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The study of process health and safety management deficiencies relative to hazardous chemical exposure

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Declaration by Supervisor

As the candidate's Supervisor I agree/do not agree to the submission of this thesis.

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Publication 1

Mr J.X. Nyawera and Prof T.C. Haupt, Process Health and Safety Management Elements: An initial review of literature - The 12^{th} Built Environment Conference, Durban. August 6-7, 2018.

Contribution: J.X Nyawera - Research and Writing; Prof. TC. Haupt - Supervision.

Publication 2

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Contribution: J.X Nyawera - Research and Writing; Prof. TC. Haupt - Supervision.

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James Xolani Nyawera

Dedication

This thesis is dedicated to my late Son, **Bayanda Nyawera** “Mr President”. This thesis is in Honour of you, with all my love.

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List of Abbreviation

ANOVA	Analysis of Variance
AGFI	Adjusted Goodness-of-Fit Index
AVE	Average Variance Extracted
CB-SEM	Covariant Based Structural Equation Modelling
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
COPD	Chronic Obstructive Pulmonary Disease
CR	Composite Reliability
DoL	Department of Labour
EFA	Exploratory Factor Analysis
FMEA	Failure Mode and Effect Analysis
FRMS	Fatigue Risk Management System
GFI	Goodness-of-Fit Index
HAZID	Hazard Identification
HAZOP	Hazard and Operability
IFI	Incremental Fit Index
ILO	International Labour Organisation
JSA	Job Safety Analysis
LC_{50}	Lethal Concentration 50
LD_{50}	Lethal Dose 50

LOPA	Layer of Protection Analysis
LPG	Liquefied Petroleum Gas
NFI	Normed Fit Index
OSHAct	Occupational Health and Safety Act 85 of 1993
PCA	Principal Component Analysis
PCFI	Parsimony Adjusted Comparative Fit Index
PLS-SEM	Partial Least Squares Structural Equation Modelling
PNFI	Parsimony Adjusted Normed Fit Index
PVC	Polyvinyl Chloride
RFI	Relative Fit Index
RMSEA	Random Measures of Sample Error Approximation
SEM	Structural Equation Model
SIL	Safety Integrity Level
SPSS	Statistical Package for the Social Sciences
Std. Dev	Standard Deviation
S.E	Standard Error
STEL	Short Term Exposure Limit
TLI	Tucker Lewis Index
TLV	Threshold Limit Value
USA	United States of America
WHO	World Health Organisation
VCM	Vinyl Chloride Monomer

ABSTRACT

The main objectives of this study were to identify the main process health and safety management deficiencies that require senior management's attention. To identify the critical drivers that could be used to improve health and safety to reach generative process health and safety culture level five and to develop a model of effectively managing hazardous chemical substance exposure in the petrochemical industry.

Ethical clearance to conduct the study was obtained from the University of KwaZulu - Natal Humanities and Social Sciences Research Ethics Committee (HSS/1094/018D). The targeted population was 800 employees in one major petrochemical enterprise in the KwaZulu-Natal province of South Africa. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants of which 259 were returned duly completed and used. The returned questionnaires were statistically analysed using descriptive statistics in SPSS version 25.

The research was planned to first explore the concepts by qualitative research methods, such as in depth literature review. The quantitative data collection and analysis is based on a quantitative research method involving questionnaire survey and statistical data analysis methods. The validation of the findings and related conclusions rely on the results from both qualitative and quantitative research methods. The mixed method was considered the best option for this study as it assisted to leverage the advantages of both quantitative and qualitative research methods in achieving the research objectives.

The key process health and safety management deficiencies to be prioritized are, namely, poor engineering design integrity, poor controls when working with suspended loads, poor controls when working at heights, poor housekeeping, poor controls of source of ignition, verifying energy isolation before starting to work on equipment, poor health and safety risk assessments, handling of hazardous chemicals, human error and fatigue management. The key process health and safety drivers to be prioritized for generative process health and safety culture are, leadership commitment, chemical exposure management, health and safety risk assessment, process hazard analysis and permit to work. The developed generative process health and safety culture model was subjected to rigorous measurement analysis using structural equation modelling, namely, principal component analysis, goodness-of-fit measure, assessment of normality, discriminant validity, multicollinearity, model adequacy, reliability and validity.

This study will assist senior management with a framework to reduce process health and safety incidents in the petrochemical industry and improve health and safety towards generative culture where organisations say, “Health and safety is the way we do business”.

Key words: Process Health and Safety Management Deficiencies.

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CHAPTER ONE

Introduction

1.1 Introduction

The world's oil and gas resources provide some of the richest, solidest, and valuable energy sources available (Kim, 2016). The petrochemical industry as the name implies is based upon the production of chemicals from petroleum such as natural gas and crude oil (Hughes & Ferret, 2007). According to Eyayo (2014) the importance of occupational health and safety is often overlooked and people tend to equate occupational illness with industrialisation and huge factories in urban areas. World Health Organisation's programme on workers' health is concerned with the control of occupational health and safety risks, the protection and promotion of the working populations and humanization of work.

The occupational health and safety plays a central role in industry as it protects all workers from health and safety related issues in their working environment (Hughes & Ferret, 2007). The workers in the oil and gas industry are exposed to a lot of hazards such as, physical hazards, chemical hazards, ergonomic hazards, psychosocial hazards and radiological hazards (Kim, 2016). According to Vitharana *et al.* (2015) health hazards are properties of a chemical that have the potential to cause adverse health effects and exposure usually occurs through inhalation, skin contact or ingestion.

It is vital to protect workers from injuries on a social level, but there is also a positive economic impact in reducing health and safety hazards (Hughes & Ferret, 2007). According to Eyayo (2014) globally, there are 2.9 billion workers who are exposed to hazardous risks at their work place. Annually there are two million deaths that are attributable to occupational diseases and injuries while 4% of gross domestic product is lost due to occupational diseases and injuries. Health and safety is without doubt, the most crucial investment and the question is not what it costs, but what it saves (Hughes & Ferret, 2007).

Chronic unease starts with openness, where bad news is welcomed and incidents are treated as an opportunity to learn (Flin, 2015). Measures and strategies designed to prevent, control, reduce or eliminate occupational hazards and risks have been developed and applied continuously over the years to keep pace with technological and economic changes (Eyayo, 2014). Material substances, processes or circumstances which pose threat to health and well-being of workers in any occupation are termed as occupational hazards (Kulkarni, 2017).

A hazard is a potential source of harm or an adverse health effect on a person or persons. "Hazard" and "Risk" are often used interchangeably (Vitharana *et al.*, 2015). Chronic unease is a pre-occupation with failure, it is about resetting tolerance to risk and understanding that small failures are signs that something needs to be corrected (Flin, 2015). According to Elssayed *et al.* (2012) management actions related to health and safety should be adequate and be prioritised to improve health and safety quality efficiently. HAZOP study provide a safe system of work during inspection and maintenance operation especially in boilers (Karthika, 2013).

