, chemical hazard was the main hazard faced due to the process that involved chemical materials. About 15 workers were involved directly at this facility. The facility manager was responsible for the safety of the workers, public, and environment. Interview was carried out with the manager of the facility, who was responsible for radiation protection, as well as occupational health and safety.

b) Accidents / Risk analysis

Facility B has been in operation since the past decade. No serious injury or death was reported in relation to radiation hazard. After an accident took place in Malaysia related to a fire on the facility, engineering safety control was implemented at this plant. This facility also managed the chemical hazard of toluene and benzene. The maintenance of fume hood was the priority. The employees faced hazard of chemical absorption.

Risks of radiation leakage, exposure, and spillage were categorised at Level 1 due to low probability and consequences. The risk of chemical hazard was recorded as low risk (Level 1).

Upon inquiry of risk analysis, it was performed only to meet the OHSAS 18001 requirement, which was performed only by the manager in the SHE-MS. The employees were excluded from the risk analysis and this completely relied on the safety officer and the RPO evaluation.

c) Safety Practices Level

By using the safety practice assessment matrix, the level of the five safety culture criteria had been determined:

i. Management - The management criterion in Facility B was Level 3. The safety planning and the safety review of the facility were inadequate. The production planning excluded safety planning. This facility needs to take further action and manage its management commitment practices.

ii. Safety Priority - The safety priority for radiation risk and hazard was at Level 5. There were adequate training and awareness activities for radiation hazard. The safety procedure and requirements for radiation safety were complied. The manager intended to give chemical safety a Level 3 due to the low priority shown by the workers. The workers followed the radiation safety procedure more than chemical safety, as they believed that radiation hazard gave worse impact.

iii. Environmental support - The safety monitoring program included inspection by regulator, audit, and self-assessment. The environmental support was at Level 5. All auditing and monitoring were recorded and scheduled.

iv. Information - The information system and its dissemination were adequate. Communication tool boxes, e.g. noticeboard, email, and internal group meetings, were practiced. Two-way communication was practiced due to the small number of employees. This criterion was at Level 5 and no immediate action needed.

v. Involvement - All the workers and the manager were involved in safety concern and matters. The employees adhered to safety requirement and procedure. Top-down approach was implemented. The employees were willing to comply with the rules, regulation, and procedure. The workers were consulted to every new safety procedure and during emergency basis. Some dialogues and internal group meetings were noted. This criterion was at Level 5

d) Best practices and lessons learnt

Several best practices were implemented that affected the safety culture and practices at this facility. ISO certification for health, environment, and management systems influenced the practices on safety at the facility. Corrective and preventive actions for non-compliance were immediately taken. The auditing processes included internal and external audits. In this facility, continuous training and awareness program on safety and health were attended by all the workers. In the case of small group members in this facility, all employees were involved in the safety events. The two-way communication between the manager and the employees was practiced. With ease of communication among them, information and any abnormality is easily communicated and disseminated. Another important thing, there is no 'blaming' culture practiced at this facility. The management and the employees were responsible for the safety at this facility.

This facility has to improve its safety practice to ensure that its operation is in compliance with the safety standard. The major challenge at this facility was the manager who was responsible for dealing with experienced employees working for more than two decades. The take-for-granted approach was noted. They implemented routine work with lack of risk and safety concern due to the good track record of accident at the facility. This approach encouraged the employees to skip self-risk assessment even for the high risk tasks, unless there was an order by the top management. In managing the safety practice at this facility, some conflicts of interest were noted between the occupational safety officer and the radiation area supervisor. The monitoring system at both areas was redundant. There was insufficient systematic template and approach in monitoring both occupational and radiation safety. It was difficult to deal with the atomic regulator, as the regulator inspectors detected non-compliance and suspended the atomic licence. This facility had high tendency to hide its safety issues and the employees only adhered to safety rules during inspection.

e) Improvements

This facility implemented continuous improvement to enhance its safety culture and practices. In monitoring radiation safety, the area supervisors used HIRARC template during inspection and reported to the radiation safety team at the facility. The template served as safety criteria and indicators to determine the level of safety practices at the facility, along with occupational safety monitoring. Both safety and operation planning must be synchronised in facility strategic plan.

6.3.3 Case study: Facility C

a) Background

Facility C is involved in irradiation processing of surgical gloves manufactured in Malaysia. The plant used ionising energy in the form of gamma radiation from Cobalt-60 source. The plant irradiation activities were for sterilisation of medical products and packaging materials.

The facility is a private-owned and profit-based firm operating for 27 years. About 24 employees were involved directly to radiation at this facility. The facility manager was responsible for the safety of the employees, public and environment. Interview was carried out with the RPO of the facility, who was responsible for radiation protection, as well as occupational health and safety.

b) Accidents / Risk analysis

Since the past decade, no serious injury or death was reported due to radiation hazard. After an accident happened in Malaysia that caused fire at the facility, the engineering safety control was implemented at the plant.

Risks related to radiation leakage, exposure, and spillage were categorised at Level 1 due to low probability and consequences.

Upon inquiry of risk analysis, it was only performed to meet the OHSAS 18001 requirement. The employees were excluded from the risk analysis and it relied completely on the safety officer and the RPO evaluation.

Although no fatal accident was reported, the management of the facility placed radiation safety as the main priority. The RPO frequently attended the national RPO Conference and established a good networking with other irradiation facilities in Malaysia.

As a private company, Facility C needs to comply with the atomic licensing process stipulated by AELB. Unplanned (spot–check) inspections from the regulatory inspectors were common. The annual renewal of the licence requires the facility to implement the safety practices of radiation protection program. The monitoring system by the regulator and the commitment from the management reduced the occurrence of accidents.

c) Safety Practices Level

By using the safety practice assessment matrix, the levels of five safety culture criteria were determined:

i. Management - The management aspect in Facility C was categorised at Level 5. The safety planning and the safety review on the corrective action were well-structured. The safety planning was integrated with other areas, such as production, human resource, financial, and infrastructure aspects.

ii. Safety Priority - The safety priority for radiation risk and hazard was at Level 3 and need to be managed. There were adequate training and awareness activities for radiation hazard. The safety procedure and requirements for radiation safety were fulfilled to ensure that the workers could prioritise their tasks. A risk analysis system was implemented to comply with the OSHA 1994 Act.

iii. Environmental support - The monitoring activities included inspection by regulator, audits, and self-assessment. The environmental support was categorised at Level 5. The auditing and monitoring for all critical areas were structured.

iv. Information - The information system and its dissemination were adequate. The communication tool boxes, e.g. noticeboard, emails, and internal group meetings, were practiced. The report to the top management was prepared when required. Reporting system to the immediate supervisor was infrequently practiced. This criterion was categorised at Level 3.

v. Involvement - All the workers and the manager were involved in safety concern and matters. The employees were engaged in safety requirement and procedure. Top-down approach was implemented. The workers were also consulted to every new safety procedure and during emergency basis. There were dialogues and internal group meetings. This criterion was categorised at Level 4.

d) Best Practices and Lessons Learnt

This facility was licensed under rules and regulation of the Act 304 in processing ionising energy in the form of gamma radiation. In compliance with the regulation requirements, this facility formed its radiation protection program led by the RPO. This safety program was submitted to the atomic regulator during the license renewal process. Incomplete and insufficient radiation protection program, including safety culture and practices, can suspend the atomic license.

In controlling the management system to ensure that the process in this facility was maintained and sustained, the ISO 9001 had been certified. The implementation of certified management system enhanced the safety aspect of the facility. Management and leadership commitment, working environment, as well as records and documentation, were controlled and implemented. Indirectly, radiation safety was monitored.

In this facility and as a concern to the national act and international standard, audits and inspections were sustained. The findings related to audit and inspection were the main indicators that ascertained if the facility implemented corrective and prevention actions in improving its safety performance, indirectly the safety culture and practices.

The continuous training and awareness in radiation safety and radiation protection had been maintained. The training needs assessment was implemented to identify employees that would need to attend the training and refreshing course on radiation safety. Due to the high risk of hazard, the awareness and hazard analysis on radiation were monitored. The management was in the highest support towards the training purposes.

Communication and networking among the RPOs in this country are established. There is an active group that discusses the radiation protection program. The radiation association has initiated and provided the emergency networking among its members. In addition, cutting-edge information on radiation safety is presented during the annual conferences. The networking with other relevant agencies is performed in circulation.

In implementing radiation safety at the facility for more than a decade, some lessons were learnt. Although the facility was licenced and certified by the regulator and certification body, its safety practices need to be monitored and given priority. The leadership and management commitment were must be resilient when dealing with experienced workers. They would prefer implementing routine work in a take-for-granted manner. This is supported by the low number of accidents that happened at the facility.

Due to the safety management system and regulatory monitoring, the workers at this facility lacked implementation of self-risk assessment for high risk tasks. The questioning attitude was not in practice when the workers could complete their work with high confidence level and without risk.

Although there was inspection and auditing from the auditors, the safety practice level was not directly assessed. The assessment of safety practices needs longer time and involves all staff at the facility. Regulator inspection would indirectly assess the safety practice level using lagging indicators.

e) Improvements

The continuous improvements were not actively implemented at this facility. Due to the low number of accidents due to radiation hazard and more than two-decade operations, the risk was estimated to be at a low level. The workers were familiar with the regulation requirements, procedures, and best practices. The management completely supported the radiation program and safety initiatives. The competent RPOs trained the new workers.

6.3.4 Case study: Facility D

a) Background

Facility D processes minerals in Malaysia. The plant is designed to treat the concentrate and produce separated Rare Earths Oxide (REO) products. The plant does not use any radiation technique to process minerals, as it is a chemical plant that operates at atmospheric pressure and temperature. The radiation hazard was generated from the by-products that could be reused and/ or recycled (in other industries) classified as residues. In this facility, the residues contained naturally occurring radionuclides. The radiation safety needs to be managed so as to control the radiation hazard from the residue.

The facility is an international and a profit-based company. About 36 workers were exposed directly to the radiation hazard at this facility. The facility manager was responsible for the safety of all the workers, public, and environment. Interview was carried out with the RPO of the facility, who was responsible for radiation protection, as well as occupational health and safety.

b) Accidents / Risk analysis

Within its five-year operation, some minor accidents related directly to the radiation hazard had occurred and a death was recorded at the plant as an employee fell into the pool due to heart attack while at the job. Besides, physical damage on the acid tank was reported and it required chemical safety intervention.

The risks of radiation leakage, exposure, and spillage were categorised at Level 3, whereas the chemical hazard for chemical spillage was categorised at Level 4 due to several recorded incidents that took place before this.

Upon inquiry of risk analysis, it was only performed to meet the OHSAS 18001 requirement. The workers were excluded from the risk analysis and it relied totally on the safety team and the RPO evaluation.

Although there was no fatal accident due to radiation, the management of the facility placed radiation safety as the main priority. The plant activities became public concern because the residues containing radionuclides. Radiation control and monitoring were implemented systematically, which need to comply with both international and national requirements.

As a private company, Facility D needs to comply with the atomic licensing requirement under the Act 304. The inspector from regulatory body was placed at the site to monitor frequently the radiation dose limit, as well as the safety of its employees and the public.

c) Safety Practices Level

By using the safety practice assessment matrix, the level of the five safety culture criteria was determined:

i. Management - The management criterion in Facility D was categorised at level 3. The safety planning and the safety review focused on the existing risk. The safety planning was integrated with other areas, such as production, human resource, financial, and infrastructure aspects. The facility appointed different people as the safety health officer and the RPO to prioritise the management and to monitor potential radiation hazard.

ii. Safety priority - The safety priority for radiation risk and hazard was at Level 3. There were training and awareness activities for radiation hazard. The training and awareness events were implemented frequently so as to ensure that the workers were familiar with the safety procedure and requirements for radiation safety compliance. A risk analysis system was implemented to comply with the OSHA 1994 Act.

iii. Environmental support - The monitoring programs included inspection by regulator, audits, and self-assessment. The environmental support was categorised at Level 3. Although the auditing and monitoring for all the critical areas were structured, the immediate supervisor and the RPO had to regularly review and check the workers to ensure of their safety at the plant (close monitoring and guidance).

iv. Information - The information system and its dissemination were adequate. The communication tool boxes, e.g. noticeboard, emails, internal group meetings, and internal training module, were practiced. The report to the top management was prepared monthly. Reporting abnormality to the immediate supervisor was done when needed. This criterion was categorised at Level 4.

v. Involvement - All the employees were encouraged to get involved in safety improvement activities. The employees adhered to the safety requirement and procedure. Top-down approach was practiced. The workers were consulted to every new safety procedure and during emergency basis. There were regular dialogues and internal group meetings to gain feedback from the workers. Most of the workers were less experienced and required more consultation on radiation protection programs. This criterion was categorised at Level 2 and it needs specific action on the workers involvement in the safety programs.

d) Best Practices and Lessons Learnt

This facility implemented best practices in managing radiation risk from the plant operation. The plant was licenced by the atomic regulation. The regulation and Act 304 requirements were complied. The safety and management system was certified under ISO. The workers at the facility were trained to comply with the provided procedures and work instruction. The involvement in radiation safety program was maintained and sustained with atomic licence renewal.

The scheduled audits and inspections were important to control the safety performance of the facility. Internal and external audits were implemented to improve their safety management system. Inspection on atomic regulatory framework was implemented to control and to reduce the radiation consequences towards employees and public.

In order to maintain and to control radiation hazard at this facility, the competent and qualified RPO was appointed permanently. The radiation protection program and radiation safety were in the right direction with the regulatory requirement and international standard practices. The RPO was familiar with the practices and was experienced in controlling workers and public acceptance on radiation safety issues.

The best practice implemented at this facility was the radiation monitoring system updated regularly. The radiation dose level was reported to the top management and displayed to the workers and public in front of the facility. There was transparent management in dealing with radiation safety practice.

This facility implemented the open door policy. There was a good relationship between the facility manager and its surrounding public. There was a lot of public awareness program regarding the facility activities. This facility is open to public visit and involvement in their operation. To ensure safety of the public and the environment, the regulator monitors the radiation dose in the daily operation.

Some lessons could be learnt in managing radiation hazard from this facility. The big challenges dealt with new workers were their lack of experience and knowledge regarding radiation science and safety. The regulation framework requirements and safety standards were detailed and mandatory to be implemented. For the new workers, close monitoring to their safety practices needs to be implemented. They were not allowed to complete a task without supervision. The frequency of training was increased to ensure the workers did understand and were familiar with the procedures and documentation. Without education and knowledge of radiation safety and consequences of the hazard, the new workers may take for granted every task given, even with possible high risk operation.

This facility has been in operation since the past 5 years. There were inadequate safety practices. Longer time is needed to establish and to develop the culture of safety at this facility. Self-assessment and awareness on the risks and hazard were not in place. The responsibility of the supervisor and the RPO requires higher competency.

In the early years of establishment of this facility, rejections were voiced from its surrounding public. The public acceptance level was very low. In introducing a new process, public involvement is important. There is a need to implement awareness program to educate the workers and its surrounding people to build trust and perception.

e) Improvements

In order to build and sustain trust and perception on the facility process, promotion and awareness were built up. The stakeholders, including workers and people, were given the right information and education on the process safety and radiation hazard involved. Mass media and social media can influence people and they need to be controlled so as to disseminate only correct information. This requires high responsibility amongst workers, public, regulators, and government in managing and controlling radiation hazard.

6.3.5 Case study: Facility E

a) Background

Facility E offers inspection and testing Service Company in Malaysia. The facility is designed to inspect defects on welding. The inspections were mainly performed at the oil and gas pipeline. The non-destructive technique was used in the inspection process of petrochemical plants. Radiation hazard comes from the gamma rays. The seal source of Iridium produces gamma rays. Iridium was used due the ease of handling and suitable for mobile inspection. The frequency of the inspection was based on the projects and requests from clients. The mobile inspections require workers to be more cautious on the safety of radiation sources.

The facility is a private and a profit-based company. About 20 workers were involved directly with radiation hazard at this facility. The facility manager was responsible to the safety of all the workers, the public, and the environment. Interview was carried out with the RPO of the facility, who was responsible for radiation protection, as well as occupational health and safety.

b) Accidents / risk analysis

Facility E has been operating since the past 10 years without any serious injury, minor accident or death due to radiation hazard. If the employees are negligent in inspecting any defect or crack at the pipeline, explosion at the rig may occur. The workers also dealt with chemicals.

Risks of radiation leakage, exposure, and spillage were categorised at Level 1 with no report of any incident, while chemical hazard was categorised at Level 4 with several reported incidents.

Upon inquiry regarding risk analysis, it was performed for the purpose of the current project and customer's requirement. The workers were excluded from the risk analysis and it completely relied on the safety team and the RPO evaluation. The workers were given briefing regarding the risk and hazard prior to start of job.

Although there was no fatal accident, the management of the facility placed radiation safety as the main priority. The inspection activities turned into public concern due to the radioactive sources that moved from site to site. Radiation control and monitoring were implemented systematically to comply with the international and national requirements. The safety from any sabotage and theft were also controlled.