Developing and implementing safe work practices provide for the control of hazards during operations such as lockout/tagout; confined space entry; opening process equipment or piping; and control over entrance into a facility by maintenance, contractor, laboratory, or other support personnel. These safe work practices shall apply to employees as well as contractor employees (Hardy, 2013). According to Stojkovic' (2013) entry into hazardous confined spaces, especially the performance in such area poses a major threat to the health and lives of people so in many technically developing countries operating in such areas is subject to previous approval of the competent authority.

It is vital that potential ignition sources are identified, and there is feedback from operational experience back into hazard assessment process to identify changes and deviations from original expectations (Puttick, 2008). Avoidance of ignition sources can then appear to be an attractive option, but it has limitations and can be a useful and reliable basis of safety in certain circumstances provided that it is restricted to the inside of chemical plants, and certain well defined charging and discharging areas (Puttick, 2008).

1.2 Petrochemical Industry Hazards

Petrochemical industries play a crucial role in various manufacturing sectors. However, potential hazards associated with these industries have raised increased concern for societies (Sharma *et al.*, 2017). According to a six-year fatal occupational injuries census conducted by the US Bureau of Labour Statistics, workers in the oil and gas industry from the Gulf countries could be up to seven times more likely to be fatally injured than workers in other industry sectors. Petrochemical industry release large quantities of toxic and deleterious substances as effluents into the atmosphere and generates solid waste that is difficult both to treat and to dispose of (Sharma *et al.*, 2017).

Typical acute health effects include headaches, nausea or vomiting and skin corrosion, while chronic health effects include asthma, dermatitis, nerve damage or cancer. A person conducting business has the primary duty to ensure, as far as is reasonably practicable, that the health and safety of workers and other persons is not put at risk from work carried out (Vitharana *et al.*, 2015). It is essential to develop control and preventive measures which are to be taken at the planning stages in these industries (Sharma *et al.*, 2017). The employers should ensure the safe use, handling and storage of hazardous substances (Vitharana *et al.*, 2015).

According to Hughes *et al.* (2007) cited in Dabup (2012) the general duties of employers as stipulated in the British health and safety work Act, include the following;

- Ensuring the health, safety and welfare of employees of all categories in the workplace including, service providers and temporary employees.
- Ensuring the health, safety and welfare of all visitors to the workplace.
- Ensuring the health, safety and welfare of all persons permitted to use the organisation's equipment.
- Ensuring the health, safety and welfare of those affected directly or indirectly by the work activity, such as host communities and the general public.
- Ensure the provision of a safe environment for workers, the general public and communities where projects are executed.

Dangerous chemicals are often used and handled in workplaces. The risk of injury or ill health upon exposure to the hazards of the chemicals at work depends on whether there are adequate safety measures in place (International Labour Organisation, 2017). The emissions of harmful substances from the petrochemical industries has reduced significantly in last few years because of using environmental developments along with an increased awareness about the health and safety aspects of plant operations (Sharma *et al.*, 2017). According to Vitharana *et al.* (2015) adverse health effects can be acute (short term) or chronic (long term). According to OSHAcademy (2017) unexpected releases of toxic, reactive, or flammable liquids and gases in process involving highly hazardous chemicals have been reported for many years.

According to Almanssoor (2008) toxicology data are available for most chemicals and the most commonly used in the industry are LC_{50}, LD_{50}, TLV and STEL. Their definitions are, namely;

- LC_{50} median lethal concentration 50: calculated concentration of a chemical in air exposure, which can cause the death of 50% of experimental animals in a specified period of time.
- LD_{50} median lethal dose 50; calculated dose of a chemical that is expected to cause the death of 50% of experimental animals when administered by any route other than inhalation.
- TLV threshold limit value: concentration of a substance in the air to which workers can be exposed without adverse effect.

- STEL short term exposure limit: is the maximum permissible concentration of a material, generally expressed in ppm in air, for a defined short period of time (typically 5 or 15 minutes, depending upon the country). This concentration is generally a time-weighted average over the period of exposure.

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) the following questions should be used to identify potential harmful worker chemical exposure hazards, namely;

- Have all potentially hazardous products that may be used, handled, or stored at the work site been identified?
- Are all material safety data sheets current, available, and readily accessible to all on site workers?
- What effect will the work operations have on the chemicals used, handled, or stored?
- How may a worker be potentially exposed to chemical hazards?
- Are written work procedures for the operation available to minimise worker exposure to chemicals?
- Have the workers involved in the operation been given the appropriate level of training in the work procedures and controls in place?
- Is all equipment readily available and in good operating conditions?
- Have all workers been properly trained in the selection and correct care, use and maintenance of the PPE required?
- Are all workers sufficiently trained in the hazards to which they may be exposed and how to recognize them?

According to Eyayo (2014) health and safety professionals, working with process, chemical, instrumentation, and metallurgical engineers assure that potential physical, mechanical and chemical. Health hazards are recognised and provisions are made for safe operating practices and appropriate protection measures. One of the major needs with regard to the construction industry is to enhance professional's interest in active safety management and implementation of awareness programs. These must be developed and implemented among construction workers (International Labour Organisation, 2017).

1.3 Health and Safety Culture

According to Hardy (2013) the most important indicator of a positive health and safety culture is the extent to which employees are actively involved in health and safety on a daily basis. An organisation that has a good health and safety culture consist of a strong senior management commitment, leadership and involvement in health and safety. Better communications between all organisational levels. Greater hazard control, good induction and follow up on health and safety training as well as ongoing health and safety schemes reinforcing the importance of health and safety, including near miss reporting (Bond, 2007).

If there is very little involvement of senior management with health and safety and a solely depend upon line management and safety representatives to be involved, the organisation fails to win people over to the health and safety effort. Therefore the organisation will not have a very good health and safety culture (Hardy, 2013). Health and Safety culture combines the whole approach of reporting health and safety matters, monitoring equipment and procedures into a health and safety management system which becomes a coherent structure that becomes acceptable and comprehensible to the employees and hence to the public (Bond, 2007).

Occupational accidents can be reduced through effective preventative measures by investing on health and safety equipment, training and educating the employees, process design and machinery and in order to develop a good health and safety culture, attitude of the workers needs to be reoriented by applying best practices, good housekeeping, change in work culture, and work practices (Beriha *et al.*, 2012).

To achieve a total health and safety culture, where employees feel as strong a sense of responsibility for the health and safety of their co-workers as they do for themselves, it is necessary to increase the openness and frequency of health and safety communication (Holstvoogd *et al.*, 2006). Potential hazards are identified based on the knowledge of operations and past experience with similar work tasks and this usually involves brainstorming – type sessions among team members having familiarity with operational activities (Campbell, 2008).

According to McKenzie (2007) organisations with positive health and safety culture learn from previous incidents and safety deficiencies and encourage reporting of health and safety concerns, issues, and problems by all levels of staff and take visible and concrete actions to remedy the issues. Human behaviour is a major contributor to occupational safety. Health and safety issues cannot be tackled effectively without interference of employers with a particular pattern of behaviour as important criteria needed to change employee’s behaviours (Zin, 2012).

1.4 Management Systems

The management systems control the interaction of people with each other and with processes. They are the high-level procedure used to control major activities such as, conducting process hazard analysis, management of change, writing operating procedures, training employees, evaluating fitness for duty, and conducting incident investigations (Bridges and Tew, 2010).

Process health and safety management systems are a proactive management and engineering approach to control risk of failures and chance of human error, however incidents still happen, people get injured, assets get damaged and environment is polluted (Eyayo, 2014). If management systems are weak, then layers of protection will fail and accidents will happen (Bridges and Tew, 2010).

Typical concerns that cause industry incidents are rule breaking, incorrect risk assessments, supervisors who are technically competent but short on personal management skills, ineffective contract management in health and safety (Holstvoogd *et al.*, 2006). Regardless of the industry that uses the highly hazardous chemicals, there is potential for an accidental release any time of hazardous chemicals if they are not properly controlled and this, in turn, creates the possibility of disaster (OSHAcademy, 2017).

According to Bridges and Tew (2010) the process related activities where errors have the most influence include designing of a process, engineering of a process, specifying the process components, receiving and installing equipment, commissioning the process equipment, operating safeguards necessary to control the risk at acceptable level and sustaining these safeguards for the life of the process, troubleshooting and shutting down the process equipment and managing process changes.

According to Thomas and Babu (2014) the key safety management systems are, namely;

- Management commitment to safety – because the attitudes and actions of management can significantly influence the entire staff, it is therefore critical that these leaders commit to the success of a safety management system implementation.
- Proactive identification of hazards – early identification and reporting of hazards can save a significant amount of time and resources down the road.
- Actions taken to manage risks – a system must be in place to determine logical approaches to counteract known risks to safe operation.
- Evaluation of safety actions – an ongoing evaluation of the impacts of risk management actions is necessary to determine if further remedial activities are required.

According to Okoye *et al.* (2016) health and safety knowledge and compliance alone are not enough to cause behavioural changes required for safety performance but a certain aspects of health and safety culture are required, there are:

- Enforceable regulatory framework
- Management commitment
- Workers involvement.

1.5 Employers Accountability

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) employers are responsible for ensuring the health and safety of employees at the work site under occupational health and safety legislation and an employer may be a contractor, lease owner, licensee, or owner's representative. According to Okoye *et al.* (2016) a vital element in health and safety management system is visible health and safety commitment from leadership and managers. Perceptions of the commitment of leadership towards health and safety rather than just the intentions have a strong bearing on the actual behaviours and performance of the people in the organisation (Holstvoogd *et al.*, 2006).

According to Bond (2007) the health and safety policy encompasses leadership, management systems, competence, responsibility and communication. Achieving health and safety excellence requires going beyond the traditional health and safety focus of engineering and regulations (Holstvoogd *et al.*, 2006). Management commitment provides the motivation force and resources for health and safety activities within the organisation and creating an environment of continuous improvement belongs to all levels of management (Okoye *et al.*, 2016).

When people fail and accidents happen, it is usually because they are working in a flawed system. Blaming a person is a simple, expedient method of removing blame from the organisation and hence hides the latent flaw in the system (Bond, 2007). Human behaviour is a contribution cause to most incidents and injuries, health and safety excellence can only be achieved by addressing the human dimensions of health and safety (Holstvoogd *et al.*, 2006).

Most of accidental losses except for natural disasters begin with a human error (Flin, 2015). For organisations to have the improved health and safety, the petrochemical industry has had to look at near misses and investigate them to get the root cause (Bond, 2007).

To prevent injuries, hazard recognition methods are introduced to identify workplace hazards and mitigate risk associated with these hazards through the use of procedural or physical controls (Campbell, 2008). According to Albert, Hallowell and Kleiner (2014) occupational safety has gained considerable attention following the OSHAct, which shifted substantial health and safety responsibility to employers. According to the regulations, employers are to provide workers with a workplace free from any recognised hazards (Campbell, 2008). There are specific requirements of employers, depending on the hazards and the work to be done (Safety Association for Canada upstream Oil and Gas Industry, 2012).

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) employers are responsible for the following,

- Identifying and assessing workplace hazards.
- Developing and implementing safe work and emergency procedures and controls
- Ensuring that workers and supervisors are adequately instructed and trained.
- Immediately investigating incidents, complete root cause analysis and close all corrective action items.
- Ensuring controls e.g. personal protective equipment are used and, in some cases, provided.
- Ensuring competent supervision as specified by local legislation.

Health and safety issues cannot be tackled effectively without interference of employers with a particular pattern of behaviours as important criteria needed to change employee's behaviours (Zin, 2012).

1.6 Problem Statement Discussion

The human, social and economic costs of occupational accidents, injuries, diseases and major industrial disasters have long been cause for concern at all levels from the individual workplace to the national and international (Eyayo, 2014). Workers are usually exposed to risk either because of their lack of knowledge about workplace hazards due to limited experience and knowledge or failure to behave safely, which may be associated with the workers' attitude toward health and safety or the underestimation of perceived risk (Vitharana *et al.*, 2015). Incidents continue to occur in various industries that use highly hazardous chemicals which may be toxic, reactive, flammable and explosive or may exhibit a combination of these properties (OSHAcademy, 2017).

Risk analysis remains an important tool in safety management for prioritizing actions and plans, in order to commit top health and safety management systems, training courses need to be further emphasised and improved to ensure better health and safety culture, performance and involvement of all workers in top health and safety management of the company (Elssayed *et al.*, 2012).

There are many process incidents that take place in petrochemical industry, BP Texas City incident is one of them. According to Broadribb (2007) the incident was an explosion caused by heavier – than air hydrocarbon vapours combusting after coming into contact with an ignition source, probably a running vehicle engine. The hydrocarbons originated from liquid overflow from the blowdown stack following the operation of the Raffinate Splitter overpressure protection system caused by overfilling and overheating of the tower contents. The failure to institute liquid rundown from the tower, and the failure to take effective emergency action, resulted in the loss of containment that preceded the explosion. Supervisors assigned to the unit were not present to ensure conformance with established procedures, which had become custom and practice on what was viewed as a routine operation.