As a private company, Facility E needs to comply with the atomic licensing process stipulated by AELB. The inspector from regulatory body monitors frequently the radiation dose limit and the safety of workers and public.

c) Safety Practices Level

By using the safety practice assessment matrix, the levels of five safety culture criteria were determined:

i. Management - The management criterion aspect in Facility E was categorised at Level 5 and no immediate action needed. The safety planning and the safety review were given focus in the existing risk. Corrective and preventive action was well structured. The safety planning was integrated with other areas, such as production, human resource, financial, and infrastructure aspects. Safety planning and briefing for every task depended on customer's requirements.

ii. Safety priority - The safety priority for radiation risk and hazard was at Level 3. There were training and awareness activities for radiation hazard implemented frequently to ensure that the workers complied with the safety procedure and requirements for radiation safety. The risk analysis was performed for every task and customer's safety policy and procedure were complied.

iii. Environmental support - The monitoring program included inspection by regulators, audits, and self-assessment. The environmental support was categorised at Level 3. Although the auditing and monitoring for all critical areas were structured, the immediate supervisor and RPO regularly reviewed and checked the workers' tasks and ensured the safety of the workers at the site of inspection.

iv. Information - The information system and its dissemination were adequate. The communication tool boxes, e.g. noticeboard, emails, internal group meeting, and internal training module, were practiced. The report to the top management was prepared monthly. Reporting of the inspection was submitted to immediate supervisor upon job completion. This criterion was categorised at Level 4.

v. Involvement - All workers were encouraged to involve in safety improvement activities. The employees adhered to the safety requirement and procedure. The workers were closely consulted to every new customer on the safety procedures and during inspection. There were regular dialogues and internal group meeting to gain feedback from the workers. New employees with less experience needed more consultation regarding the radiation protection program implemented. This criterion was categorised at Level 3.

d) Best Practices and Lessons Learnt

This facility implemented some best safety practices to ensure the safety of the workers and public. Although the services were performed at the customers' premise, the atomic regulatory framework and Act 304 must be complied. This facility obtained licence and was inspected by the atomic regulator. In order to implement the radiation processing, this facility was monitored and managed by the experienced, competent, and qualified RPO. The responsibility of the RPO drove the facility up to the international safety standard. Encouragement and supervision leadership motivated the workers to comply with the procedures, rules, and regulation.

In this facility, the tasks were team-based inspection project. Team members were briefed on the risk and hazard of the current project. Risk and hazard analyses were based on every task and project and were studied before the inspection process. There are different projects and premises to be inspected for each task. The safety tool kits of instruments, the process, and the emergency response program were maintained based on the risk and hazard analyses.

There were also engineering control to reduce exposure on the radioactive source that was moved from one premise to another. The design was also developed to reduce the exposure level and to increase safety amongst workers and public.

After operating for more than a decade, this facility had learnt some lessons regarding radiation safety management system. Human error was the main factor that needs to be monitored and controlled. In this facility, the workers and operators kept changing and new intake was always a challenge to control human error. Since employment was contract-based, the workers were easily moved in seeking better offer. The training and awareness programs for new workers were increased and required more cost and time. This disrupted the progress of safety culture at the facility. Continuation of safety practices lacked and needed longer time to develop the culture.

This facility was managed to continuously provide their workers radiation safety courses. In educating and making the employees aware of radiation safety, the module in radiation safety training courses must be upgraded. The effectiveness of the training courses to the RPO would increase their responsibility in strengthening the safety culture at the facility. The innovation in radiation safety management system encouraged the RPO to comply with the regulation requirements and shortened the time for radiation safety management. The trainings provided enhanced the workers' attitude and responsibility in managing radiation risk. In the case of this facility, the workers had to travel with the radiation source that requires radiation risk control. They must be aware of radiation safety, as well as security risk of the source from theft or being misused.

e) Improvements

This facility implemented continuous improvement on the radiation safety management system. The awareness program and training for new and experienced workers were mandatory in this facility. This facility was in the phase of enhancing the attitude of the workers towards radiation risk and the consequences of their jobs, apart from minimising human error during the operation. The inspection results mainly affected the control of plant inspection from any major accident and for the safety of the entire plant.

6.3.6 Cross-Case Analysis

Multiple case studies provide an opportunity to examine the phenomenon of the radiation safety culture and practice and to explore the differences and the similarities of the practices in various facilities and management. By attending to the activity and context of the case, one is able to make observations about correlations between events that occur concurrently (Stake, 2006). The cross-case analysis of the individual cases of each radiation facility determined the themes in line with the research objectives. By drawing on the important findings from each case report, affirmations could be made about the safety culture and practice in radiation facilities. The cross-case analysis suggested four themes that seemed consistent across the five respondents that participated in the study. These themes are perspective on safety practice level, radiation safety management system as the best practices, the culture of "take-for-granted", and the opportunity of safety practice level determination to strengthen safety culture. For each theme, findings from each case are included to display the practices of the facilities on that theme.

6.3.6.1 Safety Practice Assessment Level

The safety culture was practiced in all facilities to influence job characteristics, employees and public, nature of the facilities, and the nation. The level of the safety practices differed in each facility. It depended on the practices and routine jobs of the workers, as well as their attitudes towards safety. In this study, the findings of safety practices level matrix on each case and the perspectives on the safety practice level were determined. Table 6.4 presents the findings obtained from each case and the level of safety practice level.

Table 6.4: The cross-case analysis of safety practice level

	Facility A	**Facility B**	**Facility C**	**Facility D**	**Facility E**
Facility Type	Non-Profit (Gov)	Non-Profit (Gov)	Profit (Non- Gov)	Profit (Non- Gov)	Profit (Non- Gov)
Services/ Application	Irradiation& Sterilisation	Irradiation& Sterilisation	Irradiation& Sterilisation	Mineral Processing	Inspection& Calibration
No of Workers	900	900	1800	617	500
Radiation Workers	10	18	24	36	22
Years of Operation	20	30	27	5	13
Fatal/ Major Accident	No	No	No	No	No
Minor Accident (Radiation)	No	Yes	No	Yes	No
Minor accident (others)	Yes	Yes	Yes	Yes	Yes

Table 6.4, continued

	Facility A	**Facility B**	**Facility C**	**Facility D**	**Facility E**
Safety Practice Level					
Management	1	3	5	3	5
Env Support	5	3	3	3	3
Safety Priority	5	5	5	3	3
Information	5	5	3	4	4
Involvement	4	5	4	2	3

In this study, facilities that have been operating for more than 20 years displayed higher safety practice level for most of the criteria at Levels 4 and 5. For facilities that operated less than 20 years, the safety practice level stood at Levels 2 and 3, hence require further improvement on their safety practices for most of the criteria studied. The experienced workers exerted good safety practices in controlling radiation risk. On top of that, different types of facilities had different safety practice levels. As for non-profitable facilities, the safety practice levels were higher than that sought profit in terms of environmental support, safety priority, and information criteria.

The outcomes of cross-case analysis showed that the management factor was at Levels 3 and 5. Those facilities that experienced minor accidents caused by radiation hazard had determined the highest level and agreed that the management had given full support in the safety practices. Facilities that had never experienced accident cases due to radiation risk were at Level 3. A respondent claimed that the management commitment of the facility was at Level 1 and needed immediate action to improve this criterion. From the management criterion, the risk of radiation was at medium to high level. Management and leadership commitment practices need to be properly managed.

The environmental support criterion has shown that the cases share commonalities, except for facility A. The safety practice level was determined at Level 3 for most of the cases. Based on the assessment matrix, the safety practices on environmental support need to be managed. This situation may influence the radiation risk to be at medium level. This results show that facility with less number of radiation workers achieved the highest level.

This result indicated that the safety climate factors contribute to the safety practices of the facilities in increasing their organisational safety culture. Most of the facilities in this study implemented the safety practices based on those criteria, even though the level of the safety practices differed for the criteria and facilities.

6.3.6.2 Radiation Safety Management System as the Best Practices

Radiation safety management system has been introduced by the regulation requirements. This management system is the best practices to comply with the international standard and regulation. The cross-case analysis showed that most of the facilities did implement quality and safety management systems to control and monitor the safety performance at the facilities. The implementation of quality and safety management systems with certification of ISO 9001, ISO/IEC 17025, OHSAS 18000, and ISO 14000 has enhanced the radiation safety management system at the facilities. Most of the respondents agreed that the management systems were improvised with documentation, controlled documents, and recordkeeping. The management commitment and leadership at the facilities were developed and strengthened. The facilities received full support and commitment from the management on safety planning and resources in implementing safety practices. Continuous training, awareness, and risk assessment programs were implemented and maintained in most of the facilities.

The regulatory framework on radiation safety has been established in the country. Act 304 stipulates the regulation and control of atomic energy, for the establishment of standards on liability for nuclear damage and for any related matters. This act requires facility that in relation to any radioactive material, nuclear material, prescribed substance or irradiating apparatus to be controlled and to gain license. The regulator of AELB exercises control and supervision over production, application, and use of atomic energy and related matters. In order to sustain and maintain certification and license in operating the radiation technique in the process, most of the facilities practiced auditing and inspection activities, internal and by third party. Some respondents agreed that self-assessment contributes to risk control and monitoring. Frequent auditing and inspection practices can increase the safety priority behaviour amongst the workers. These practices also motivate workers to adhere to the safety culture.

These results indicate that the safety management system has been practiced at the facilities. This management system encourages the facility to manage radiation hazard in controlling and monitoring the risk level and accidents at the workplace.

6.3.6.3 The culture of take-for-granted attitude

Lessons learnt refer to the experiences derived from the project or study that needs to be taken into account for further improvement. In this study, some lessons learnt were determined that need to be managed and improved to strengthen the safety practices at the radiation facilities. In cross-case analysis and observations made during the site visit, the lessons learnt from the individual case were analysed. Table 6.5 shows the lessons learnt and best practices from the safety practices at the radiation facilities.

Table 6.5: Best practices and lessons learnt on safety practices

Criteria	Best Practices	Lesson Learn
Management Commitment	1. ISO certification and accreditation (commitment on responsibility, funding, and authority) 2. Implementation of Quality and Safety Management System 3. Safety Planning and Review twice a year	1. Take-for-granted attitude (no death/ serious injury) 2. Lacking in Bottom –up (follow order and policy) 3. Doing safety to fulfil the top management order
Safety Priority	1. Continuously Training Program (internal and external)- 4 times a year 2. Awareness program – once a year 3. Risk and hazard analysis – once a year	1. The effectiveness of the training and awareness program to the workers 2. Lacking in self- risk analysis and hazard consequences determination (questioning attitude) 3. Take-for-granted attitude
Information	1. Risk communication tool box (email, Group meeting, newsletter, social media application) 2. Formal reporting system	1. Lack of feedback from workers (bottom-up) 2. No formal reporting system from workers (operators) to the supervisor 3. Lacking in information from colleagues (hand–over job) take-for-granted attitude
Environmental Support	1. Internal and external audit 2. Regulator/licensing inspection 3. Self-assessment audit 4. Monitoring system (dose exposure)	1. Development the culture of safety (new workers) 2. Implement routine work-take-for-granted attitude
Involvement	1. Experienced worker (more than 5 years) engage to the safety issues 2. Involvement policy on workers established	1. Close consultation and engagement for new workers 2. Small group – easy to handle 3. Big group – need more attention 4. Work load – the less involvement in safety program

The results showed that most of the facilities experienced the culture of take-for-granted attitude. It appeared in each of the criterion assessed. The management commitment criteria lacked bottom-up policy and planning. Most of the workers implemented safety practices to fulfil management and supervisors' instructions.

Sometimes, the management team overlooked the safety activities and safety resources at the facilities.

Most of the facilities did not practice self-assessment on the risk and hazard of their work and lacked questioning attitude. The employees believed in their routine work and took radiation safety for granted. Most of the workers at the facilities did report during job hand-over. Information dissemination among colleagues was not practiced. People surrounding the control work area were also cultured with the take-for-granted attitude.

The results displayed that the take-for-granted attitude was present in the involvement criteria. Some workers were reluctant to participate in the safety activities. They believed that the safety issues had to be managed by the safety team and RPO. Some workers did not attend and or were not engaged in safety awareness and safety consultancy. One respondent described that the RPO of the facility and the supervisor need to push and instruct the workers to get involved in the safety activities.

6.3.6.4 Opportunity of safety practice level assessment matrix to strengthen safety culture

In this study, the safety practice level assessment matrix was verified to be an opportunity in strengthening the safety culture of the facilities. From the case study and observations made on the best practice and lessons learnt, strategies to improve and strengthen the safety culture were designed. Figure 6.1 shows the safety climate factors that need to be explored and managed.

The safety climate factors that influenced radiation risk were explored. In improving and strengthening the safety culture and practices, the safety practice level of the factors need to be assessed. Those practices that achieved Level 5 would maintain the best practices, while for those that did not achieve Level 5 would need to take immediate corrective action and develop mitigation plan to improve safety practices. Figure 6.1 proposes the best practices and the strategies outlined in strengthening the safety culture and practices at the facilities for each safety climate factor. These practices could be adapted to enhance the safety practices level to achieve Level 5.

The best safety practices of the radiation facilities could be shared with other facilities, regardless of sectors within the industrial process. The benchmark with other facilities and nations can determine the best practices in encouraging workers and management to strengthen and to enhance the culture of radiation safety.

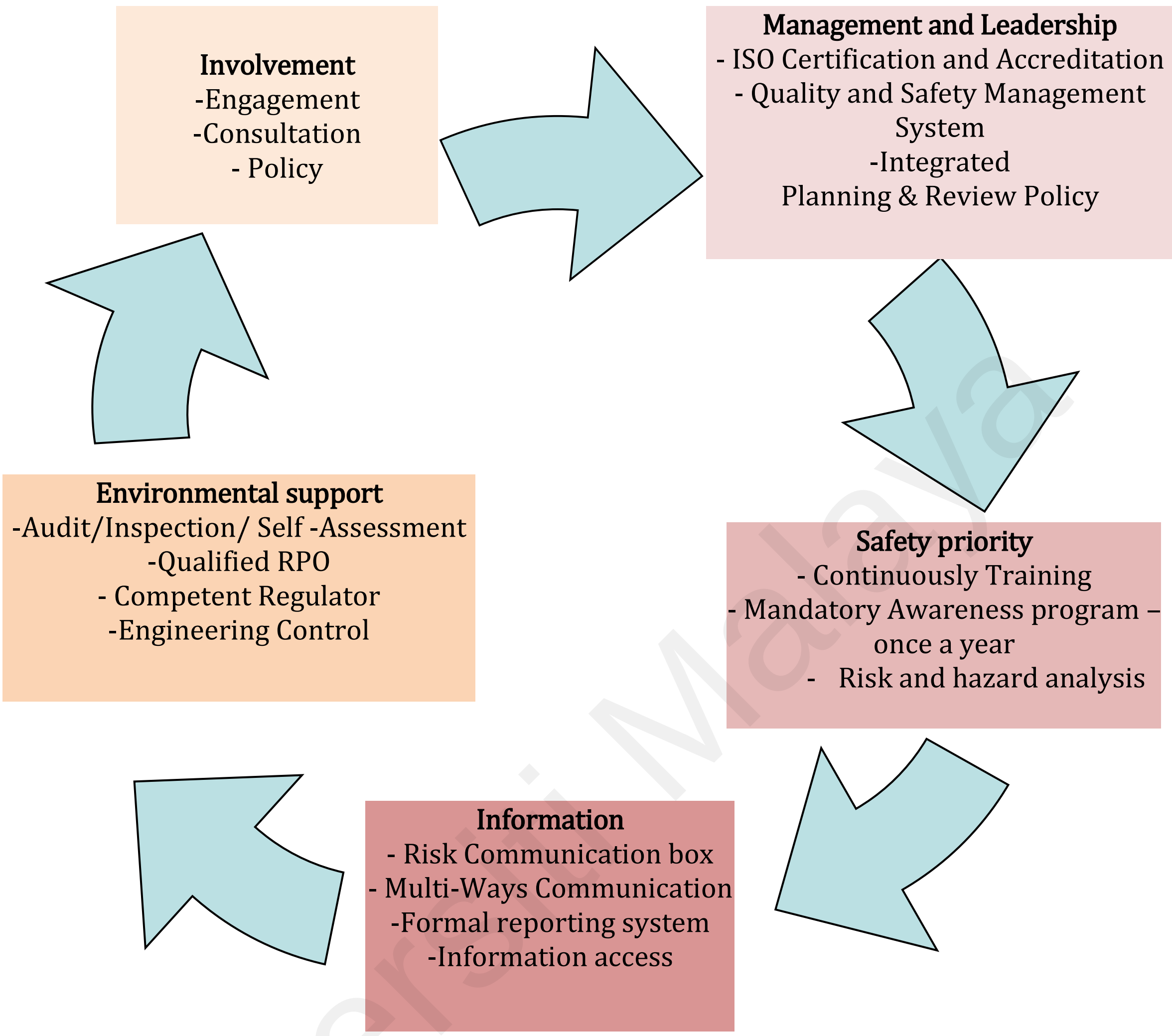

Figure 6.1: Strategies devised to strengthen the radiation safety culture and practices

6.4 Summary of Phase Three of the Study

The purpose of triangulation method and case studies employed in this study was to validate the safety practice level assessment matrix that has been developed in phase two of this study and to explore the safety practice level, best practices, and lessons learnt in managing radiation risk. Five radiation facilities in the Malaysian industry were selected for the multiple case studies.

In this study, the safety practice level of the facilities had been determined. The results indicated that the facilities could be at different levels with the same criteria. Through the perception survey, the respondents determined criteria to be at Level 5 were management commitment (60%), environmental support (17%), safety priority (35%), information (61%), and involvement (48%). Next, through site visit and observation, most of the respondents determined the safety practice level to be at Level 3; 27.7% for management, 66.7% for environmental support, 33.3% for safety priority, 40.0% for information, and 26.7% for involvement. Most of the case studies indicated different safety practice levels, with the most frequently at Levels 3 and 4 for each criterion assessed.

In this study, most of the respondents emphasised that regulatory framework, certification to international standard, and continuously monitoring system were the best practices in controlling risks and managing the radiation safety system. The take-for-granted attitude found in each criterion for most of the cases need to be nipped in the bud. This attitude may decrease the safety practice level and open for human error and major consequences of the radiation risk. The strategies to improve the level of safety practices have been determined.

The next chapter discusses each finding obtained from this study.

CHAPTER 7: DISCUSSION OF THE RESEARCH FINDINGS

7.1 Introduction

This chapter explores the implications of the study outcomes presented in the previous chapter, as well as their connections to the scholarly literature and prior researches. The discussion starts by assessing the study findings.

7.2 Determination and Measuring Factors that Affect the Safety Practices in Radiation Facilities in Malaysia

The first objective of this study is to determine the factors that affect the safety practices at radiation facilities. It was hypothesised that the participants in this study were a group of employees that dealt with radiation hazard in Malaysia. The study was designed to determine the factors that affected the safety culture and the significant variances among the factors.

The demographic data shows that the greatest proportion for working experience in radiation hazard was more than a decade (36.9%) with age ranging from 31 until 40 years old (43.3%), and degree qualification (37.5%). The demographic results of the participants in this study showed that the respondents were experienced, young, and educated. Supervisors represented the greatest proportion of job position (34.3%).

Respondents with more than 10 years of work experience have more knowledge and skills on the competency. They responded to the questionnaire based on their experiences in the field. The operational experience of the process in the facility referred to the best practices. The safety practices from the experienced workers can be shared with the young generation to maintain the culture of safety in the facility. The safety practices of organisation were influenced by work experience. The safety assessment should be carried out by a team of qualified and experienced people who are knowledgeable about all aspects of safety assessment and analyses that are applicable to the particular facility or activity concerned (IAEA, 2016a) . Work experience is needed in managing and controlling the hazard and risk of radiation. Supervisors appear to be the main proportion in the job position, who manages all risks and safety of the facilities. As mentioned in IAEA's Basic Safety Principles, a good nuclear safety culture has several characteristics, including the role of supervisor in the facility. The goal of supervisory and management personnel in nuclear safety culture is that every task should be done right at the first time. They are expected to accept and insist upon full accountability for the success of each work activity and to be involved in the work to the extent necessary to achieve success (IAEA, 1999).

In the radiation facility, male was the dominant group that handles and deals with tasks related to radiation hazard, which is similar to that reported by Sangau (2012)[AS35]. According to Kenney (2016), gender difference in nuclear power is pronounced when compared to other industries, but is representative of the gender gap in engineering- and science-based industries where men are still more prevalent. In this study, the number of male workers that dealt with radiation hazard exceeded that of female workers.

7.2.1 Safety climate as factors affecting the safety practices in radiation facilities in Malaysia

In this study, respondents from three main radiation sectors showed that they generally "agreed" with the safety climate factors in their facility. The factors studied were management and leadership commitment, communication strategies, questioning attitude, their involvement in safety programs, safety prioritisation, prudent approach, and environment support. The respondents in this survey "totally agreed" with information sharing and dissemination of safety issues at the facility. Besides, they "moderately disagreed" if the working environment was inadequately managed at the facility.

This finding corroborates the ideas put forward by Cooper and Phillips (2004), Cox and Cheyne (2000), Li et al. (2017), Mearns et al. (2004), Flin (2000), and Zohar (2010). The study supports the use of safety climate measures as useful diagnostic tools in ascertaining employees' perceptions regarding the way safety is operationalized. Over 30 years of safety climate study and enormous task of validating, safety climate is a robust leading indicator or predictor of safety outcomes across industries and countries (Zohar, 2010). Therefore, safety climate is an effective assessment tool in assessing safety climate and practices in radiation facilities established in Malaysia to strengthen the safety culture and performance.

In this study, most of the respondents have estimated that chemical and radiation hazard in their respective facilities were at low-level risk. There were low probability accidents rate and no major occurrence of accident. In this regard, the implementation of safety climate control and risk level was estimated to be low. This finding supports a previous research into this brain area that linked safety climate factors with accidents rate (Smith et. al, 2006; Ajslev et al., 2017; Liu et al., 2015), which described that the company level safety climate was negatively and significantly associated with injury rates. These findings may be due to over adjustment of hazard risk, or the overwhelming effects of industry-specific hazards relative to safety climate effects. In contrast to the earlier findings, Marín et al. (2017) revealed that the relationship of safety climate with actual injury rates is inconsistent. It was found that safety climate could be a parallel outcome of workplace safety practices, instead of a direct determinant of workers' safety behaviour or outcomes of injury rates. This study implies that the safety practices may also influence safety climate and safety culture of the high risk facilities and indirectly control the number of accidents in the plants and facilities.

The statistical data of reliability and mean value results in this study showed that the data were indeed reliable and the mean values were higher than the mid of scale. The Cronbach's alpha value of each variable in this study exceeded 0.6; hence, it can be concluded that the internal consistency reliability of the questionnaire is adequate. The highest mean value was 6.06 for communicative information, while the lowest mean value was 1.54 for organisation effect. The mean value for safety climate factors was the highest among all components studied. All components showed higher mean values than the mid of scale, except for organisation effect. The respondents appeared to agree with the statements outlined in this study.

This finding has important implications for developing the inferential study to identify the relationship between the safety practices factors. Reliability refers to the extent to which assessments are consistent. It measures bias and distortion of an assessment. The safety assessment has to be reliable to ensure no bias and consistent. In this study, the safety climate assessment tool of radiation safety, Malaysian Radiation Safety Tool Kit (MRSTK), which had been adopted and adapted from Malaysia Safety Toolkit (MSTK) and IAEA recommendation, was reliable in assessing the safety practices in radiation facility. These results are similar with that reported by (Abdullah, 2009; Hahn, 2008; Isha, 2012; Lin, Tang, Miao, Wang, & Wang, 2008). The evidence suggests that this measure is a reliable and valid method to assess global safety climate in the organisation. The scale and measure may differ based on sector, job specification, organisation, country, and nature.

MSTK is a tool that has been used in Malaysian petrochemical industries, which was adopted and adapted in this study for usage in domestic radiation facilities. Consistent to the study hypotheses, the factor structure of the safety climate model (MSTK), as reported by (Isha, 2012), was replicated in the sample of Malaysian nuclear and radiation sector. Therefore, the findings from this study are consistent with those of past studies (see Cox et al., 1998; Oliver et al., 2002; Tomás et al., 2011). The factor analysis using MRSTK yielded nine factors with eigenvalues greater than 1, hence accountable for 67.81% of the total variance and contributed to the safety practices. Six factors, namely work environment, management and communication, personal safety priorities, supportive environment, personal view, and involvement, were expected to influence the practices similar to the manufacturing sector and offshore environment (Cox et al., 1998; Oliver et al., 2002). Meanwhile, the other three factors, namely questioning attitude, prudent approach, and communicative information, displayed contributory influences, as suggested in the safety series no 75 (IAEA, 1991) for nuclear and radiation facilities. Furthermore, the factor analysis revealed that the questioning attitude as an individual response to safety was the strongest factor that contributed to safety practice. It required individual self-assessment towards their individual risk and hazard via questioning attitude (Tronea & Ciurea, 2014), which is a similar outcome presented by Martinez et al. (2014). The particular study reaffirmed that positive individual response does contribute to a strong safety culture for nuclear and radiation hazard. A worker should not be limited to being involved with his safety; he should always evaluate every task given to him and be mindful of possible consequences of any risk and hazard that may occur. This is particularly correlated to their awareness, training, and practice towards safety and health at workplace (Hui-Nee, 2014).

Therefore, it is necessary for radiation facilities to advocate more practices on each individual's response to their task, whereas self-assessment and hazard assessment for each task should be made mandatory. Next, communicative information approach as the fifth factor of MRSTK in ensuring proper dissemination of information on safety and risk among colleagues and during shift turnover can improve safety culture and practices. Each individual acknowledges that communicative approach involves obtaining useful information from others, transmitting such information to others, as well as reporting on and documenting the results of work alike are essential to maintain their safety. Nesheim and Gressgård (2014), in particular, described daily report and safety condition updates after task completion are capable of preventing any misunderstanding and misinterpretations, rendering safety as the top priority. This has emerged as an important implication for the practice as the element of speaking up about safety issues has been acknowledged as a critical aspect of positive safety culture development (Mearns & Yule, 2009). Each individual should practice informing and communicating the information regarding any hazard and risk in their tasks to ensure that the safety and control processes are updated from time to time. Personal safety priorities and individual involvement in safety have subsequently contributed as the fourth and ninth factors, respectively. Individual priority on safety and their involvement is capable of improving the safety performance in an organisation, as personnel.

From the exploratory factor analysis and comparison with the petrochemical sector, the six factors of MSTK are contribute to the safety practices in both petrochemical and radiation sectors in Malaysia. This displays that the safety climate instruments developed in the petrochemical sector could be successfully transferred to nuclear and radiation sector for the purpose of fulfilling the nuclear safety regime requirements. In petrochemical sectors, the management factors were independent, while in radiation and nuclear sector, items in management were loaded in the communication factor. Items in communication of petrochemical sector seemed to be loaded in supportive environment. In this regard, the identified factors differed in loading factor and the total percentage of variance. Thus, this study specifically emphasised on the responsibility of the management hierarchy and individual response, referring to the staff attitude across all levels in responding to and benefiting from the safety culture framework (IAEA, 1991). This is related to the awareness, training, and practice towards safety and health at the workplace (Hui-Nee, 2014). Furthermore, safety climate in the organisation does also influence the factors that contribute to safety practices amongst workers (Kouabenan et al., 2015). Safety management and work environment as organisational commitment seem to affect the safety culture and practice more than individual commitment in petrochemical facilities. Wahlström and Rollenhagen (2014) described that organisations that practice effective safety management system and provide safe workplace environment would ensure the practice of positive safety culture.

7.2.2 Significant mean difference among the safety practice factors

The highest mean level was personal priority, while the lowest mean level was work environment. This shows that individual factor had more impact on safety practices than workplace environment; consistent with that reported by Cox (2000) that the highest mean level was personal priority.

A repeated measure ANOVA with Greenhouse-Geisser correction and Bonferroni post-hoc test resulted in statistical significance between the nine factors of safety practices in the present study. Meanwhile, the pairwise comparison also revealed significant means difference between communication, personal priority, work environment, and questioning attitude. The mean value for all safety practice factors were higher than those for mid-point of the response scale (4), suggesting that respondents generally rated the survey items favourably. Most of the means fell between values 5 and 6 on the 7-point scale, corresponding to the response options of "somewhat agree" (5) and "agree" (6), excluding work environment (mean=3.51). These findings are, thus, consistent with those obtained by Morrow et al., (2014); indicating that the respondents generally agreed with the positive statements concerning their safety cultures. It is possible for facilities to have significantly varied cultures and perform equally well in terms of safety (Reiman & Oedewald, 2007).

In this study, the highest mean level was obtained for communicative information, whereas the lowest mean level was for work environment. This asserts the notion that individual factor is more influential on safety practices rather than workplace environment, which is consistent with that reported by Cox and Cheyne (2000). The work previously suggested personal priority as the highest mean level and involvement as the lowest mean. Additionally, the difference between certain occupational groups and organisation may cause (Mearns et al., 1998) one to assume that individuals and teams often times belonging to other organisation or 'parent organisation' may have their own sub-culture. Thus, they may find themselves to be outside of the various communication channels available.

7.2.3 Development of Measurement Model and Relationships between Safety Climate Factors, Risk Control Measures, Decision-Making Attitude, and Individual Risk Level Estimate

The main purpose of the first phase of this study is to determine the reliability and validity of the nine safety climate factors, three components of individual risk estimate, three components of risk control measures, and decision-making attitude. In relation to this, it is important to note that all these have been statistically proven and can be appropriately used for further analysis. Meanwhile, another purpose of this study is to determine the direct path and mediating role of risk control, as well as decision-making attitude, on the relationships between safety climate factors and individual risk estimate.

The results of the path analysis managed to illustrate the evidence of the hypothesised model. Figure 4.17 illustrates that the overall model was found to have an acceptable fit to the data, as well as the significant path coefficients. Since only a handful of studies have looked into radiation workers' safety culture and practice in Malaysia; this study displays proactive effort into safety practices, and its relation with risk estimate, risk control measure, and decision-making attitude to address the research gaps in regard to the safety of radiation workers in Malaysia.

A total of six out of the nine safety climate factors, including management commitment, priority to safety, communicative information, personal involvement, supportive environment, and questioning attitude, had **strong influence on safety practices and risk estimate**. Hence, H1 is supported. This study displayed the implications in regard to the transferability of safety climate models, as well as the type of interventions that can be used to improve safety. Hence, it is expected for the policy makers to prepare the human resource and financial planning in regard to the factors for the purpose of supporting the development of nuclear and radiation technology in the country. This finding is supported by Kim et al. (2016), who emphasised on several main drivers, namely procedures, training, experience of personnel, and workload, which can be used to perform human reliability analysis for low power and shutdown operation.

This study also highlighted the role of **informative communication and questioning attitude** with the purpose of influencing and encouraging safety practice.

These factors affected risk control measure, decision-making attitude, and risk estimate of the organisational effect, as well as chemical and radiological hazard. The management has to provide the highest level of priority and ensure that the employees are aware about the importance of sharing and disseminating information. Hence, it is best for the communication and information planning to provide adequate knowledge about various processes, associate risks and consequences, as well as the safety measures during abnormal situations and emergencies. It is also crucial to develop information disseminate medium, such as matrix indicators of risk level and status. In relation to this, the frequency of training and awareness programmes on information sharing, as well as questioning attitude of individuals, can be increased. More importantly, the employees can be motivated by giving them the opportunity to assess their own risk, as well as to prepare for emergency preparedness in dealing with the high harmful effects of hazard occurrences, such as explosion and radiation exposure.

Awareness on accidents and administrative control of the task were found to influence the risk control measures with the purpose of reducing the impact of the risk. On a more important note, strong safety practices with good information sharing, questioning attitude, priority to safety, and involvement in safety had been believed to influence workers to implement the risk control measures to reduce the risk level. Hence H2 is supported. This finding is in agreement with the outcome described by (Sorenson, 2002), which stated that good communication, as well as learning and management commitment to safety, can be attributed to the safety culture, and more importantly to reduce errors. However, it was quite revealing that training on safety and health had no influence on risk control measures. This happens to support the findings reported by Hsu et al. (2010), which indicated that safety training should put more emphasis on how the trust relationship of teamwork can be developed to improve teamwork and information sharing in Taiwanese high-risk industries, which had been believed to produce greater effects on individual safety awareness and practices. Training and awareness programmes on information sharing and questioning attitude may be conducted regularly and the participation may be made compulsory. Vinodkumar and Bhasi (2009) highlighted the scarcity in training program implementation and suggested that safety training shall be designed to impart information and knowledge regarding various processes, associated hazards, and the safety measures to be taken by the employees in case of emergencies. In this case, training programs are expected to teach the employees how to control the risk, as well as educate them with the knowledge about risk, hazard, and its consequences.

Safety climate factors were found to motivate workers to have **good decision-making attitude**, as it is believed that they will make calm decisions, choose safe decisions, prioritise practical aspects, and control one's feeling during emergency situation through the practice of strong safety culture. Hence, H3 is supported. This attitude encourages workers to make the right decision while managing risk. Meanwhile, the results proposed that informative communication tend to encourage information sharing as the safety climate attribute that can have direct effects on risk control measures and decision-making attitude. More importantly, the results can be explained by the fact that a wide range of information, insights, and perspectives on risk assessment can influence designers, operators, and regulatory bodies to adopt risk information in their decision-making (IAEA, 2011).

Nevertheless, **risk control measures and decision-making attitude did not mediate** the relationship between safety climate factors and risk estimates of chemical and radiological hazard. Hence, H4 and H5 are not supported. This finding contradicts the study outcomes reported by Huang et al. (2006), which describes that employee safety control mediates the relationship between safety climate and occupational injury.

This contradiction is believed to be caused by the difference in the priority to safety concerns among workers in various industrial sectors. There is also no major deadly incident that involved radiation hazard in Malaysia. The perceived control of employees on safety may be affected by the event as well. Furthermore, risk control measures implemented after the risk were analysed and estimated, which appeared to be relevant to the risk level and the implementation driven by the safety practice.

In this study, the reliability and validity of the six safety climate factors, three determinants of individual risk estimate, three components of control measure, and decision-making attitude had been successfully demonstrated. The path coefficients are significant and the overall model has an acceptable fit to the data. As very few studies are linked with radiation workers safety culture in Malaysian societies, this study provides proactive effort into the relationship of safety practices, risk estimate, and perception of radiation hazard. This relationship indicated that the strong safety practices encourage the risk control measure undertaken, motivate workers to choose the right decision, and reduce the risk level. The assessment on safety practice level, thus, has to be explored to enhance the safety culture amidst organisations.