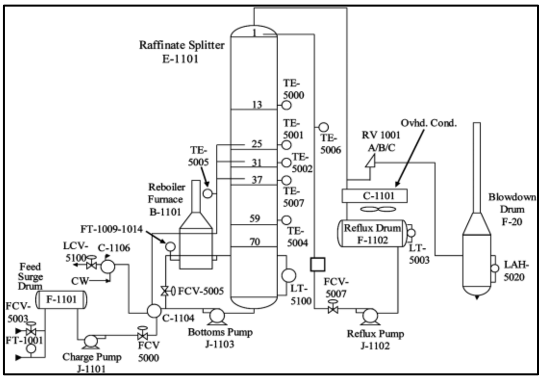

Figure 1.1 Blowdown Drum and Isomerisation Unit after Incident

According to Broadribb (2007) March 23, 2005 explosion happened and huge fire, 15 deaths and 180 injuries. This incident took place during start-up, tower and blowdown drum overfilled. Liquid hydrocarbon released, vapour cloud was formed and ignited. The three initiating conditions in this incident were, namely;

- The overfilling of the distillation tower.
- The use of blow down drum and stack that is open to the atmosphere.
- The placement of the contractor work trailers adjacent to high hazard process units.

The root cause was reported to be the following,

- Human error, numerous underlying conditions influenced operator's decision-making and actions. Lack of shift communication policy or emphasis on communication.
- The start-up procedure required the tower level control valve be open and the tower be filled within the range of the level transmitter. However, the board operator closed the tower level control valve and filled the tower above the amount specified in the procedures. In a majority of the start-up the tower was filled above the range of the level transmitter. Tower ran with high level to protect equipment and none of these start-up was considered abnormal or investigated to correct problems. Management did not revise out-dated procedures.
- Communication was ineffective between operations personnel, instructions for routing feed led to the level control valve being closed; the condition of equipment was not communicated from one shift to the next. The organisation had no policy for effective communication between operations personnel during shift changes.
- Instrument malfunctioned, six pieces of instrument malfunctioned on the day of the incident, a redundant high level alarm, a sight glass on the tower and miscalibrated level transmitter. The level transmitter's setting was incorrect, likely not altered since it was set 30 years ago.
- Operators were likely fatigued, operators worked 12 hours shift, 7 days a week, 29 days. Acute sleep loss and cumulative sleep debt resulted. The organisation had no corporate or site specific fatigue prevention policy or maximum shift work regulations. No fatigue prevention guidelines widely used.
- Supervisor and operator staffing was insufficient, unit start-up are especially hazardous but no supervisor assisted with start-up. 25% budget cut target in 1999 led to Isomerisation unit staffing cuts – control room consolidation and increased workloads followed. Hazard review recommended two board operators during all start-up, but only one was working March 23, 2005.
- Operator training was not effective, move to computer-based training without effective verification methods of competency. Switch to computer-based training was a business decision driven by cost. From 1998 to 2004 central training staff reduced from 28 to 8 and budget cut in half, concurrent with instruction to cut costs by 25%. Audit and review from 2002 – 2005 identified on-going deficiencies in operator competency, yet managers adopted a compliance strategy that relied on engineering controls to prevent accidents due to cost. No effective training for abnormal situation management or simulation technology made available.

Worker fatigue can adversely impact personal health and safety as well as the efficiency and safety of the operation (Lerman *et al.*, 2012). The most effective method to minimizing worker fatigue is through a comprehensive fatigue risk management system (FRMS). An FRMS requires the active participation of all parts of the organisation, including management, support functions, and workers (Lerman *et al.*, 2012).

It is not enough to determine the level of health and safety knowledge and compliance among the construction workers in the state and/or their impact on project performance, rather it is important to establish a relationship between the level of health and safety knowledge and compliance; health and safety knowledge and project performance; and the level of health and safety compliance and project performance (Okoye *et al.*, 2016).

According to Almanssoor (2008) determining the fire potential of a chemical substance is accomplished through its flammability characteristics; no single factor, however, defines a substance's flammability and when a flammability comparison is to be made between different substances, the following factors should be considered, namely;

- Flammability limits (or explosion limits)
- Flash Point
- Auto-ignition temperature
- Vapour pressure
- Burning velocity
- Ignition energy

According to Almanssoor (2008) the most important and widely used factors are the first three, namely;

- Flammability limits – flammability limits of a gas define the concentration range of a gas-air mixture within which an ignition source can start a self-propagating reaction.
- Flash point – the flash point of liquid is the lowest temperature at which the liquid releases vapour in a sufficient amount to form an ignitable mixture with air near its surface.
- Auto-ignition temperature – the auto-ignition temperature is the minimum temperature required to cause or initiate self-sustained combustion independent of the source of heat. A substance will ignite spontaneously when it reaches its auto-ignition temperature.

Safety measures are chosen to eliminate an element of the fire triangle whilst causing minimal interference to plant operation (Puttick, 2008). According to Almanssoor (2008) to produce combustion, three conditions must coexist: flammable substance, oxygen, and a source of ignition. Avoidance of ignition sources can be useful and reliable basis of safety in certain circumstances provided that it is restricted to the inside of chemical plants, and certain well defined charging and discharging areas (Puttick, 2008).

Figure 1.2 Bhopal Tragedy (Isocyanate Gas Leak)

According to Peterson (2009) in December 2-3, 1984, a gas leak of some 40 tons of methyl isocyanate gas mixed with unknown other gases from chemical plant at the Union Carbide India Limited pesticide plant caused one of the highest casualty industrial accidents of the 20th century. Over 500,000 people were exposed to methyl isocyanate gas and suffered respiratory problems and injuries of varying severity and more than 2000 people died immediately. The methyl isocyanate release at Bhopal, India, in 1984 that killed over 2000 people and injured tens of thousands is one of the reasons why we need process health and safety management systems to be appreciated by the petrochemical industry. A fire and explosion at a PEMEX LPG terminal in Mexico City, also in 1984, killed more than 600 people and injured around 7000 people (Ness, 2015).

Figure 1.3 Phillips Petroleum Explosion

There was an accident October 1989 in Phillips Petroleum Company, Pasadena, incident resulting in 23 deaths and 132 injuries.

In a petrochemical industry control of ignition sources is vital (Puttick, 2008). According to Almanssoor (2008) explosion is a sudden and violent release of energy, this energy could be physical energy, chemical energy and nuclear energy and most chemical explosions involve a limited set of simple reactions, all of which involve oxidation. Fire and explosion hazards prevention involves dealing with the elements of the fire triangle and they fall into three categories, namely absence of flammable atmospheres achieved by limited fuel quantities, control/avoidance of ignition sources and absence of flammable atmospheres by limiting the quantities of oxidant present (Puttick, 2008). An explosion can be spontaneous or initiated by light, heat, friction, impact, or a catalyst (Almanssoor, 2008).

Explosions are not confined to closed systems; explosions may occur in an open area such as a process plant in which case the pressure wave will expand itself until the pressure gradient becomes insignificant (Almanssoor, 2008).