7.3 Development of Safety Practice Level Assessment Matrix

The purpose of Delphi techniques in phase two of this study is to acquire in-depth understanding, opinions, perspectives, and consensus of radiation safety experts in regard to develop the five safety practice levels, five criteria, and ten leading indicators in monitoring and assessing the safety practice levels within the context of safety amongst radiation facilities in Malaysia.

The Delphi technique implemented in this study had delivered in-depth understanding on the safety practices employed at the radiation facilities. The respondents, who have been working for more than 20 years, shared their experiences and opinions in managing radiation safety. The opinions, reviews, and suggestions collected from the experts were drove the consensus on the development of criteria and indicators of safety practice level.

In this study, Delphi technique had successfully provided consensus on the framework matrix of level, criteria, and indicators to assess the safety practices level in the radiation facilities. Even though it required longer time and difficulties in meeting the experts, the results had driven to achieve the research objectives. This is similar to the study conducted by Barzekar (2011) that proved this method was the most effective means for participants to identify criteria and indicators for measuring sustainability of ecotourism. In health and safety, Delphi techniques have extensively succeeded in generating forty-nine effectiveness indicators in eight core components to effectively reduce health-risk behaviours (Vantamay, 2015). In addition, the Delphi technique has been proven as a method that unearths information in areas where consensus has not been reached. In health and safety performance measurement indicators for construction SMEs, the success of reaching consensus using multiple parameters to decide on consensus is vital as only one or two parameters could be flawed to give incorrect results (Agumba, 2015).

Delphi technique is an excellent way to generate a consensus of expert opinions, unearth information, and provide in-depth understanding on the criteria and indicators to support available and solid statistical data to develop safety practice level assessment matrix. This reliable assessment matrix assesses the safety practice levels and improves the safety activities to strengthen both safety culture and performance at the facilities.

7.3.1 Level of safety practices in managing culture of safety

In safety performance assessments, the safety assessment tool kit was developed to assess the safety climate of the organisations. In determining the level of safety practice level, the safety culture maturity model built by Hudson (Hudson et al., 2000) was adapted. This model contained five levels: pathogen, reactive, calculative, proactive, and sustainable. It was applied to assess safety maturity of petrochemical industries, coal mining, information security, hospital and healthcare, as well as software industries.

In this study, consensus was made by the experts regarding the safety maturity model adopted and adapted to develop the safety practice level framework. The numbering format was employed to identify the levels, instead of the labelling the levels as introduced in the safety maturity model. The numbering format eliminates the confusion in the level description. The level category used in safety maturity matrix was difficult to understand and had higher possibility to be misinterpreted by workers at every level. This is supported by (Goncalves Filho et al., 2010), as he changed the 'generative' level to 'sustainable' level for the highest level in the safety culture framework. The varied interpretation for the label did affect the assessment outcomes.

In order to avoid misinterpretation by the experts, assessors, and workers, the levels were named based on number code. Level 1 was the lowest, while Level 5 was the highest. This notion of using numbering code for the safety culture level is supported by Fleming (2001) and IAEA (2016a). The number code, basically, is a group that corresponds on related issues, wherein the numbering may be consecutive. The code is used for reference purposes, for example, to help with translations, but it is the actual phrase that should appear on labels and data sheets (Society, 2015).

Radiation safety practice level in Malaysia seems to be at its early stages of assessment and lacks understanding, mechanism, and assessment tools. Since this study is a preliminary stage in determining the safety practice level, additional suggestions on levels, stages, and assessment framework were not proposed.

7.3.2 Criteria and indicators in assessing safety practices

The safety climate factors have been statistically identified as significant factors that have impact upon safety practices. The direct relation path with risk estimate is elaborated in Sections 4.3 and 4.4. The safety climate factors have been proposed to be safety practices criteria in the assessment matrix. The experts involved in this study made consensus and agreed that the criteria were applicable and fitted to be used in the assessment matrix. In this study, most of the respondents in both the survey method of questionnaire (phase one study) and the interview sessions (phase two study) gave similar responses. Surprisingly, the respondents agreed that the safety climate factors that have been implementing in their facilities refer to the criteria of safety practices that could influence the estimated risk level and risk control measure.

The findings of this study are consistent with those reported by Varonen and Mattila (2000) and Chen, McCabe, and Hyatt (2018), who discovered that safety climate correlated both with safety level of workplace environment and with company safety practices, wherein the former correlation was stronger. Cooper and Phillips (2004) further support the use of safety climate measures as useful diagnostic tools in ascertaining employees' perceptions of the way that safety is being practiced.

In this study, management commitment scored the highest mean during the site visit interview. Most of the respondents believed that the management commitment plays an important role in practicing safety culture in their facilities. This is supported by Zohar and Luria (2004) that the supervisory safety practices predict (safety) climate level and strength, as moderated by leadership quality. Transformational leadership mitigated these effects due to closer leader-member relationships. This is also seem to be consistent with Dedobbeleer and Béland (1991) and Li et al. (2017) that management commitment towards safety and workers' involvement in construction safety were the main factor in improving safety practices to be highlighted in safety policy.

Lastly, ten indicators of the criteria were selected by the experts to be used to indicate the safety practices level at radiation facilities. The indicators were classified as leading indicators. Leading indicators refer to the driving indicators that channel a facility to maintain safety programs and performance. These indicators provide requisite information and insight view of an organisation to hinder accidents.

In this study, the leading indicators were evidenced to be used in assessing the safety practice level at a radiation facility. Besides controlling and mitigating risks, these indicators provide mechanisms and strategies to improve the safety culture and safety performances. This result is in agreement with Reiman and Pietikäinen (2012) that leading indicators offer a view on the dynamics of organisation: practices, abilities, skills, and motivation of the personnel – organisational potential for safety.

Monitoring leading indicators in determining the safety practice level provide an organisation with some early warning signs on the risk level at the facilities. It provides information to estimate the probability of the risk and hazard, which is not being counter in traditional safety assessment system. Herrera and Hovden (2008) described that leading indicators are precursors based on a model of safety implying a significant possibility of event that has an impact on safety and performance. This arguments are similar to that highlighted by Leveson (2015) that the goal of leading indicators for safety is to identify the potential for an accident before it occurs. In this study, leading indicators were derived from the safety climate factors based on the safety practices criteria. This result differs from Shea et al. (2016) who found that organisation performance metric could be used as an initial ‘flag’ of the leading indicators with potential to be a benchmarking tool for workplaces.

Although several criteria had been selected as the leading indicators, the role of leading indicators were to drive and improve the organisation’s safety system, to provide information and view on the risk and hazard, as well as to ensure the best safety practices implemented in the facilities. This is to ensure that the risk is controlled and minimised to reduce the impact and the number of accidents at workplace. The improved safety practices and profitability in industry is possible when one understands the cause and effect relationship between incidents and intervention of safety program (Iyer et al.,2004). To improve the safety practices culture, an organisation should better acknowledge the significance of monitor and drive indicators in safety management (Reiman & Pietikäinen, 2010).

The assessment of leading factors in the facility can lead to the development of risk-informed decision- making. The integration of leading indicators and lagging indicator in a safety system can strengthen the safety culture and the performance of an organisation. The past two decades have noted an evolution of risk-based to risk-informed safety management approaches, in which quantitative outcomes of risk assessment (lagging indicator) are only one component of the decision-making process, which is combined with other criteria, such as social preferences, political concerns, and budgetary constraints (Torabi et al., 2006). Leading indicator complements the lagging indicator that has been widely monitored in the radiation safety program. This approach heightens the high level safety practices culture in managing radiation hazard.

Safety practice level assessment matrix was developed to assess the level of safety climate factors at radiation facilities. In this study, information on the safety practice level assessment had higher possibility to be shared among the workers at the facilities. The matrix showed the safety practice level and the estimate risk level at the facilities that could occur with their present level of safety practices. In the matrix framework, the action for improvement has been suggested for each level of safety practices. This information could be an important message to the facility management in making a decision. The matrix has been developed to be clear and informative. The incidents, injuries, and accidents from the hazard could be controlled, prevented, and minimised.

The consensus on the development assessment matrix was to develop a comprehensive, user-friendly, and vibrant description on the matrix. Safety maturity model and assessment have been implemented in the western nations to determine the level of their safety culture maturity. The study on the issues was conducted by Garzás et al., (2013) that the assessment is not so complex or costly. The model remains a need to assess more systematically, regardless if the content of the descriptions is internally consistent in terms of the levels of safety culture, as well as to investigate the underlying structure of the perceptions of the framework (Parker et al., 2006).

This safety practices level assessment matrix informs not only the level, but also describes the best practices to be maintained and practices to be improved in strengthening safety culture. This will be early warning signs to the safety performance and safety culture of the facility. The assessment of safety culture mainly affects the organisation or facility safety practices, safety management, and belief on the safety. This is similar with Fleming (2001) who reported that in deciding the level that is most appropriate, one will need to be based on the average level achieved by the organisation or installation being evaluated.

The design of safety practice level assessment matrix is structured and systematic. This indicator matrix encourages the communication and information on the risk level assessment among workers at the facilities. Awareness on risk and hazard, safety practice level, and criteria assessed will enhance the self-assessment practices and would minimise the risk consequences and impact. The self-assessment approaches provide a unique learning opportunity for an organisation to develop such expertise to examine and to understand its own culture, apart from supporting the on-going monitoring and continuous improvement in a way that periodic external assessments cannot (IAEA, 2016c).

7.4 Assessment Matrix Validation for Evidence to Support the Safety Practice Level Assessment

The purpose of triangulation method and case studies in this study was to validate the safety practice level assessment matrix, to assess the safety practice level, and to explore both best practices and lessons learnt in managing radiation risk. In this study, the safety practice level of the facilities was determined via survey questions from the assessment matrix statements, site visit interviews and observations, as well as case studies. Five radiation facilities in the Malaysian industry were selected for multiple case studies. The results indicate that the organisations could be at different levels with similar criteria.

In this study, most of the facilities safety practice assessed ranged between Level 3 to Level 5 for most of the criteria. Based on the safety practice assessment matrix, the radiation risk was at medium to low level, while some of safety practices on relevant criteria need to be managed to reduce the risk level at the facilities.

Some issues that emerged from this finding are related specifically to Levels 3 and 5 as the most frequent choice. First, the respondents were working in the organisations that continuously improved their safety aspect. The number of accidents caused by nuclear and radiation did not portray an increasing trend (Social Security Organisation, 2014). Second, all the companies have licences and are frequently audit by the AELB and other certification bodies to comply with the standard and regulation requirement for licensing purposes. Third, the organisations are aware that the hazard and risks have a huge impact on both the communities and the environment. The highest safety performance was promoted in organisations with continuous training and awareness programs.

The management commitment and communicative information practice criteria were identified at Level 5 from the perception survey, while it was assessed to be at Level 3 during the site visit interview and observation. Involvement and environmental support practice was classified to be at Levels 4 and 3 in survey, while most of the interviewed respondents agreed that those factors should be placed at Level 3. The safety practice level of observed facilities displayed varied levels of each criterion. Most of the respondents during site visit interviews observed safety practice level was at Level 3. This indicates the medium level of safety practice implementation, which needs to be managed as it is open to risks at a medium level.

The results indicated that the assessment to identify the level of safety practices can be implemented in both methods; survey and site visit observation. After all, it is better to verify the level assessment with the site visit and observation to complete the assessment. In measuring the safety climate, most of the organisations practiced safety assessment tool kits with questionnaire survey approach. The outcome was workers' perception on the safety implemented at the facility. From this study, in order to improve the assessment results, triangulation validation may be implemented via site visit observation, either by self-assessment or by the third party observation. This is supported by Ammenwerth et al. (2003) and McLinton, Dollard, and Tuckey (2018) that the triangulation method is the best approach for evaluative research when both outcomes validation and outcomes completeness are supported by triangulation.

The different levels of safety practice found in this sample are consistent with the safety culture maturity concept, as safety culture does not develop at the same pace in all companies and in all dimensions (Fleming, 2001; IAEA, 2002a, Goncalves Filho, 2010). Hudson et al. (2000) found similar results in the oil industry in other countries, such as in Oman. The reason for this is unclear, but it may have something to do with awareness, training, and priority to the safety dimension and area to be improved. It may be that these workers can benefit from best practices in the organisation safety.

7.5 Best Practices and Strategies to Strengthen the Radiation Safety Management System

From the case study, the safety practice levels of five facilities had been different from each other. In fact, several factors had influenced the safety practice level for each criterion. It could also be similar to other facilities observed.

Facilities with radiation employees exceeding 10 people had Level 3 for safety practice level of environmental support. The facility needs to manage the safety procedure compliance, apart from scheduling audits and inspection, as well as organising self-assessments. Facilities with less radiation workers showed that the safety practice was at Level 5. Increment in the number of workers at the facility requires the safety management team to provide more support in its safety system to increase job satisfaction and attitude in safe working environment. This is similar to the findings of a study carried out by Raziq and Maulabakhsh (2015), which signified that good working environment maximises the level of employee job satisfaction. Workers with **high level satisfaction** in their job with effective safety management system tend to increase commitment on safety practices, efficiency, and productivity.

The type of the facilities was also taken into account in these case studies. In the case of non-profitable facilities with small-sized operation, highest level of safety practices was achieved for communicative information. There were formal reporting system, wherein the workers reported the task to their colleagues and supervisors and all workers were willing to share and disseminate their risk information and level of risk at the facility. As for profit-based and large facilities, there is limited communicative information and strategies on the risk status and progress. Workers and management tend to have high priority on the **balancing of production and safety target**. This is similar to that reported by Karanikas et al. (2017), who described that the size of the facility and the length and type of employment were occasionally correlated with responses to some communication and human factors topics in the equilibrium between productivity and safety.

The safety practices levels of involvement and safety priority were assessed to be at the highest level for facilities with more than 20 years' operation. Workers will be able to get involved and given the highest priority to radiation safety in the facilities that may relate to their experience. In the case of new facilities with less than 20 years' operation, they need to develop more initiative to ensure that every personnel is consulted and engaged in the safety programs and awareness. These results indicate **that time and experiences** are needed to develop the highest involvement of workers and to prioritise safety at the facility. Zhou et al. (2008) suggested that a joint control of both safety climate factors and experience factors worked most effectively to enhance human safety behaviour.

The case study indicated that the safety practice level of management commitment achieved the highest level for those facilities with experience in dealing and handling accidents caused by radiation hazard. Regardless of minor accidents, the **management has given full support and commitment** towards safety planning and its resources. The facilities involved and experienced in accidents believed that accidents of radiation hazard may happen and the risk level needs to be measured and controlled. Rundmo and Hale (2003) suggested that managers' attitude, such as high management commitment, low fatalism, high safety priority, and high risk awareness, are interesting because they may affect behavioural intentions and the managers' behaviour is related to the achievement of safe working practices.

In this study, the safety practices in the radiation facilities have been measured, assessed, observed by studying several cases. The results identified several best practices and strategies implemented to strengthen the safety culture performance at the facilities, as listed in the following:-

a) The radiation safety management system

This management system is the best practice that encourages the facility to manage radiation hazard and to control risk level at workplace. This system has been supported by the **effective regulatory framework and regulatory body** in the country (IAEA, 2014). Act 304 and its regulations have been maintained by controlling the application of radiation and radioactive sources in Malaysia. The regulatory framework was adopted and adapted from international practices and requirements. In order to ensure the occupational health and safety, the OSHA 514 and its regulations were complied. The regulatory framework has been shared, compared, and discussed at national, regional, and international community levels.

In order to fulfil the regulatory requirement and international standard, the safety practices framework and the safety management need to be improved and strengthened. The performance of regulatory functions is commensurate with the radiation risks associated with facilities and activities, in accordance with a graded approach that provides a high degree of confidence in safety (IAEA, 2016b). This finding is supported by a study on the regulatory framework as a determinant of occupational health and safety (OSH) programmes, which showed a positively significant relationship between legal framework and implementation of OSH programmes (Ndegwa et al., 2014, Himanen et al., 2012).

b) The competent auditor and regulatory body

The persons shall be professionally trained, competent, and qualified. In this study, it was observed that the radiation facilities were at different levels of safety practices. There is still a need to implement **monitoring and assessment**. It will be challenging to implement the auditing and inspection of safety practices culture at the facilities. IAEA has suggested that the ability of a regulatory body is to fulfil its responsibilities depending largely on the competence of its staff. The criteria and the competency of regulatory body, along with its staff to be inspectors and auditors, are stated in the Safety Report Series: Managing Regulatory Competence. Besides, IAEA Safety Standard Series, GSR Part 1, Governmental, Legal and Regulatory Framework for Safety, appear to address issues related to competences of the regulatory body by requiring the following:

"A process shall be established to develop and maintain the necessary competence and skills of staff of the regulatory body, as an element of knowledge management. This process shall include the development of a specific training programme on the basis of an analysis of the necessary competence and skills. The training programme shall cover principles, concepts and technological aspects, as well as the procedures followed by the regulatory body for assessing applications for authorisation, for inspecting facilities and activities, and for enforcing regulatory requirements" (para. 4.13 of GSR 1).

c) **Continuously Safety Training**

In order to ensure the effectiveness of the safety practices at the radiation facilities, there is a need to provide **continuously training on regulator competency, attitude, and behaviour**. The monitoring should be implemented in systematics and transparent with high confidentiality.

Even though the regulatory framework and monitoring system were effectively implemented to control radiation risk; attitude and behaviour of the people at the facilities need to be managed. In this study, the most important finding was the take-for-granted attitude. It appeared almost in all facilities studied, observed, and visited. This attitude is related to the culture of the nation that has noted since years ago. It has become a tradition in the nation and difficult to be changed. The take-for-granted attitude may reduce when some accidents and events occur at the workplace.

d) Attitude and Behaviour Controls

The workers attitude and **behaviour need to be controlled to maintain** the safety at the radiation facilities. This is supported by Saunders et al. (2017) that there is a need to measure the workers attitude towards safety that can affect occupational health and safety within the industry. The take-for-granted attitude for every safety practice occurred when there was no fatal or major accident that happened at the facilities and they believed that such accident would never occur. The facilities had to spend more time and cost to provide training and awareness to eliminate this attitude at the facility. Hence, **supervisors must monitor** the safety practice frequently (Barling et al., 2002).

This approach may lead the facility to increase human error in the operation and give high probability of major accidents to happen. The take-for-granted attitude can lead to loss of trust and credibility from the stakeholders and the public. People outside the facility need to trust the workers, the system, and the safety aspect of the operation. Trust and acceptance towards a facility display their credibility in handling radiation hazard.

The safety practices strategies determined from the observation of best practices and lessons learnt obtained from this study are given as follows:-

a) Implement the best practices of the safety climate factors

To improve the safety culture strategies, the radiation facilities should give priority and implement the **best practices of the safety climate factors**, such as management commitment, environmental support, safety priority, communicative information, and involvement. The level of safety practices of these criteria need to be measured to identify their current risk status.

b) The facility shall maintain to be at Level 5 of the safety practices level at all times. **Assessment of safety practice level shall be mandatory to be implemented at least once a year**. Those criteria that achieve Level 4 and below the safety practice level shall implement mitigation plan and corrective action in timely manner to increase up to Level 5.

c) **The safety practice level assessment shall be integrated with other safety assessment, risk and hazard analyses, safety performance measurement, and safety analysis report.** The integration of probabilistic and deterministic shall complement each other and balance the culture of safety in the facility and to strengthen safety performance. The integration approach will improve safety by providing enhanced awareness of factors influencing safety and taking each of these factors into account in its implementation (IAEA, 2011).

d) **The independent auditing and inspection**

In the assessment of safety practices level, the development of the assessment matrix as a tool increased the trust and credibility of the regulators, inspectors, and auditors. The auditing and inspection findings were more reliable and valid. The facilities have correct information and understand their current safety practices finding, as well as the consequences to the facility and its workers on radiation hazard. The awareness of workers on their roles and practices in the safety of the facility will increase. From the assessment, each personal knows and understands that their safety practices largely contribute to the organisational safety culture and performance. This encourages employers and employees to be in the same level of understanding and have developed strong relationships.

e) **The two-way communication was effective in implementing corrective action and mitigating risks with strong supervisory approach**

Zohar and Luria (2003) concluded that supervisory safety-oriented interaction results in significant changes in workers' safety behaviour and safety climate with mitigation effect of transformational leadership due to closer leader-member relationships.

f) **The benchmarking with other facilities either in the same or different sectors to improve safety practices and to develop a safety culture**

With similar criteria and indicators, the level of safety practice benchmarking with other facilities and plant could be implemented. The safety practice level assessment matrix provides the criteria and indicators that can be used in other sectors as well. The criteria were adapted from safety climate factors; indicators of practices that were generally implemented in all sectors for their safety management system and based on international standard. Benchmarking studies of organisations with similar interests in safety management have developed several key factors as a practical safety assessment method in safety assessment. The method has been successfully implemented and it is an effective tool to evaluate safety management (Fang et al., 2004).

In the benchmarking, the facility and the RPO may have the opportunity to exchange information and the best practice activities implemented to their benchmark facilities or plant. Benchmark study on the best-practice levels of performance on health and productivity expenditure showed that the benchmarking has also collated best practices activities of benchmark organisation (Goetzel et al., 2001).

In the management organisation, especially for facilities and plants that deal with high risk operation, they need to have high priority on the safety aspect. There is a need to have continuous improvement in the safety management system. Currently, after a few of major events of accidents that happened in some countries and studies on the lessons learnt from the accidents, it can be concluded that safety needs to be continuously improved. Hence, it is imminent that safety practices are monitored and assessed.

The independent investigation commission on the Fukushima nuclear accident reported that the safety culture needs to be strengthened. Radiation facilities must undergo fundamental corporate changes, including strengthening its governance, working towards building an organisational culture that prioritises safety, changing its stance on information disclosure, and establishing a system that prioritises site safety. The lacking of safety culture may lead to operation failure and accidents (NAIIC, 2012). The continuous improvement of safety performance shall increase the public's acceptance and trust on both the operation and the sustenance of the technology.

7.6 Summary of the Chapter

This chapter discusses features and demographic data, findings, statistical analysis, structural equation model, development of safety practice level assessment matrix, validation, and multiple case studies. Each part is described in detail with some arguments and support from past studies to enlighten the study outcomes as a whole. At the end of this chapter, the safety practice level in Malaysian radiation facilities, the best practice activities, and strategies of safety practices to improve and strengthen the safety culture and performance are discussed. This is to prove that the safety practice level assessment matrix with significant safety practices criteria is significant in controlling and minimising the risk level and hazard of radiation. This is to ascertain that the safety of workers, facilities, environment, and public are the priority of the organisations.

The next chapter draws conclusion about the study; highlights the problems and limitations; emphasises its contribution to the industry, the regulator, and the policy maker; and suggests future researches and a few recommendations on creating an effective safety assessment tool to increase safety culture, trust, and acceptance on radiation technology.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

This chapter concludes and brings together the study outcomes by emphasising the major findings and the highlights of this study discussed in previous chapters. The contribution of this study, the lessons learnt, and the best practices that emerge from this study appear to be beneficial in developing the strategies to strengthen the safety culture and practices in the radiation sector within the Malaysian context. This chapter also presents the drawbacks and the strengths of this present study in outlining several recommendations and direction for future researches.

The statistical analyses have successfully determined the significant safety climate factors and effects of safety practice assessment on radiation risk for Malaysian industrial employees. This study has demonstrated the validity and reliability structure model on the correlations of safety climate factors with risk control measures, decision-making attitude, and risk level estimate. Based on the experts' consensus by Delphi Technique, more than 70% agreed with the viability of the assessment matrix obtained in evaluating the level of safety practice of radiation risk. The results indicated that an organisation can be at varied safety practice levels with the same criteria using leading indicators. Therefore, the study outcomes may be deemed as consistent with a generic safety climate model, as it displays the statistical significance between the factors and the benefits of leading indicators in examining the safety practice level.

8.2 Conclusions

All the research objectives outlined in this study have been successfully achieved. This study contributes substantially towards the greater comprehension of safety climate factors from the stance of safety practices at radiation facilities. The study has described and analysed the safety practice level, the best practices, and the lessons learn in developing viable strategies to strengthen and to improve both the safety culture and the safety performance of the related organisations.

The mix method employed in this study assured reliable and valid research outputs in achieving the study objectives through the use of multiple data collection methods and procedures. The quantitative approach adopted in this study had explored and measured the statistical significance, as well as the reliability and validity of the correlation between safety climate factors and risk estimates. This was supported by the qualitative approach that gave in-depth understanding, information, perspective, and opinions from experts pertaining to radiation safety practice in the process of developing the framework assessment matrix. The consensus given by panel of experts via Delphi technique had determined the level, the criteria, and the leading indicators of safety practice assessment matrix to assess, including the level of safety practices at radiation facilities. The best practices, the lessons learnt, and the strategies of the facilities in managing, improving, and strengthening their safety culture and safety performance were explored through multiple case studies.

This study has successfully determined the factors that affected the safety practice assessment of radiation hazard for Malaysian industrial employees. The safety climate assessment tool of radiation safety, which is known as the Malaysian Radiation Safety Tool Kit (MRSTK), refers to an alternative nine-factor model composed of 32 items encompassing: questioning attitude, communicative information, work environment, management commitment, communication, safety priority, personal view, involvement and prudent approach. These items are an appropriate tool with adequate reliability and validity. The mean variance between the nine safety climate factors were statistically significant and contributed to the dependency of each component as an influential factor that affected the safety practices of employees at the facilities. This study reaffirms that positive individual response does contribute to a strong safety culture for radiation hazard in Malaysia. Hence, the outputs generated from this study are consistent with a generic safety climate model, mainly because it displays the statistical significance between the factors of safety practice. It is important to note here that the scale and the measure may differ based on sector, job specification, organisation, nation, and culture.

This study has demonstrated the adequate construct and convergence validity, as well as the good reliability structure model of the six perceived safety climate factors, three components of risk control measures, three components of decision-making attitude, and three components of risk estimates. The fit indices of the hypothesised and modified models in SEM exhibited that the required level and the structural models of all constructs were indeed accepted. The results suggest that the survey items were appropriate indicators of their respective constructs and proved to be discriminant of each other. Apart from that, the study displayed that three proposed hypotheses are supported. The perceptions of safety climate factors tend to influence risk control measures, decision-making attitude, and radiation risk estimate of radiation employees. The safety climate factors will improve the radiation safety management were found to have a strong influence on the safety practices and risk estimate. These variables also urge the administrative control, training programs and awareness activities well maintained and implemented to control the significant risk. This significant relationship of safety climate factors and decision-making attitude motivate workers and supervisors to make a correct and safe decision during the emergency to reduce the risk level.

In regard to this, risk control measures and decision-making attitude had no mediation role on the correlation between safety climate factors and risk level estimate.

Moreover, the study findings highlighted the significance of information sharing, dissemination, and questioning mechanism while assessing the level of radiation risks. These findings serve as a valuable guide for researchers, practitioners, and policy makers in allowing them to identify the framework and the strategies that can assist them to effectively manage radiation risks that may erupt at the facilities.

The Delphi technique had successfully provided consensus on the development of the safety practice level assessment matrix on five levels, five criteria and ten indicators. Although there were constraints in terms of time and difficulties in meeting the experts, the results had driven to achieve the research objectives. The interviews analysis showed that all the respondents' perceptions shared a similar goal, which was to strengthen and improve the safety practices of radiation safety. Such enhancement requires continuous updating and monitoring of safety practices level so as to ensure the safety of employees, public, and environment. The respondents accepted the overall framework as 71%, 100%, and 86% stated their agreement with safety practice level, safety climate criteria, and the indicators, respectively. This assessment matrix portrays clear level determination, assessment criteria, leading indicators, risk level, and actions for improvement. In general, the assessment matrix may be applied to evaluate the safety practice level, apart from providing essential risk information, including the level of radiation risks at the facilities.

This study has determined the safety practice level and its association to radiation risk level of the facilities. The results indicate that the organisation can be at varied levels within similar criteria. The difference in the level serves as good indicators and strategies to enhance the area of radiation safety practices. It is possible, therefore, that self-assessment and benchmarking to be implemented for facilities that achieve level 1 up to level 4 in order to adapt and to adopt the lessons learnt and the best practices to strengthen their safety culture and practices.

From the multiple case studies, the radiation safety management system (RSMS) had been introduced and implemented in most of the radiation facilities. The implementation of quality and safety management system with certification of ISO 9001, ISO/IEC 17025, OHSAS 18000, and ISO 14000, including regulatory framework, has somewhat contributed to the best practices of radiation safety management system at the facilities. In RSMS, most of the facilities seemed to comply with the act and licensing requirement. Information concerning radiation risk, SAR, radiation protection program, and safety performance is successfully reported to the regulatory body and the facility management. This is further supported with practices of auditing and inspection activities by internal and third party certification agencies. Some respondents agreed that self-assessment also contributes to risk control and monitoring.

The case studies also showed that most of the facilities have experienced the culture of "taking things for granted'. This seems to appear in every criterion assessed as a lesson learnt in managing radiation risk. The top management took safety planning for granted, while the employees took radiation safety practices for granted. This attitude needs to be scrapped to ascertain an effective implementation of safety practices at the facilities. Finally, based on the case studies and the observations made on both best practices and lessons learnt, several viable strategies to improve and to strengthen the safety culture are proposed to be adapted by radiation facilities.

Thus, it can be concluded that the development of the safety practices level assessment matrix to assess the safety practice level in radiation facilities can highly influence and substantially contribute towards strengthening the safety practice culture, aside from effectively managing the risk level of radiation hazard in Malaysia. In conclusion, the study offers the following:

- Determination of safety climate factors that affect safety practices at radiation facilities and MRSTK as safety climate assessment tool.
- Significant, reliable, and valid correlations between safety climate factors and risk level estimates.
- The safety practice level assessment matrix with significant safety practices criteria and leading indicators, which are essential to control and to minimise both risk level and hazard of radiation.
- The safety practice level of facilities showcases the best practices and the lessons that can be learnt from the facilities so as to encourage benchmark activities.

8.3 Research Contributions

The contributions of this study to several stakeholders are elaborated as follows:-

a) Policy makers

The study outcomes have displayed implications regarding the transferability of safety climate factors and the type of interventions to enhance safety. All the factors contributing to the safety practice and level of safety practices determined in this study have been implied to be correlated with radiation protection policy, risk level,emergency responses, corrective and preventive action. Therefore, it is vital for policy makers, in this case the Malaysian Nuclear Agency and Ministry of Energy, Science, Technology, Environment and Climate Change, to prioritise human and financial resources with other national agencies to control the aspect of radiation safety in the country. Additionally, these factors and safety practice level assessment matrix contribute to inter-agency network communication, awareness, and safety performance of radiation facilities.

The incorporation of assessments for safety practices, risk control measures, decision-making attitude, and risk estimation into the radiation safety management systems enables an integrated risk assessment, particularly in terms of the effectiveness of managing risk and hazards. This further indicates that the correlation of safety practices has a strong impact upon risk estimate of radiation hazard. The study outcomes also are able to convince public trust and awareness pertaining to high-risk operations, such as nuclear power program, which can be developed with the strength of safety culture and practices and the intervention of safety assessment.

b) Regulatory agencies

The results obtained from this study should be able to facilitate the regulators, such as the AELB and safety auditors, in monitoring and identifying non-compliance of safety practices. As such, a systematic safety audit process may be enhanced with the interventional impact of these factors that contributes towards safety practices, whereby specific guidelines and regulations can be upgrade and updated to serve as a checklist during monitoring, inspections, and auditing processes.

The safety practice level assessment matrix developed in this study contributes to the safety culture assessment and monitoring of safety practices at the facilities. This supports the licensing process with the determination of safety practice level and significant radiation risk level. Facilities that score low level of safety practice are exposed to high level of risk, which can be controlled via regulation. This ensures transparent and trusted enforcement of the act and regulation.

The leading indicators in this study have been directly assessed and monitored to complement the probabilistic safety assessment. The evolution in safety assessment is deemed to offer a better approach for the decision-making process. This contributes to the implementation of RIDM at the radiation facilities established in Malaysia. The holistic approach employed in the safety assessment developed in this study displays both the credibility and the authority of regulatory bodies in inspecting and monitoring radiation safety. This also ascertains the trust the public has in radiation safety management and technology acceptance for sustenance and growth.

c) Radiation facilities and operators

Safety climate instruments should be validated at the facilities of intended use, particularly prior to the design and implementation of safety interventions. Practitioners of radiation facilities should be able to identify the influential factors that contribute to the safety practices specific to their facilities to be analysed and reported accordingly. This should aid the management in determining the areas for improvement associated to safety system. The MRSTK and safety practice assessment level matrix that has been developed in this study contributes as a basis for self-assessment and fundamental indicators of the safety practice at the facilities.

The study outputs have unravelled the causal correlations between the characteristics of safety climate factors and risk level via multivariate techniques. Apart from that, the validity and reliability aspects of the relationship are expected to minimise the impact of radiation in unusual circumstances. These results are beneficial to RPOs and facility owners as the outcomes viably allow them to develop radiation risk control strategies, mitigation and corrective action on the deterministic and probabilistic elements for the purpose of managing, as well as to minimise the impacts of the consequences.

Communication and information sharing on both the experience and the knowledge amongst employees play a significant role in radiation safety management system. The assessment matrix of safety practices serves as an effective communication and information platform that determines the risk level at the facilities. This encourages the involvement of employees from all levels to enhance their safety practices, including adhering to the safety procedures and instructions. Indirectly, safety priority and attitude to safety are bound to improve.

d) Training and education centre

The study outcomes indicated the significance of training providers and promoter agencies in determining the prioritised areas of training. These factors have subsequently led to the context of awareness programs and innovative safety intervention. Thus, this study and the development of the safety practice level assessment matrix contribute to the planning of safety training, auditing, monitoring, and increasing awareness. Nevertheless, the training scale and the content of the syllabus need to be upgraded so as to increase one's awareness regarding safety culture and practices and the essential factors that need to be prioritised.

The competency of regulators, inspectors, and radiation experts in this field is mandatory to ensure that the safety of radiation is properly controlled and managed. Only certified employees should be permitted to handle radiation-related activities and tasks. Continuous training, refreshment courses, and assessments are the main activities of training centre. The lessons learnt, the best practices, and the strategies proposed in this study substantially contribute to initiate experience sharing amongst the radiation workers in the nation via training session. This opens avenues for continuous improvement and benchmark activities between various facilities and sectors.

e) Methodological contribution

In MSTK, management and organisational factors have more heavily influenced safety culture , whereas MRSTK has rendered the safety culture and practice to be more influenced by individual factors. Questioning attitude and communicative information are the two responsive factors that must be enhanced in MRSTK. Apart from assessing the attitude of an individual employee towards safety practices and risk, questioning attitude may also contribute to the consequences and affect one's job, appropriate action, and the right decision to be taken so as to minimise the after effects in unusual circumstances.