Figure 1.4 Amuay Oil Refinery Explosion

On August 25, 2012 the Amuay Oil Refinery in north western Venezuela suffered an explosion. This unprecedented incident in the national oil industry killed 48 people and injured 156.

These incidents call for highly increased focus to process health and safety management systems in the petrochemical industry (Zin, 2012). Employer must develop and implement written operating procedures that provide clear instructions for safely conducting operations and maintenance (Hardy, 2013).

According to Ness (2015) three contract workers were killed and a fourth worker was seriously injured in an explosion and fire at the Patridge-Raleigh oilfield in Mississippi. The contractors, who were employees of Stringer Oilfield Services, were tasked with installing a pipe between two oil production tanks. Welding sparks ignited flammable vapour that was escaping from an open-ended pipe near the welding activity. The root cause of this incident was hot work being conducted in the presence of flammable atmosphere without using any safe work permitting procedure. A gas detector should have been used to test for flammable vapour. The open pipe on tank was not capped or isolated. All of the tanks were interconnected, and some of the tanks still contained flammable residue and crude oil. Key lessons learned in this incident are, namely;

- Safe work practices, such as hot work permits, are necessary to ensure a safe work environment when hazardous chemicals, in this case flammable vapours, are present. The contractor did not require the use of safe work procedures, specifically hot work permits in this case.
- Contractors need to be managed in such a way as to ensure they know about and use safe work practices. The owner of the wells and tanks relied on contractors to do most of its well commissioning work, such as installing tanks, pumps, and piping. The owner should have managed the contractors to make sure they used safe work practices.

1.7 Research Questions

1.7.1 What deficiencies exist in process health and safety management systems when dealing with hazardous chemicals?

1.7.2 How should the major deficiencies be prioritised by top management to prevent process health and safety incidents when handling hazardous chemicals?

1.7.3 What are the critical drivers to achieve generative process health and safety culture?

1.8 Research Objectives

The research objectives are,

- Review the process health and safety management systems within industries where hazardous chemical substances are being used and identify the deficiencies;
- Identify health and safety hazards and describe the awareness of occupational health and safety hazards to the employees in the petrochemical industry;
- Test the effectiveness of the existing process health and safety management systems in petrochemical industry;
- Assess the existing process health and safety management systems deficiencies and prioritise the major deficiencies that need urgent senior management’s attention;
- Identify critical drivers to achieve generative health and safety culture;
- Develop a conceptual model and validate it using structural equation modelling.

1.9 Methodological Approach

The objectives of the research were achieved by the following research approach,

- Literature review to identify the critical process health and safety management elements that need to be prioritised by senior management.
- Development of a conceptual model from literature review.
- Questionnaire development for the survey.
- Questionnaire design, validity, types of validity is also discussed under research instrument design. Systematic random sampling was used.
- Data collection strategies are discussed that includes cross sectional, longitudinal, survey strategies, sample size and population. The data was collected by using a self - administered questionnaire survey in this research.
- Structural Equation Modelling was used to validate the conceptual model and identify the best fit generative process health and safety culture model.

1.9.1 Literature Review

An extensive literature review on health and safety in the petrochemical industry was conducted in order to describe and understand the challenges in this industry. The health and safety management systems were used to identify the process health and safety elements that influences process health and safety incidents in the petrochemical industry. The literature review was also use to identify the process health and safety management deficiencies to be prioritised by senior management in the petrochemical industry.

1.9.2 Conceptual Model

The literature review was used to identify the top process health and safety management elements that were used to develop a theorised conceptual model. The conceptual model included the process health and safety management elements, namely, Leadership Commitment, Training and Competency, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Process Health and Safety Information, Operating Procedure, Control of Ignition Source, Control of Confined Space Entry and Permit to Work among others. The process health and safety management elements were tested against a generative health and safety culture as latent variable. There were 35 observed variables in this research. The conceptual framework was tested and validated.

1.9.3 Questionnaire

The questionnaire was used as a research instrument and was shared with the petrochemical industry employees to answer the questions. The research questions used a Likert scale. The neutral option was used to accommodate participants that prefer not to comment or that were puzzled about the statement. The five options were presented to the participants to choose the answer that expressed their feelings most accurately about the statement. The respondents were requested to use any type of indication be it a cross, or a tick or they could circle in the relevant answer.

The questionnaire used in this research had two parts. Part one was the particulars of respondents and part two was the research questions. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants of which 259 were returned duly completed and used. They were statistically analysed using SPSS version 25. The response rate was 64.75%.

1.9.4 Structural Equation Modelling

Structural equation modelling was used in this research. The observed variables were identified in this research and tested against the latent variable. The observed variables were identified as rectangular shape and the latent variable were displayed as an eclipse or circle in AMOS version 25. The regression path was expressed by an arrow. Model specification was the first step in path models as it determines every relationship and parameters. Model identification was the second step in this research and the third step was model estimation. Model testing was the fourth step as it determines how well the data fits the model. Model modification was carried out in order to improve the model so that a better fitting model can be more interpretable.

1.9.5 Reliability and Validity

According Zohrabi (2013) one of the main requirements of any research process is the reliability of the data and findings. Internal consistency gives an estimate of the equivalence of sets of items from the same test and the coefficient of internal consistency provides an estimate of the reliability of measurement and is based on the assumption that items measuring the same construct should correlate (Kimberlin and Winterstein, 2008). Reliability refers to the extent to which our measurement process provides consistent or repeatable results (Zohrabi, 2013). Validity is often defined as the extent to which an instrument measures what it purports to measure and validity requires that an instrument is reliable without being valid (Kimberlin and Winterstein, 2008).

According to Hair *et al.* (2010) cited in Zhao (2017) composite reliability is frequently used to quantity how well all the measurement indicators reliably represent the corresponding latent construct. Reliability indicates how closely the results of repeated measurements of the same concept agree: a reliable measurement of quantity known not to have changed that is performed twice with the same person will produce the same value both times and the same is true where two different people are involved who do not differ on the measured characteristic (Zohrabi, 2013).

This research used, Cronbach's alpha, correlation and corrected-item-correlation to measure reliability. Validity was ensured in this research by a severe examination of literature review, adequacy of samples, representatives of samples, adequacy of data processing and analysis, appropriate interpretation and justifiable conclusions. Composite reliability, discriminant validity and convergent validity of the final study model were evaluated.

Testing for discriminant validity can be done using one of the following methods, namely, O-sorting, Chi-square difference test and the average variance extracted analysis (Zait and Bertea, 2011). This research discriminant validity was used to assess the shared variance between the constructs by calculating the average variance extracted.

1.9.6 Ethical Consideration

In this research an informed consent form for the participants was used to ensure that the respondents are aware that their participation is voluntary by nature and the participant has the right to withdraw partially or completely from the process. The questionnaire was explained to the small groups and they were allowed to decide whether they were willing to participate to this research or not.

Confidentiality is vital when doing research and the respondents were assured that their response will be held in confidence. Those that were willing to participate were then allowed to answer the questionnaire and those that decided to not participate were allowed to leave the room without answering the research questionnaire. The participants that were willing to proceed and participate were requested to be truthful and honest when answering the questionnaire and were told everything about the research without compromising the truth to avoid deception.

The researcher ensured that an informed consent form was used when questionnaire was distributed, and confidentiality was highlighted to the research participants. The privacy of the research data was ensured by using a secured and personal laptop that requires a password known by the researcher. The final research data was then transferred to the desk computer in the supervisor's office, where there is no access given to anyone without supervisor's permission. In order to ensure ethical standards, the researcher obtained an ethical clearance certificate from the University of KwaZulu-Natal. Ethical clearance to conduct the study was obtained from the University of KwaZulu - Natal Humanities and Social Sciences Research Ethics Committee (HSS/1094/018D).

1.10 Study Limitations and Delimitations

The scope of data collection for this research was limited to South Africa KwaZulu-Natal Province. The research was also limited to the petrochemical industry and the participants invited to participate in this study were from petrochemical and chemical industry. Limitations of this research comprise the short duration for the study period within which the questionnaire data were collected as planned.

Literature sources used in order to meet the secondary data objectives were limited to those readily available in online search engines databases as well as publications available in libraries within the boundaries of South Africa. This study was also limited to employees working in the petrochemical industry and responsible for production, technical services, maintenance, health, safety and environment, turnarounds or plant shutdowns and engineering projects. The research is based on survey instrument which was designed by the authors and so have not been extensively validated. The reliability and validity of the research instrument may be questioned as it was not sufficiently assessed for face validity through a panel of experts. Predictive and constancy were not assessed.

International factors could influence health and safety culture, particularly for countries that do not have trade unions, different culture, autocratic to mention a few. The examination did not include any international stimuli to reduce possible difficulties and to achieve results that could provide starting points for research in the future.

The study limitations need some attention concerning the magnitude to which the results can be generalised beyond the scope of the empirical data due to the complex nature of health and safety culture. This study was based entirely on quantitative research data. A mixed methods approach would have provided a check on the validity of the findings by comparing results from a qualitative data source. The proposed generative health and safety model was not validated by testing too establish its effectiveness when used.

1.11 Overview of the Research Study

The thesis is organised in nine chapters, which are divided into three parts. Part One contains four chapters:

The objectives addressed by Part One are, namely;

- Identify health and safety hazards and describe the awareness of occupational health and safety hazards to the employees in the petrochemical industry;
- Test the effectiveness of the existing process health and safety management systems in petrochemical industry;

Chapter One describes the problem statement and provides a topical introduction. This chapter also discusses the significance of this research towards health and safety of petrochemical employees. This chapter discusses objectives, research questions, limitations and knowledge contribution to academia. The overview of all the other chapters in this research are also summarised in this chapter. The key contribution of this study arises from the application and refinement of the framework for the empirical analysis of the health and safety management systems in order to identify main deficiencies when handling hazardous chemicals.

Chapter Two reviews the literature available in health and safety to develop the theoretical framework. This chapter discusses the process health and safety elements and attempts to recommend the key ten process health and safety management elements from literature to be prioritized for an effective process health and safety management system. This chapter presents a concise literature review regarding the importance of occupational health and safety in the petrochemical industry. This chapter reviews the five levels in the health and safety culture ladder, and the concept of health and safety culture and the development of health and safety culture. An extensive literature review will be conducted in order to understand the process health and safety concerns and its effect on petrochemical and chemical industries. This chapter also shares some of the challenges in the petrochemical industry with the focus on the following hazards, namely, physical hazards, ergonomic hazards, chemical hazards, psychosocial hazards and radiological hazards.

Chapter Three develops the theoretical framework. This chapter proposes conceptual process health and safety elements model, based on the latent variable (Generative Health and Safety Culture) and observed variables (Leadership Commitment, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Permit to Work, Training and Competency, Process Health and Safety Information, Control of Confined Space Entry, Operating Procedure and Control of Ignition Source) identified through literature review.

Chapter Four describes the methodological tools used and research design as well as data collection techniques employed in the fieldwork. This chapter outlined the philosophical assumptions underpinning this research. These correspond to the epistemological and ontological assumptions of positivism research. This chapter discusses research design and methodology used in this study. The topics discussed are, namely, research philosophy, research methodology and approach, research instrument, data collection strategies, sampling techniques and data analysis. The research philosophy expands on the concepts ontology, realism, relativism, epistemology, positivism, interpretivism, methodology, quantitative and qualitative in the research paradigm.

This research also shares different research strategies, namely, Case study, Ethnographic study, Ground theory study, Phenomenological study, Experimental study, Archival research and action research. In this chapter data analysis include the following topics, Analysis techniques, Bias, Response Bias and Types of Response Bias, Deliberate Falsification, Misrepresentation, Validity Reliability and Challenges with data access.

Part Two, which contains Chapter Five, Six and Seven focuses on the analysis of results, model development and model validation.

The objectives addressed by Part Two are, namely

- Review the process health and safety management systems within industries where hazardous chemical substances are being used and identify the deficiencies;
- Assess the existing process health and safety management systems deficiencies and prioritise the major deficiencies that need urgent senior management's attention;
- Identify critical drivers to achieve generative health and safety culture;

Chapter Five focuses on the presentation of the results. This chapter discusses the analyses of the results acquired from the survey. This includes descriptive statistics using frequencies, means, and standard deviation.

Chapter Six addresses the model development and model development is considered an effective research method as it assists investigators and scientists in relating more accurately to reality; it also aids the researcher to describe, predict, test or understand complex systems or events (Shafique and Mahmood, 2010). Fit indices found using exploratory factor analysis and confirmatory factor analysis.

Chapter Seven validates the model. This chapter discusses structural equation modelling and how it was used to establish the interrelationships of the hypotheses. In quantitative research, the researcher analyses the data in order to test one or more formulated hypotheses. The aim of which is to find out if the relationships between the observed variables in one or more groups are statistically significant

(Gelo, Braakmann and Benetka, 2008). According to Kline (2011); Raykov (2006) cited in Harinarain, (2013).The aim of structural equation modelling is to see how well the proposed model accounts for the observed relationships among these variables These two chapters are responds to the last objective that is to develop a model and validate it using structural equation modelling.

Part Three discusses the findings, concludes and recommends for future research for this research topic in Chapter Eight and Nine.