The Delphi technique in this study contributes to the in-depth research in the radiation safety practices in Malaysia. This method allows for in-depth understanding of safety practices in real-life, instead of weighing in perceptions of employees towards their attitude during the survey assessment. A panel of experts with more than 20 years' experience and knowledge shared valuable information in developing the matrix. This technique assisted in constructing close relationships with the experts and to develop networking in radiation safety. In determining the level of safety practices, survey regarding perceptions alone is insufficient. This study displays that observations and site visit auditing via in-depth interviews and documentary analyses are essential to verify the assessment. Such multi-method research approach offers new information to enhance and to clarify the study outcomes.

In short, the methodological contribution of this study lies in its depth and through the use of questionnaire survey, semi-structured qualitative interviews, documentary analysis, and cases studies. In order to have a glimpse of how employees at the radiation facilities implement safety practices at their workplace, consensus and perceptions provided by the panel of experts were brought to focus. A significant product of this study refers to the factors that contribute to the safety practices level assessment at the radiation facilities.

8.4 Limitations of the Study and Recommendations for Future Research

Despite of the careful preparation devoted for this study, it is not free from several shortcomings. First, the experimental group population was represented by a majority of radiation employees attached to industrial sectors, which may be less representative for those working in medical, agricultural, and nuclear power plants. Hence, the outcomes would be of heavier weight if the study incorporated nuclear power plant with higher risk of radiation. Hence, future studies may embed all sectors of nuclear application in Malaysia with a higher number of respondents.

Second, the questionnaire was designed to measure the attitudes exerted by employees towards factors contributing to safety practice. Hence, individual perception of safety practice can yield useful information pertaining to the impacts of safety strategies, but may not substantiate adequate evidences about one's actual behaviour towards safety culture and their resulting safety performance. In addition, the pre- and post-test assessments were carried out by the researcher; suggesting a certain degree of subjectivity in this study.

Third, the results of path analysis are an explanation instead of prediction after considering that the initial aim is to explain the relationship. Next, this study had failed to predict risk estimate. It is obvious that there is lack of generalisation in the findings obtained from SEM, which are subjected to the sampling method or variables with respect to individuals, measures, and occasions (Jeon, 2015).

Next, the number of experts interviewed in the Delphi techniques is also a drawback in this study. Although more other experts are available in various sectors of nuclear technology application, the number of experts incorporated in this study reflected the representative group of radiation experts throughout the nation. A total of 16 experts were interviewed to explore in an in-depth manner and to gain consensus in developing the safety practices assessment matrix. The findings and the consensus in this study are limited to those who understand and share similar perspectives of the experts within the safety practice aspect at their facilities.

For future research, additional work is indeed necessary to explore the nature of safety climate of radiation in all sectors throughout Malaysia, as well as across the various sectors. For example, a prior research revealed the common themes for safety climate, but differed in terms of item components for each theme (variables). They have displayed the likelihood of being industry- or even company-specific in nature, which is comparable across the varied industrial sectors of energy, chemical, transport, construction, and manufacturing. Such research is, therefore, essential to extend the present understanding regarding cross-sector culture influences on safety climate and safety behaviour, in relation to specific work practices or policies. The present study and other related researches have stumbled upon insufficient knowledge regarding such influences; suggesting that the existing models of safety climate and framework matrix may not be readily transferable across sectors without organisational and cultural adjustment. In terms of generalisation of this study, it is recommended that the case studies and the benchmarking activities to incorporate radiation facilities and nuclear power plants established in other nations. International benchmarking offers the real gap analysis and the safety practices that have to be implemented in managing the high risk of radiation hazard.

REFERENCES

Abdullah, N. A. C.,Spickett, J. T., Rumckev, K. B., & Dhaliwal, S. S. (2009).Validity and reliability of the safety climate measurement in Malaysia. *International Review of Business Research Papers, 5*(3), 111-141.

Adler, M., & Ziglio,E. (1996).*Gazing into the oracle: The Delphi method and its application to social policy and public health*. London, UK: Jessica Kingsley Publishers.

AELB (2014).*Annual report 2014*. Selangor, Malaysia: Atomic Energy Licensing Board.

Ahn, K.-I., & Park, S.-Y. (2009).Development of a risk-informed accident diagnosis and prognosis system to support severe accident management. *Nuclear Engineering and Design, 239*(10), 2119-2133.

Ajslev, J., Dastjerdi, E. L., Dyreborg, J., Kines, P., Jeschke, K. C., Sundstrup, E. & Andersen, L. L. (2017). Safety climate and accidents at work: cross-sectional study among 15,000 workers of the general working population. *Safety Science, 91,* 320-325

Ali, N. M. (2004).*Trends in occupational exposure in Malaysia*. Paper presented at the 11th International Congress of Occupational Protection Association, Madrid, Spain.

Ali, N. M. (2007).*Challenges in promoting radiation safety culture*. Paper presented at the 4th Symposium on Radiation Safety and Detection Technology, Korea.

Ali, N. M. (2011). Evolution of radiation protection trends – The Malaysian perspective. *Progress in Nuclear Science and Technology, 1,* 14-19.

Ali, N. M. (2014).Challenges in promoting radiation safety culture.*Journal of Nuclear Science and Technology, 45*(sup5), 623-626.

Al-Refaie, A. (2013). Factors affect companies' safety performance in Jordan using structural equation modeling. *Safety Science, 57,* 169-178.

Al-Sharrah, G. K., Edwards, D., & Hankinson, G. (2007).A new safety risk index for use in petrochemical planning. *Process Safety and Environmental Protection, 85*(6), 533-540.

Aluko, O. O., Adebayo, A. E., Adebisi, T. F., Ewegbemi, M. K., Abidoye, A. T., & Popoola, B. F. (2016). Knowledge, attitudes and perceptions of occupational hazards and safety practices in Nigerian healthcare workers. BMC research notes, 9(1), 71.

Amendola, A. (2001). Recent paradigms for risk informed decision making. *Safety Science, 40,* 17-30.

Amirah, N. A., Asma, W. I., Muda, M. S., & Amin, W. A. A. W. M. (2013). Safety culture in combating occupational safety and health problems in the Malaysian manufacturing sectors. *Asian Social Science, 9*(3).

Ammenwerth, E., Iller, C., & Mansmann, U. (2003). Can evaluation studies benefit from triangulation?A case study. *International Journal of Medical Informatics, 70*(2-3), 237-248.

Anspaugh, L. R., Catlin, R. J., & Goldman, M. (1988).The global impact of the Chernobyl reactor accident. *Science, 242*(4885), 1513-1519.

Arezes, P. M., Miguel, A. S. (2008). Risk perception and safety behavior: Study in an occupational environment. *Safety Science, 46*(900-907).

Arikawa, H., Cao, Y., & Matsumoto, S. (2014). Attitudes toward nuclear power and energy-saving behavior among Japanese households. *Energy Research & Social Science, 2,* 12-20.[AS36]

Aven, T. (2012). Foundational issues in risk assessment and risk management. *Risk Anal, 32*(10), 1647-1656.

Aven, T., & Kørte, J. (2003). On the use of risk and decision analysis to support decision-making. *Reliability Engineering and System Safety, 79,* 289-299.

Aven, T., & Krohn, B. S. (2014). A new perspective on how to understand, assess and manage risk and the unforeseen. Reliability Engineering & System Safety, 121, 1-10. doi:10.1016/j.ress.2013.07.005

Awang, Z. (2012). *Research methodology and data analysis* (2nd ed). Malaysia: UiTM Press.

Ayob, A. M. (1992). *Kaedah penyelidikan sosioekonomi*. Kuala Lumpur: DBP.

Badri, A., Gbodossou, A., & Nadeau, S. (2012). Occupational health and safety risks: Towards the integration into project management. *Safety Science, 50*(2), 190-198.

Bahari, A., Hassan, H., & Jainoo, I. (2013). *Sustainable occupational safety and health at the workplace*. Kangar, Perlis: Universiti Malaysia Perlis Press.

Barling, J., Loughlin, C., & Kelloway, E. K. (2002). Development and test of a model linking safety-specific transformational leadership and occupational safety. *Journal of Applied Psychology, 87*(3), 488.

Barzekar, G., Aziz, A., Mariapan, M., & Ismail, M. H. (2011). Delphi technique for generating criteria and indicators in monitoring ecotourism sustainability in Northern forests of Iran: Case study on Dohezar and Sehezar Watersheds. *Folia Forestalia Polonica, 53*(2), 130-141.

Basri, N., Hashim, S., Ramli, A., Bradley, D., & Hamzah, K. (2016). Regulatory requirements for nuclear power plant site selection in Malaysia - A review. *Journal of Radiological Protection, 36*(4), R96.

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur Jr, W. (2010). Safety climate and injuries: An examination of theoretical and empirical relationship. *Journal of Applied Psychology, 95*(4), 713-727.

Bowers, K. C., & Fleming, M. (2017). *Understanding railway employees' perceptions of senior managers' safety commitment*. Paper presented at the International Conference on Applied Human Factors and Ergonomics, Los Angeles, California, USA.

Bowers, K. C., Fleming, M., & Bishop, A. (2017). Senior management safety leadership behaviour. *Leading to Occupational Health and Safety: How Leadership Behaviours Impact Organizational Safety and Well-Being,* 33.

Broughton, E. (2005). The Bhopal disaster and its aftermath: A review. *Environmental Health, 4*(1), 1.

Bryant, P., Croft, J., & Cole, P. (2017). Integration of risks from multiple hazards into a holistic ALARA/ALARP demonstration. *Journal of Radiological Protection, 38*(1), 81.

Bryman, A., & Cramer, D. (2001). *Quantitative data analysis with SPSS release 10 for Windows: A guide for social scientists.* Abingdon, UK: Routledge.

Caballero-Anthony, M., Cook, A. D., Trajano, J. C. I., & Sembiring, M. (2014). The sustainability of nuclear energy in Southeast Asia: Opportunities and challenges. *Non-Traditional Security Studies,* 1.

Casey, T., Griffin, M. A., Flatau Harrison, H., & Neal, A. (2017). Safety climate and culture: Integrating psychological and systems perspectives. *Journal of Occupational Health Psychology, 22*(3), 341.

Center for Chemical Process Safety (2005). *Building process safety culture: Tools to enhance process safety performance*. Retrieved from https://www.aiche.org/sites/default/files/docs/embedded-pdf/Columbia_Case_History.pdf

Chang, M. K., Chang, R. R., Shu, C. M., & Lin, K. N. (2005). Application of risk based inspection in refinery and processing piping. *Journal of Loss Prevention in the Process Industries, 18*(4-6), 397-402.

Chauvin, B., Hermand, D., & Mullet, E. (2007). Risk perception and personality facets. *Risk Anal, 27*(1), 171-185.

Chen, Y., McCabe, B., & Hyatt, D. (2018). A resilience safety climate model predicting construction safety performance. *Safety Science, 109,* 434-445.

Cheok, M. C., Parry, G. W., & Sherry, R. R. (1998). Use of importance measures in risk-informed regulatory applications. *Reliability Engineering and System Safety 6*(60), 213-226.

Cheyne, A., Tomas, J. M., Cox, S., & Oliver, A. (2003). Perceptions of safety climate at different employment levels. *Work & Stress, 17*(1), 21-37.

Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: a meta-analysis of the roles of person and situation factors. *Journal of Applied Psychology, 94*(5), 1103.

Cole, P., Hallard, R., Broughton, J., Coates, R., Croft, J., Davies, K., ... & McGeary, R. (2014). Developing the radiation protection safety culture in the UK. *Journal of Radiological Protection, 34*(2), 469.

Collins, A. M. (2002). Safety Culture: A review of the literature. *Health and Safety Laboratory, Human Factors Group, Sheffield, 35*.

Cooper, M. D. (2000). Towards a model of safety culture. *Safety Science, 36,* 111-136.

Cooper, M. D., & Phillips, R. A. (2004). Exploratory analysis of the safety climate and safety behavior relationship. *Journal of Safety Research, 35*(5), 497-512.

Cox, S. J., & Cheyne, A. J. T. (2000). Assessing safety culture in offshore environment. *Safety Science, 34,* 111-129.

Cox, S., Tomás, J. M., Cheyne, A., & Oliver, A. (1998). Safety culture: The prediction of commitment to safety in the manufacturing industry. *British Journal of Management, 9*(Special Issue).

Coyle, I. R., Sleeman, S. D., & Adams, N. (1995). Safety climate. *Journal of Safety Research, 26*(4), 247-254.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publication.

Curcuruto, M., Griffin, M. A., Kandola, R., & Morgan, J. I. (2018). Multilevel safety climate in the UK rail industry: A cross validation of the Zohar and Luria MSC scale. *Safety Science*. Retrieved from https://doi.org/10.1016/j.ssci.2018.02.008

Cushinery, C. W. (2011). *Factors influencing music teacher retention: A mixed method study* (Doctoral dissertation, University of Nevada, Las Vegas).

Dalkey, N. C. (1972). *Studies in the quality of life: Delphi and decision-making*. Lanham, MD: Lexington Books.[AS37]

Dallat, C.,Salmon, P. M., & Goode, N. (2018).Identifying risks and emergent risks across sociotechnical systems: the NETworked hazard analysis and risk management system (NET-HARMS). *Theoretical Issues in Ergonomics Science*, 19(4), 456-482.

Dedobbeleer, N., & Béland, F.(1991). A safety climate measure for construction sites *Journal of Safety Research, 22*(2), 97-103.

Desa, A. F. N. C.,Habidin, N. F., Hibadullah, S. N., Fuzi, N. M., & Zamri, F. I. M. (2013). Occupational Safety and Health Administration (OSHA) practices and OSHA performance in Malaysian automotive industry. *Journal of Studies in Social Sciences, 4*(1), 1-15.

Didla, S., Mearns, K., & Flin, R. (2009). Safety citizenship behaviour: A proactive approach to risk management. *Journal of Risk Research, 12*(3-4), 475-483.

do Nascimento, C. S., Andrade, D. A., & de Mesquita, R. N. (2017). Psychometric model for safety culture assessment in nuclear research facilities. *Nuclear Engineering and Design, 314,* 227-237.

Donovan, S.-L.,Salmon, P. M., Horberry, T., & Lenné, M. G. (2018). Ending on a positive: Examining the role of safety leadership decisions, behaviours and actions in a safety critical situation. *Applied ergonomics*, 66, 139-150.

Donovan, S.-L.,Salmon, P. M., Lenné, M. G., & Horberry, T. (2017). Safety leadership and systems thinking: application and evaluation of a Risk Management Framework in the mining industry. *Ergonomics*, 60(10), 1336-1350.

DOSH (2008). *Guidelines for hazard identification, risk assessment and risk control for hazard identification, risk assessment and risk control* (Vol. JKKP DP 127/789/4-47). Kuala Lumpur: Department of Occupational Safety and Health.

DOSH (2011). *Ammonia gas cylinders explosion*. Kuala Lumpur: Department of Occupational Safety and Health.

DOSH (2012). *Fire and explosion in a gas processing plant*. Kuala Lumpur: Department of Occupational Safety and Health.

Dunteman, G. H. (1989). *Principle component analysis*. USA: Sage Publications.

Fang, D., Huang, X., & Hinze, J. (2004). Benchmarking studies on construction safety management in China. *Journal of Construction Engineering and Management, 130*(3), 424-432.

Faridah Ismail, H. H., Razidah Ismail, Abdul Majid, M. Z. (2010). A framework of safety culture for the Malaysian construction companies: A methodological development. *Pertanika Journal of Social Science & Humanities, 18*(1), 45-54.

Fefer, J. P. (2016). Using the Delphi technique to identify key elements for effective and sustainable visitor use planning frameworks. *SAGE Open,* 1-16.

Fernandez-Muniz, B., Montes-Peon, J. M., & Vazquez-Ordas, C. J. (2007). Safety culture: Analysis of the causal relationships between its key dimensions. *Journal of Safety Research, 38*(6), 627-641.

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2014). Safety leadership, risk management and safety performance in Spanish firms. *Safety Science, 70,* 295-307.

Findley, M., Smith, S., Gorski, J., & O'neil, M. (2007). Safety climate differences among job positions in a nuclear decommissioning and demolition industry: Employees' self-reported safety attitudes and perceptions. *Safety Science, 45*(8), 875-889.

Firestone, R. E. H. A. W. A. (1983). Multisite qualitative policy research: Optimizing description and generalizability. *Educational Researcher, 12*(2), 14-19.

Fisher, R. H. S. A. D. L. (2004). Development, validation and application of a Malay translation of an elementary version of the questionnaire on teacher interaction. *Research in Science Education, 34,* 173-194.

Fleming, M. (2001). *Safety culture maturity model*. Offshore Technology Report-Health and Safety Executive OTH, Colegate, Norwich.

Fleming, M. (2012). *Assessing employee safety motivation*. WorkSafeBC.

Fleming, M., & Wentzell, N. (2008). Patient safety culture improvement tool: development and guidelines for use. *Healthcare Quarterly, 11*(Sp).