1.12 Contribution of the Study Findings to Knowledge

The study offers an innovative analytical and methodological approach in process health and safety culture assessment. The thesis is part of the larger discussion of increasing importance in health and safety policymaking. This study aims at contributing to the literature in the field of health and safety by incorporating management deficiencies that require senior management's attention and the drivers towards a generative health and safety culture. It offers an innovative methodology in assessing petrochemical industry performance in health and safety.

Methodological contribution lies in the experience gained through the application of positivism approach and techniques applied for data collection. The other methodological contribution relates to the appropriateness of applying theoretical concepts and theories developed in other contexts. The successful use of these theories in this study contributes towards providing examples of the positivism research approach. The study contributes methodologically the five drivers and ten main deficiencies that require senior management's undivided attention. The research utilised reliability measures and validity to ensure that the research instruments were reliable and valid.

One of the practical contributions of this research is the detailed insights provided by the literature review done in this study. The literature review reveal that senior management need to acquire new skills of improving health and safety culture in the petrochemical industry. The contribution of this research is to understand, based on theoretical assumptions, how the health and safety can be institutionalised in an organisation and how it contributes to happy employees. The due model can be used as a practical tool.

1.13 Chapter Summary

This chapter introduced the research topic of process health and safety management systems deficiencies relative to hazardous chemical exposure in petrochemical industry. This chapter also stated the research questions and presented the objectives of the study. The research design and methodology and research limitations were introduced in this chapter. The research structure was shared in this chapter. This chapter also shared the envisioned contribution of the study findings to knowledge

This research also includes appendices that contain sample of the questionnaire, ethical clearance approval for the research, and conference papers published through this research. In the next chapter, literature review on process health and safety management systems is presented.

CHAPTER TWO

Literature Review

2.1 Introduction

This chapter is devoted to studying the literature on the key theories in the research topic. This chapter also explores the magnitude to which the key research questions and objectives have been addressed in the previous studies. The chapter includes deliberations on the concept of health and safety in the petrochemical industry and key contributors to poor statistics that indicate high fatalities, lost time injuries and major asset damage that has huge financial impact to the industry. Different hazards in petrochemical industry are discussed in this chapter, namely, physical hazards, ergonomic hazards, chemical hazards and psychosocial hazards. This research exposed a wide range of chemical hazards of diverse nature, although this is not quite surprising given that a great deal of chemical substances is associated with activities of the petrochemical industry. The chapter ends with a summary of literature review and how the research intended to contribute to filling the knowledge gap.

2.2 Background to the Study

The petroleum industry began with the successful drilling of the first commercial oil well in 1859, and the opening of the first refinery two years later to process the crude into kerosene (Kumar *et al.*, 2017). A petrochemical plant is a high risk industry with potential risks of fire, explosion and poisoning of employees (Thomas and Babu, 2014). The evolution of petroleum refining from simple distillation to today's sophisticated processes has created a need for health and safety management procedures and safe work practices (Kumar *et al.*, 2017). The health and safety of workers is most important. Operations and processes in petroleum industries are hazardous, due to properties of the petroleum products and raw materials (Kulkarni, 2017). Industry becomes successful by not only meeting the production requirements but also should have high employee satisfaction by providing the health and safety requirements in the workplace (Purohit *et al.*, 2018).

According Ezejiofor (2014) for many occupational toxicologists, industrial hygienists, and others with stake in the field of occupational health and safety, the safety of the work place has always been a major concern. Failures of process health and safety management systems are deadly and costly. Major accidents have emphasized the need for process health and safety within the petrochemical industries (Ness, 2015).

Health and safety issues should be based on job health and safety analysis or comprehensive hazard or risk assessment, using established methodologies such as a hazard identification study (HAZID), hazard and operability study (HAZOP), or a quantitative risk assessment (QRA) (International Labour Organisation, 2017). The health and well-being of workforce of accompany which is their most valued asset should not be ignored by the management (Eyayo, 2014).

Health and safety management systems are a systematic and continuous management system based on proactive identification of hazards, and analyses of their risk (Thomas and Babu, 2014). In spite of the immense benefits derived from work, work itself has become a source of several deaths, ill-health and injuries, as clearly illustrated by data from relevant authorities including the World Health Organisation (WHO) and International labour organisation (ILO). World Health Organisation report for year 2000 concluded that workplace hazards are responsible globally for 37% of back pain, 16% of hearing loss, 13% of chronic obstructive pulmonary disease (COPD), 11% of asthma, 10% of injuries, 10% of lung cancer, and 2% of leukaemia. The occupational hazards are major issue in oil and gas extraction industry. According to studies by an investigator, fatality rate in this industry is 2.5 times more than construction industry and 7 times more than general industry (Kulkarni, 2017).

The occupational health and safety act 85 of 1993 is leading OHS legislation in South Africa. Its primary aim is to provide for health and safety of employees and for health and safety of persons in connection with the use of plant and machinery, the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with activities of persons at work (Thomas and Babu, 2014). Occupational health hazard which is different from occupational safety hazards is prevalently on the rise as industrialization increases in the global world (Eyayo, 2014).

According Ezejiofor (2014) in spite of the difficulty in obtaining information concerning occupational diseases and injuries in developing countries due to lack of comprehensive and harmonious data collecting systems, ILO still estimates that 2 million workers die each year from work related injury and illness. In 2002, in sub-Saharan Africa alone, ILO estimated more than 257,000 total work related fatalities, including about 50,000 injuries.

According to Ness (2015) accidents almost always have more than one cause. For many years, safety experts have used the Swiss cheese model to help managers and workers in the process industries understand the events, failures, and decisions that can lead to a catastrophic incident or near miss. According to the Swiss model each layer of protection is depicted as a slice of Swiss cheese, and the holes in the cheese represent potential failures in the protection layers, namely;

- Human errors
- Management decisions
- Single-point equipment failures or malfunctions
- Knowledge deficiencies
- Management system inadequacies, such as a failure to perform hazard analyses, failure to recognise and manage changes, or inadequate follow-up on previously experienced incident warning signs.