Fleming, M., Bowers, K. C., Thibault, T., & Cregan, B. (2017). *Development and initial testing of a regulatory body safety culture perception survey*. Paper presented at the International Conference on Applied Human Factors and Ergonomics.

Flin, R., Mearns, K., O' Connor, P., & Bryden, R. (2000). Measuring safety climate: Identifying the common features. *Safety Science, 34*(1-3), 177-192.

Frazier, C. B., Ludwig, T. D., Whitaker, B., & Roberts, D. S. (2013). A hierarchical factor analysis of a safety culture survey. J Safety Res, 45, 15-28. doi:10.1016/j.jsr.2012.10.015

French, D. J., Elander, J., & Wilding, J. M. (1993). Decision-making style, driving style, and self-reported involvement in road traffic accidents. *Ergonomics, 36*(6), 627-644.

Ferguson, E., & Daniel, E. (1995). The Illness Attitudes Scale (IAS): A psychometric evaluation on a non-clinical population. Personality and Individual Differences, 18(4), 463-469. Garzás, J., Pino, F. J., Piattini, M., & Fernández, C. M. (2013). A maturity model for the Spanish software industry based on ISO standards. *Computer Standards & Interfaces, 35*(6), 616-628.

Gil, F. (2008). *Incidents that define process safety*. Hoboken: Wiley.[AS38]

Goetzel, R. Z., Guindon, A. M., Turshen, I. J., & Ozminkowski, R. J. (2001). Health and productivity management: Establishing key performance measures, benchmarks, and best practices. *Journal of Occupational and Environmental Medicine, 43*(1), 10-17.

Goncalves Filho, A. P., Andrade, J. C. S., & de Oliveira Marinho, M. M. (2010). A safety culture maturity model for petrochemical companies in Brazil. *Safety Science, 48*(5), 615-624.

Greenberg, M. R., Weiner, M. D., Kosson, D., & Powers, C. (2014). Trust in the U.S. Department of Energy: A post-Fukushima rebound. *Energy Research & Social Science, 2,* 145-147.

Greene, V. J. C. (1993). Data analysis strategies for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 15*(2), 195-207.

Grice, J. W., Craig, D. P. A., & Abramson, C. I. (2015). A simple and transparent alternative to repeated measures ANOVA. *SAGE Open, 5*(3), 215824401560419.

Guldenmund, F. W. (2000). The nature of safety culture: A review of theory and research. *Safety Science, 34,* 215-257.

Guldenmund, F. W. (2007). The use of questionnaires in safety culture research – an evaluation. *Safety Science, 45*(6), 723-743.

Guldenmund, F. W. (2017). *Are safety culture assessments really necessary?* Paper presented at the International Conference on Applied Human Factors and Ergonomics, Orlando, FL, USA.

Gunasekaran, S. (2006). *Hazard identification, risk assessment and control* (Bachelor degree dissertation, Technical University of Malaysia, Malacca).

Hahn, S. E., & Murphy, L. R. . (2008). A short scale for measuring safety climate. *Safety Science, 46*(7), 1047-1066.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis* (Vol. 5): Upper Saddle River, NJ: Prentice Hall.

Hämäläinen, P., Takala, J., & Kiat, T. B. (2017). Global estimates of occupational accidents and work-related illnesses 2017. *World, 2017,* 3-4.

Hanafi, W. M. H. B. W. (2007). *Safety assessment in petrochemical industry: A study on planning & procedure in health, safety & environment management system* (Bachelor Degree of Manufacturing, Universiti Teknikal Malaysia Melaka).

Harding, M. I. A. (1995). Human rights, the environment and radioactive waste: A study of the Asian rare earth case in Malaysia. *Review of European Comparative & International Environmental Law, 4*(1).

Hassan, C. R. C., Balasubramaniam, P. A., Raman, A. A. A., Mahmood, N. Z., Hung, F. C., & Sulaiman, N. M. N. (2009). Inclusion of human errors assessment in failure frequency analysis—A case study for the transportation of ammonia by rail in Malaysia. *Process Safety Progress, 28*(1), 60-67.

Health and Safety Executive (2005). A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit. *Research Report 367*.

Health, S. (2015). *Annual report and accounts 2015*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/539602/DH_Annual_Report_Web.pdf

Hee, O. C. (2014). Factors contribute to safety culture in the manufacturing industry in Malaysia. *International Journal of Academic Research in Business and Social Sciences, 4*(4).

Herrera, I., & Hovden, J. (2008). *Leading indicators applied to maintenance in the framework of resilience engineering: A conceptual approach*. Paper presented at The 3rd Resilience Engineering Symposium.

Himanen, R., Julin, A., Jankala, K., Holmberg, J. E., & Virolainen, R. (2012). Risk-informed regulation and safety management of nuclear power plants--on the prevention of severe accidents. *Risk Anal, 32*(11), 1978-1993.

Ho, R. (2006). *Handbook of univariate and multivariate data analysis and interpretation with SPSS*. Abingdon, UK: Taylor & Francis Group.

Hopkins, A. (2011). Risk-management and rule-compliance: Decision-making in hazardous industries. *Safety Science, 49*(2), 110-120.

Hsu, C. C. (2007). The Delphi technique: making sense of consensus. *Practical Assessment, Research & Evaluation, 12*(10), 1-8.

Hsu, S. H., Lee, C. C., Wu, M. C., & Takano, K. (2008). A cross-cultural study of organizational factors on safety: Japanese vs. Taiwanese oil refinery plants. *Accid Anal Prev, 40*(1), 24-34.

Hsu, S. H., Lee, C.-C., Wu, M.-C., & Takano, K. (2010). The influence of organizational factors on safety in Taiwanese high-risk industries. *Journal of Loss Prevention in the Process Industries, 23*(5), 646-653.

Huang, C.-C., Wang, Y.-M., Wu, T.-W., & Wang, P.-A. (2013). An empirical analysis of the antecedents and performance consequences of using the moodle platform. *International Journal of Information and Education Technology,* 217-221.

Huang, Y. H., Ho, M., Smith, G. S., & Chen, P. Y. (2006). Safety climate and self-reported injury: Assessing the mediating role of employee safety control. *Accid Anal Prev, 38*(3), 425-433.

Huang, Y. H., Ho, M., Smith, G. S., & Chen, P. Y. (2006). Safety climate and self-reported injury: assessing the mediating role of employee safety control. *Accid Anal Prev, 38*(3), 425-433.

Huang, Y. H., Leamon, T. B., Courtney, T. K., Chen, P. Y., & DeArmond, S. (2007). Corporate financial decision-makers' perceptions of workplace safety. *Accid Anal Prev, 39*(4), 767-775.

Hudson, P. (2001). *Safety culture-theory and practice*. Leiden Univ (Netherlands) Centre for Safety Science.

Hudson, P. (2003). Applying the lessons of high risk industries to health care. *Qual Saf Health Care 2003*. Retrieved from http://qualitysafety.bmj.com/content/12/suppl_1/i7

Hudson, P. (2007). Implementing a safety culture in a major multi-national. *Safety Science, 45*(6), 697-722.

Hudson, P., Parker, D., Lawton, R., Verschuur, W., Van der Graaf, G., & Kalff, J. (2000). *The hearts and minds project: Creating intrinsic motivation for HSE*. Paper presented at the SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production.

Hui-Nee, A. (2014). Safety culture in Malaysian workplace: An analysis of occupational accidents. *Health and the Environment Journal, 5*(3), 32-43.

Hussein, A. (2015). The use of triangulation in social sciences research: Can qualitative and quantitative methods be combined? *Journal of Comparative Social Work, 4*(1).

IAEA (1991). *Safety culture*. Vienna, Austria: International Atomic Energy Agency.

IAEA (1997). *Examples of safety culture*. Vienna, Austria: International Atomic Energy Agency.

IAEA (1999). *Basic safety principles for nuclear power plants*. Vienna, Austria: International Atomic Energy Agency.

IAEA (2002). *Occupational radiation protection: Protecting workers against exposure to ionizing radiation*. Paper presented at the International Conference, Geneva, IAEA.

IAEA (2002). *Safety culture in nuclear installations*. Vienna, Austria: International Atomic Energy Agency.

IAEA (2011). A framework for an integrated risk informed decision making process. Vienna, Austria: International Atomic Energy Agency.

IAEA (2016a). *IAEA safety standards safety assessment for facilities and activities* (Vol. No. GSR Part 4). Vienna, Austria: International Atomic Energy Agency.

IAEA (2016b). *IAEA safety standards series: Governmental, legal and regulatory framework for safety* (Vol. GSR Part 1 Rev.1). Vienna, Austria: International Atomic Energy Agency.

IAEA (2016c). *Programme and abstract exploring 30 years of safety culture*. Paper presented at the International Conference on Human and Organizational Aspects of Assuring Nuclear Safety Vienna, Austria.

IAEA (2017). *Nuclear technology review 2017*. Paper presented at International Atomic Energy Agency, Vienna, Austria.

International Labour Organization. (2011). ILO Introductory Report: Global Trends and Challenges onOccupational Safety and Health. Retrieved from Geneva:

Isha, A. S. N. (2012). *Occupational health and safety practices in the petrochemical industries of Malaysia* (Doctoral dissertation, University of Nottingham).

Ismail, F., Hashim, A. E., Ismail, R., & Majid, M. Z. A. (2009). The operationalisation of safety culture for the Malaysian construction organisations. *International Journal of Bussiness and Management, 4*(9), 226-237.

Ismail, Z., Doostdar, S., & Harun, Z. (2012). Factors influencing the implementation of a safety management system for construction sites. *Safety Science, 50*(3), 418-423.

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field methods, 18*(1), 3-20. [AS39]

Iyer, P. S., Haight, J. M., Del Castillo, E., Tink, B. W., & Hawkins, P. W. (2004). Intervention effectiveness research: Understanding and optimizing industrial safety programs using leading indicators. *Chemical Health and Safety, 11*(2), 9-19.

Jeon, J. (2015). The strengths and limitations of the statistical modeling of complex social phenomenon: Focusing on SEM, path analysis, or multiple regression models. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 9*(5), 1634-1642.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly, 24*(4), 6012-6611.

Johannessen, J.-A. (1997). Aspects of cusal processes in social system: Discussions of methodology. *Kybernetes, 26*(1), 30-51.

Johansen, I. L., & Rausand, M. (2014). Foundations and choice of risk metrics. *Safety Science, 62,* 386-399.

Joreskog, K. A. S. (1993). *Introduction in testing structural equation models*. Newbury Park, CA: Sage.

Jung, K.-Y., & Roh, M.-S. (2017). A study for an appropriate risk management of new technology deployment in nuclear power plants. *Annals of Nuclear Energy, 99,* 157-164.

Justus N. Agumba, T. H. (2015). Validating and identifying health and safety performance improvement indicators: Experience of using Delphi technique. *Journal of Economics and Behavioral Studies, 7*(3), 14-22.

Justus N., & Agumba, T. H. (2015). Validating and identifying health and safety performance improvement indicators: Experience of using Delphi technique. *Journal of Economics and Behavioral Studies, 7*(3), 14-22.

Kadak, A. C., & Matsuo, T. (2007). The nuclear industry's transition to risk-informed regulation and operation in the United States. *Reliability Engineering & System Safety, 92*(5), 609-618.

Kapp, E. A. (2012). The influence of supervisor leadership practices and perceived group safety climate on employee safety performance. *Safety Science, 50,* 1119-1124.

Karanikas, N., Melis, D. J., & Kourousis, K. I. (2017). The balance between safety and productivity and its relationship with human factors and safety awareness and communication in aircraft manufacturing. *Safety and Health at Work, 9*(3), 239-364.

Kastenberg, W. E. (2015). Ethics, risk, and safety culture: Reflections on Fukushima and beyond. *Journal of Risk Research, 18*(3), 304-316.

Keeney, S., McKenna, H., & Hasson, F. (2010). *The Delphi technique in nursing and health research*. Hoboken, NJ: John Wiley & Sons.

Keller, W., & Modarres, M. (2005). A historical overview of probabilistic risk assessment development and its use in the nuclear power industry: A tribute to the late Professor Norman Carl Rasmussen. *Reliability Engineering & System Safety, 89*(3), 271-285.

Kennedy, R., & Kirwan, B. (1998). Development of a hazard and operability - based method for identifying safety management vulnerabilities in high risk systems. *Safety Science,* 30.

Kenney, T. R. (2016). Women in leadership in the nuclear power industry. *Production Staff*, 56.

Kim, D.-H., Lee, Y.-H., & Lee, J.-W. (2008). Assessment of job stress factors and organizational personality types for procedure-based jobs in nuclear power plants. *Journal of Nuclear Science and Technology, 45*(8), 784-792.

Kim, A. R., Park, J., Kim, J. T., Kim, J., & Seong, P. H. (2016). Study on the identification of main drivers affecting the performance of human operators during low power and shutdown operation. Annals of Nuclear Energy, 92, 447-455. doi:10.1016/j.anucene.2016.02.010

Kitada, A. (2016). Public opinion changes after the Fukushima Daiichi Nuclear Power Plant accident to nuclear power generation as seen in continuous polls over the past 30 years. Journal of Nuclear Science and Technology, 53(11), 1686-1700.

Klinke, A., & Renn, O. (2002). A new approach to risk evaluation and management: Risk-based, precaution-based, and discourse-based strategies. *Risk Analysis, 22*(6), 1071-1094.

Knegtering, B., Pasman, H. J. . (2009). Safety of the process industries in the 21st century: A changing need of process safety management for a changing industry. Journal of Loss Prevention in the Process Industries, 22(2), 162-168. doi:http://dx.doi.org/10.1016/j.jlp.2008.11.005

Kock, N. (2015). Hypothesis testing with confidence intervals and P values in PLS-SEM. *International Journal of e-Collaboration (IJeC), 12*(3), 1-6.

Kouabenan, D. R., Ngueutsa, R., & Mbaye, S. (2015). Safety climate, perceived risk, and involvement in safety management. *Safety Science, 77,* 72-79.

Kovacs, L. R. B. A. P. J. (2013). Writing a mixed methods report in social work research. *Research on Social Work Practice, 23*(3), 354-360.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. Educational and Psychological Measurement, 30, 607-610.

Larcker, C. F. A. D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39-50.

Lee, J., Huang, Y. H., Robertson, M. M., Murphy, L. A., Garabet, A., & Chang, W. R. (2014). External validity of a generic safety climate scale for lone workers across different industries and companies. *Accid Anal Prev, 63,* 138-145.

Lee, T., & Harrison, K. (2000). Assessing safety culture in nuclear power stations. *Safety Science, 34*(1-3), 61-97.

Leech N, O. A. (2008). A typology of mixed methods research designs. *Quality and Quantity, 43*(2), 265-275.

Leveson, N. (2015). A systems approach to risk management through leading safety indicators. *Reliability Engineering & System Safety, 136,* 17-34.

Li, H., Apostolakis, G. E., Gifun, J., VanSchalkwyk, W., Leite, S., & Barber, D. (2009). Ranking the risks from multiple hazards in a small community. *Risk Anal, 29*(3), 438-456.

Li, Q., Ji, C., Yuan, J., & Han, R. (2017). Developing dimensions and key indicators for the safety climate within China's construction teams: A questionnaire survey on construction sites in Nanjing. *Safety Science, 93,* 266-276.

Lin, S.-H., Tang, W.-J., Miao, J.-Y., Wang, Z.-M., & Wang, P.-X. (2008). Safety climate measurement at workplace in China: A validity and reliability assessment. *Safety Science, 46*(7), 1037-1046.

Lingard, L., Albert, M., & Levinson, W. (2008). Grounded theory, mixed methods, and action research. *BMJ, 337*(459-461).

Liu, X., Huang, G., Huang, H., Wang, S., Xiao, Y., & Chen, W. (2015). Safety climate, safety behavior, and worker injuries in the Chinese manufacturing industry. *Safety Science, 78,* 173-178.

MacKenzie, C. A. (2014). Summarizing risk using risk measures and risk indices. *Risk Anal, 34*(12), 2143-2162.

MacKinnon, D. P. (2008). *Introduction to statistical mediation analysis*. New York: Taylor & Francis Group.

Madalina Tronea, C. C. (2014). Nuclear safety culture attributes and lessons to be learned from past accidents. *International Nuclear Safety Journal, 3*(3), 1-7.

Magnuson, L. A. (2012). *A Delphi study to understand relational bonds in supervision and their effect on rehabilitation counselor disclosure in the public rehabilitation program*. Iowa: The University of Iowa.

Malaysia, F. A. R. D. O. (2014). *Annual report 2014*. Putrajaya, Malaysia.

Malaysia, N. (2010). *The impact of nuclear technology to the national socio-economy in Malaysia.* Kuala Lumpur, Malaysia: Malaysian Nuclear Malaysia.

Marín, L. S., Lipscomb, H., Cifuentes, M., & Punnett, L. (2017). Associations between safety climate and safety management practices in the construction industry. *American Journal of Industrial Medicine, 60*(6), 557-568.

Martin, P. G., Connor, D., Payton, O. D., Leal-Olloqui, M., Keatley, A. C., & Scott, T. B. (2018). Development and validation of a high-resolution mapping platform to aid in the public awareness of radiological hazards. *Journal of Radiological Protection, 38*(1), 329.

Martinez-Corcoles, M., Gracia, F. J., Tomas, I., & Peiro, J. M. (2014). Strengthening safety compliance in nuclear power operations: A role-based approach. *Risk Anal, 34*(7), 1257-1269.

Masilamani, R. (2010). Recent development in occupational health services in Malaysia. *Malaysian Journal of Public Health Medicine, 10*(2), 5.

Maxwell, J. A. (2016). Expanding the history and range of mixed methods research. *Journal of Mixed Methods Research, 10*(1), 12-27.

Mbaye, S., & Kouabenan, D. R. (2013). How perceptions of experience-based analysis influence explanations of work accidents. *Journal of Safety Research, 47,* 75-83.

McLinton, S. S., Dollard, M. F., & Tuckey, M. M. (2018). New perspectives on psychosocial safety climate in healthcare: A mixed methods approach. *Safety Science, 109,* 236-245.

McQuaid, J. (2000). The application of risk control concepts and experience to sustainable development. *Process Safety and Environmental Protection, 78*(4), 262-269.

Mearns, K. J., & Flin, R. (1999). Assessing the state of organizational safety-culture or climate? *Current Psychology, 18*(1), 5-17.

Mearns, K., & Yule, S. (2009). The role of national culture in determining safety performance: Challenges for the global oil and gas industry. *Safety Science, 47*(6), 777-785.

Mearns, K., Rundmo, T., Flin, R., Gordon, R., & Fleming, M. (2004). Evaluation of psychosocial and organizational factors in offshore safety: A comparative study. *Journal of Risk Research, 7*(5), 545-561.

Mearns, K., Whitaker, S. M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science, 41*(8), 641-680.

Mely Caballero-Anthony, A. D. B. C., Julius Cesar I. Trajano, Margareth Sembiring. (2014). The Sustainability of Nuclear Energy in Southeast Asia: Opportunities and Challenges. Retrieved from Singapore:

Mohammad, M., Mann, R.,Grigg, N., & Wagner, J. P. (2010). The right improvement initiative for the right situation: A contextual and systems approach. Paper presented at the Computers and Industrial Engineering (CIE), 2010 40th International Conference on.

Morrow, S. L.,Kenneth Koves, G., & Barnes, V. E. (2014). Exploring the relationship between safety culture and safety performance in U.S. nuclear power operations. *Safety Science, 69,* 37-47.

Morse, J. M. (2016). *Mixed method design: Principles and procedures*. Abingdon, UK: Routledge.

Musa, H. D., Yacob, M. R., Abdullah, A. M., & Ishak, M. Y. (2015). Delphi method of developing environmental well-being indicators for the evaluation of urban sustainability in Malaysia. *Procedia Environmental Sciences, 30,* 244-249.

Nagai, Y., & Hayashi, C. (2000). Structure and intensity of public attitudes toward nuclear power generation. *Journal of Nuclear Science and Technology, 37*(9), 729-739.

NAIIC (2012). *The official report of The Fukushima Nuclear Accident Independent Investigation Commission*. Retrieved from https://www.nirs.org/wp-content/uploads/fukushima/naiic_report.pdf

Ndegwa, P. W., Guyo, W., Orwa, G., Ng'ang'a, R., & Murigi, E. M. (2014). Legal framework as a determinant of implementation of occupational health and safety programmes in the manufacturing sector in Kenya. *International Journal of Human Resource Studies, 4*(4), 21.

Neal, A., & Griffin, M.A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology, 91*, 946-953.

Nesheim, T., & Gressgård, L. J. (2014). Knowledge sharing in a complex organization: Antecedents and safety effects. *Safety Science, 62,* 28-36.

Nicol, J. (2001). *Have Australias major hazard facilities learnt from the Longford disaster?: An evaluation of the impact of the 1998 Esso Longford explosion on major hazard facilities in 2001*. Barton, A.C.T.: Institution of Engineers, Australia.

Nunnally, J. C. (1978). *Psychometric theory* (2nd edition). New York: McGraw-Hill.

Oliver, A., Cheyne, A., Tomás, J. M., & Cox, S. (2002). The effects of organizational and individual factors on occupational accidents. *Journal of Occupational and Organizational Psychology, 75*(4), 473-488.

Organisation, S. S. (2013). *Social Security Organisation Malaysia annual report 2013*. Kuala Lumpur: PERKESO.

Organisation, S. S. (2016). *Social Security Organisation Malaysia annual report 2016*. Kuala Lumpur: PERKESO.

Organization, I. L. (2018). Improving the Safety and Health of Young Workers. Retrieved from Geneva:

Parker, D., Lawrie, M., & Hudson, P. (2006). A framework for understanding the development of organisational safety culture. *Safety Science, 44*(6), 551-562.

Pate-Cornell, M. E. (1993). Learning from the piper alpha accident: A postmortem analysis of technical and organizational factors. *Risk Analysis, 13*(2), 215-232.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research, 34*(5 Pt 2), 1189.

Plonsky, B. (2015). Non-Destructive Testing Helps Malaysia's Competitiveness. International Atomic Energy Agency.

PEMANDU. (2010). Powering the Malaysian Economy with Oil, Gas and Energy Economic Transformation Programme: A Roadmap For Malaysia, Kuala Lumpur.

Ramli, A. H. (2014). *Relationships between safety climate factors and occupational safety and health level of awareness in Malaysia government agencies* (Doctoral dissertation, University of Malaya, Kuala Lumpur).

Rashid, R. F. B. A. (2012). *The influence of safety culture on safety performance: A case of Perodua* (Doctoral dissertation, Universiti Utara Malaysia, Kedah, Malaysia).

Raziq, A., & Maulabakhsh, R. (2015). Impact of working environment on job satisfaction. *Procedia Economics and Finance, 23,* 717-725.

Reiman, T., & Oedewald, P. (2007). Assessment of complex sociotechnical systems – Theoretical issues concerning the use of organizational culture and organizational core task concepts. *Safety Science, 45*(7), 745-768.

Reiman, T., & Pietikäinen, E. (2010). *Indicators of safety culture-selection and utilization of leading safety performance indicators* (No. SSM--2010-07). Swedish Radiation Safety Authority.

Reiman, T., & Pietikäinen, E. (2012). Leading indicators of system safety–monitoring and driving the organizational safety potential. *Safety Science, 50*(10), 1993-2000.

Rodrigues, M. A., Arezes, P., & Leão, C. P. (2015). Safety climate and its relationship with furniture companies' safety performance and workers' risk acceptance. *Theoretical Issues in Ergonomics Science, 16*(4), 412-428.

Rollenhagen, C., Westerlund, J., & Näswall, K. (2013). Professional subcultures in nuclear power plants. *Safety Science, 59,* 78-85.

Rundmo, T. (2000). Safety climate, attitudes and risk perception in Norsk Hydro. *Safety Science, 34*(1-3), 47-59.

Rundmo, T., & Hale, A. R. (2003). Managers' attitudes towards safety and accident prevention. *Safety Science, 41*(7), 557-574.

Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods, 15*(1), 85-109.

Saji, G. (2003). Safety goals in 'risk-informed, performance-based' regulation. *Reliability Engineering & System Safety, 80*(2), 163-172.

Salant, P., & Dillman, D. A. (1994). *How to conduct your own survey.* New York: John Wiley and Sons.

Salleh, A. (2010). *Safety behaviour in the Malaysia petrochemical industry* (Doctoral dissertation, University Utara Malaysia, Malaysia).

Sangau, K. J. K. (2012). *Understanding The determinants of industrial radiographer compliance with safety behaviour in Malaysia* (Master dissertation, University Utara Malaysia, Kedah, Malaysia).

Saunders, L. W., Kleiner, B. M., McCoy, A. P., Ellis, K. P., Smith-Jackson, T., & Wernz, C. (2017). Developing an inter-organizational safety climate instrument for the construction industry. *Safety Science, 98,* 17-24.

Scott, N., Fleming, M., & Kelloway, E. K. (2014). 17 understanding why employees behave safely from determination theory perspective. *The Oxford Handbook of Work Engagement, Motivation, and Self-Determination Theory,* 276.

Shaluf, I. M., & Ahmadun, F. L. R. (2006). Major hazard control: the Malaysian experience. *Disaster Prevention and Management: An International Journal, 12*(5), 420-427.

Shea, T., De Cieri, H., Donohue, R., Cooper, B., & Sheehan, C. (2016). Leading indicators of occupational health and safety: An employee and workplace level validation study. *Safety Science, 85,* 293-304.

Shipping, A. B. O. (2012). *Safety culture and leading indicators of safety*. Houston, USA.

Silverman, D. (2006). *Interpreting qualitative data: Methods for analyzing talk, text and interaction.* New York: SAGE Publications.

Singh, V., Rana, R. K., & Singhal, R. (2013). Analysis of repeated measurement data in the clinical trials. *J Ayurveda Integr Med, 4*(2), 77-81.

Singh, Y. K. (2006). *Fundamental of research methodology and statistics*. New Delhi: New Age International (P) Ltd.

Slovic, P., Peters, E., Finucane, M. L., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health Psychology, 24*(4, Suppl), S35-S40.

Smibert, D., & Fleming, M. (2017). *Is it me or is it you? Assessing the influence of individual and organizational factors on safety performance in the North American railway industry advances in human aspects of transportation* (pp. 45-55). Berlin: Springer.

Smith, G. S., Huang, Y. H., Ho, M., & Chen, P. Y. (2006). The relationship between safety climate and injury rates across industries: the need to adjust for injury hazards. *Accid Anal Prev, 38*(3), 556-562.

Social Security Organisation, S. (2014). *Annual report 2013.* Retrieved from www.perkeso.gov.my

Society, A. C. (2015). *Identifying and evaluating hazards in research laboratories*. United States of America.

Sorenson, J. N. (2002). Safety culture: A state of the art. *Reliability Engineering & System Safety, 76,* 189-204.

Soysa, I. B., Jayamaha,N. P., & Grigg, N. P. (2018). Developing a strategic performance scoring system for healthcare nonprofit organisations Benchmarking: An International Journal (just-accepted), 00-00.

Soysa, I. B., Jayamaha,N. P., & Grigg, N. P. (2016). Operationalising performance measurement dimensions for the Australasian nonprofit healthcare sector. The TQM Journal, 28(6), 954-973.

Srinivasan, R., & Natarajan, S. (2012). Developments in inherent safety: A review of the progress during 2001–2011 and opportunities ahead. *Process Safety and Environmental Protection, 90*(5), 389-403.

Srinivasan, T. N., & Gopi Rethinaraj, T. S. (2013). Fukushima and thereafter: Reassessment of risks of nuclear power. *Energy Policy, 52,* 726-736.

Stake, R. E. (2013). *Multiple case study analysis*. New York: Guilford Press.

Sukadarin, E. H., Suhaimi, N. S., & Abdull, N. (2012). Preliminary study of the safety culture in a manufacturing industry. *International Journal of Humanities and Social Science, 2*(4), 176-183.

Swan, J. (1997). Using cognitive mapping in management research: Decisions about technical innovation. *British Journal of Management, 8*(2), 183-198.

Swedler, D. I., Verma, S. K., Huang, Y. H., Lombardi, D. A., Chang, W. R., Brennan, M., & Courtney, T. K. (2015). A structural equation modelling approach examining the pathways between safety climate, behaviour performance and workplace slipping. *Occup Environ Med, 72*(7), 476-481. doi:10.1136/oemed-2014-102496

Tabachnick, B. G., & Fidell, L. S. (1996). *Using multivariate statistics* (3rd edition). New York: Harper Collins.

Taber, K. S. (2017). The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Research in Science Education,* 1-24.

Tang, D. K. H., Leiliabadi, F., Olugu, E. U., & Md Dawal, S. Z. B. (2017). Factors affecting safety of processes in the Malaysian oil and gas industry. *Safety Science, 92,* 44-52.

Thomas, G. (2015). *How to do your case study*. New York: SAGE Publications.

Tobi, S. U. M. (2016). *Qualitative research, interview analysis & NVIVO 11 exploration*. Kuala Lumpur, Malaysia: ARAS Publisher.

Tomás, J. M., Cheyne, A., & Oliver, A. (2011). The relationship between safety attitudes and occupational accidents: The role of safety climate. *European Psychologist, 16*(3), 209.

Tomás, J., Cheyne, A., & Oliver, A. (2011). The relationship between safety attitudes and occupational accidents. *European Psychologist, 16*(3), 209.

Tong, D. Y. K., Rasiah, D., Tong, X. F., & Lai, K. P. (2015). Leadership empowerment behaviour on safety officer and safety teamwork in manufacturing industry. *Safety Science, 72,* 190-198.

Torabi, K., Karimi, B., Parmar, R., Oliverio, M., & Dinnie, K. (2006). Quantitative risk assessment for process design modification and maintenance optimization in refineries and petrochemical plants. *The Canadian Journal of Chemical Engineering, 84*(6), 722-728.

Tronea, M. C., C. (2014). Nuclear Safety Culture Attributes And Lessons To Be Learned From Past Accidents International Nuclear Safety Journal, 3(3), 1-7.

Tsujikawa, N., Tsuchida, S., & Shiotani, T. (2016). Changes in the factors influencing public acceptance of nuclear power generation in Japan since the 2011 Fukushima Daiichi nuclear disaster. *Risk Anal, 36*(1), 98-113.

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & Health Sciences, 15*(3), 398-405.

Van Griethuijsen, R. A. L. F., van Eijck, M. W., Haste, H., den Brok, P. J., Skinner, N. C., Mansour, N., … & BouJaoude, S. (2014). Global patterns in students' views of science and interest in science. *Research in Science Education, 45*(4), 581-603.

Vantamay, N. (2015). Using the delphi technique to develop effectiveness indicators for social marketing communication to reduce health-risk behaviors among youth. *Southeast Asian J Trop Med Public Health, 46*(5), 949-957.

Varonen, U., & Mattila, M. (2000). The safety climate and its relationship to safety practices, safety of the work environment and occupational accidents in eight wood-processing companies. *Accident Analysis & Prevention, 32*(6), 761-769.

Vinodkumar, M. N., & Bhasi, M. (2009). Safety climate factors and its relationship with accidents and personal attributes in the chemical industry. *Safety Science, 47*(5), 659-667.

Wachter, J. K., & Yorio, P. L. (2014). A system of safety management practices and worker engagement for reducing and preventing accidents: An empirical and theoretical investigation. *Accid Anal Prev, 68,* 117-130.

Wahlström, B., & Rollenhagen, C. (2014). Safety management – A multi-level control problem. *Safety Science, 69,* 3-17.

Wakeford, R. (2016). Chernobyl and Fukushima - Where are we now? *Journal of Radiological Protection, 36*(2), E1.

Weightman, D. (2017). *Organizational safety perception survey*. Minnesota, USA.

Westrum, R. (1993). Cultures with requisite imagination. In V. D. Wise, & P. Stager (Ed.), *Verification and validation of complex systems: Human factors issues* (pp. 401-416). New York: Springer-Verlag.

Westrum, R. (2004). A typology of organisational cultures. *Quality and Safety in Healthcare, 13*(Suppl. II), ii22–ii27.

Wheatley, S., Sovacool, B. K., & Sornette, D. (2016). Reassessing the safety of nuclear power. *Energy Research & Social Science, 15,* 96-100.

Whitton, J., Parry, I. M., Akiyoshi, M., & Lawless, W. (2015). Conceptualizing a social sustainability framework for energy infrastructure decisions. *Energy Research & Social Science, 8,* 127-138.

World Energy Council, W. (2012). *World energy perspective: Nuclear energy one year after Fukushima*. United Kingdom: World Energy Council.

Xia, N., Wang, X., Griffin, M. A., Wu, C., & Liu, B. (2017). Do we see how they perceive risk? An integrated analysis of risk perception and its effect on workplace safety behavior. *Accident Analysis & Prevention, 106,* 234-242.

Yang, J.-E. (2014). Fukushima Dai-Ichi accident: Lessons learned and future actions from the risk perspectives. *Nuclear Engineering and Technology, 46*(1), 27-38.

Zhang, W., Huang, Y. H., Roetting, M., Wang, Y., & Wei, H. (2006). Driver's views and behaviors about safety in China - What do they not know about driving? *Accid Anal Prev, 38*(1), 22-27.

Zhou, Q., Fang, D., & Wang, X. (2008). A method to identify strategies for the improvement of human safety behavior by considering safety climate and personal experience. *Safety Science, 46*(10), 1406-1419.

Zikmund, W. G. (2003). *Business research methods*. Mason, US: Thomson/South-Western.

Zio, E. (2009). Reliability engineering: Old problems and new challenges. *Reliability Engineering & System Safety, 94*(2), 125-141.

Zio, E and Pedroni, N.(2012). Risk-informed decision-making processes: An overview. France: Foundation for an Industrial Safety Culture.

Zohar, D. (2000). A group-level model of safety climate: Testing the effect of group climate on micro accidents in manufacturing jobs. Journal of Applied Psychology, 85(4), 587.

Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accid Anal Prev, 42*(5), 1517-1522.

Zohar, D., & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behavior: A cross-level intervention model. *Journal of Safety Research, 34*(5), 567-577.

Zohar, D., & Luria, G. (2004). Climate as a social-cognitive construction of supervisory safety practices: Scripts as proxy of behavior patterns. *Journal of Applied Psychology, 89*(2), 322.

Zohar, D., Huang, Y. H., Lee, J., & Robertson, M. (2014). A mediation model linking dispatcher leadership and work ownership with safety climate as predictors of truck driver safety performance. *Accid Anal Prev, 62,* 17-25.