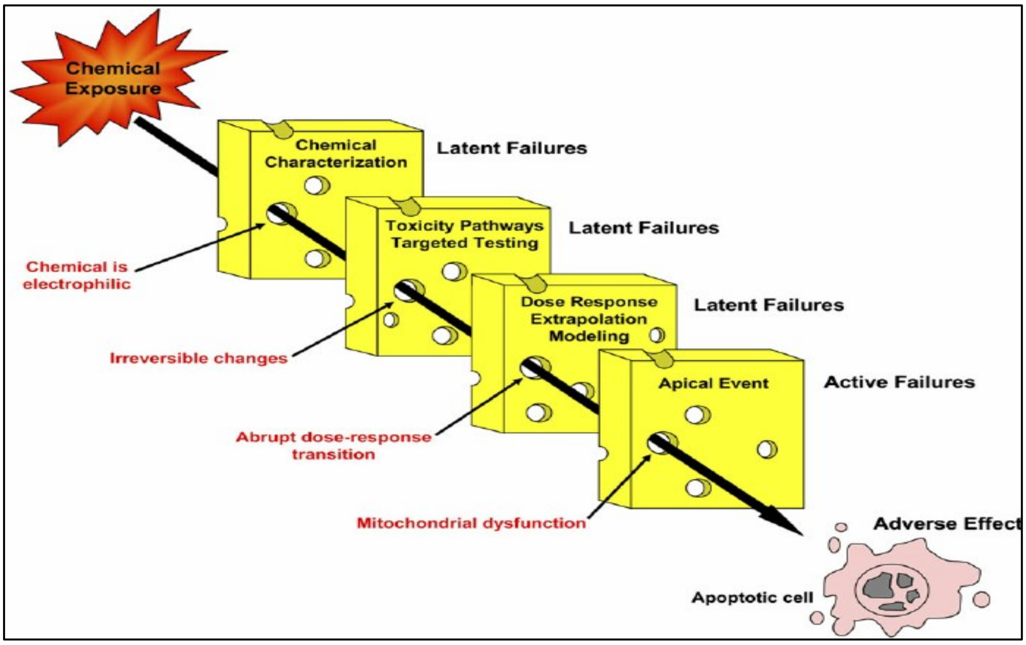

Figure 2.1 Reason's Swiss Cheese Model.

According to Kumar *et al.* (2017) health and safety professionals, working with process, chemical, instrumentation, and metallurgical engineers, assure that potential physical, mechanical, chemical, and health hazards are recognised and provisions are made for safe operating practices and appropriate protective measures. These measures may include hard hats, safety glasses and goggles, safety shoes, hearing protection, respiratory protection and protective clothing such as fire – resistant clothing where required. These health hazards, usually, could be associated with most industrialised organisation and the oil and gas refinery is not left out (Eyayo, 2014). A critical part of any safety and health program is the identification, assessment, elimination and/or control of hazards in the workplace (Dunbar, 2014).

Health hazards which could result in the development of diseases and sickness is categorised into physical health hazard, chemical health hazard, biological health hazard, mechanical/ergonomic health hazard and psychosocial health hazard (Eyayo, 2014). As a general approach, health and safety management planning should include the adoption of a systematic and structured approach for prevention and control of physical, ergonomic, biological, chemical, psychosocial and radiological health and safety hazards (International Labour Organisation, 2017).

According to Makin and Winder (2008) cited in Elssayed, Hassan and Hosny (2012) the term hazard profile is used to indicate the particular blend of characteristics or exposures within a given work environment that have the potential to cause harm or loss to those whom a duty of care is owed. It is impossible to eliminate all hazards, so the goal is to eliminate and/or control the hazards with critical and high potential and to reduce the rest of the hazards to the lowest reasonable risk level to protect workers from harm (Dunbar, 2014).

2.2.1 Physical Hazards

According to Eyayo (2014) physical hazards are often said to be less important than chemical hazards but this not so. A physical hazard is a factor within the environment that can harm the body without necessarily touching it. Vibration and noise are examples of physical hazards (International Labour Organisation, 2017). According to Ezejiofor (2014) hand arm vibration syndrome and noise induced hearing loss are some of the health effects associated with occupational exposures to vibration and noise. In areas nearby petrochemical industries, elevated sound levels induce noise pollution associated with feelings of headache, annoyance, uneasiness, stress, impatience, displeasure, hypersensitivity, extreme anxiety, anger, endangerment and violence (Sharma *et al.*, 2017). The environmental factors of heat stress are air temperature, water vapour pressure, radiant heat, and air velocity (Ezejiofor, 2014).

According to Eyayo (2014) the nature of physical agents is wide and should not be underrated but the main ones capable of causing occupational disorders and injuries are, namely;

- Noise
- Illumination
- Vibration
- Radiation (ionizing and non-ionizing)
- Microclimatic conditions in the case of extreme heat and cold.

Employees may be at risk of heat stress when exposed to hot environment or extreme heat and this can result in illnesses including heat stroke, heat exhaustion, heat syncope, heat cramps and heat rashes or death (International Labour Organisation, 2017).

Heat stress is the aggregate of environmental and physical work factors that constitute the total heat load imposed on the body (Ezejiofor, 2014). Heat also increased the risk of workplace injuries such as those caused by sweaty palms, fogged-up safety glasses or dizziness, and may reduce brain function responsible for reasoning ability, creating additional hazards (International Labour Organisation, 2017).

Different types of mechanical energy such as noise, vibration, radiation and temperature extremes can physical injury hazards (Vitharana *et al.*, 2015). According to Ezejiofor (2014) vibration and noise militate against health generally, since exposure to both are linked to sundry physiological and psychological health effects including annoyance, sleep disturbances, electroencephalographic changes and cardiovascular disorders. Noise is inevitable in construction sites due to the nature of construction activities (Vitharana *et al.*, 2015). Bruises, sprains, fracture, concussions and lacerations are injuries that result from some form of physical contact, usually the worker is moving and hits a stationary object or the moving object hits a stationary worker (International Labour Organisation, 2017).

Vibration is oscillatory motion about a point and occupational/chronic exposure to hand transmitted vibration results in various disorders sometimes collectively known as the hand arm vibration disease or vibration syndrome (Ezejiofor, 2014). The syndrome includes vascular, neurological and musculoskeletal disorders that may become manifest individually or collectively. Loss of hearing, burns, hypothermia, heat stroke, skin rash and blistering are some of the injuries or illnesses caused by exposure to unseen physical hazards, are slips, trips and falls, electricity, tools and machinery, cold stress and fire (International Labour Organisation, 2017).

The wet bulb temperature index (WBGT) index is one of the most commonly used heat stress indices, and the standard in South Africa in industrial settings and is mentioned in occupational health and safety legislation (Joubert and Bates, 2008).

Physical work contributes to the total heat stress of the job by producing metabolic heat in the body, heat being in proportion to the work intensity and not only the environment and physical factors, but also age, gender, physical fitness, health status, clothing and acclimatization may be major factor contributing to the changes which occur in human physiological response to heat stress (Ezejiofor, 2014). The World Health Organisation states that it is inadvisable to exceed a rectal temperature of 38 degree C during prolonged exposure to heavy work. The thermal work limit defined as the maximum sustainable metabolic rate that euhydrated (adequately hydrated), clothed, acclimatised individuals can maintain in a specific thermal environment, whilst maintaining a safe deep body core temperature (<38.2 degrees C) and sweat rate (<1.2 kg/hr) (Joubert and Bates, 2008).

Human beings maintain thermal and other bio-physiological factors in the body within relatively narrow limits and the balance between man and the environment is especially important when one is working in extreme thermal conditions (Ezejiofor, 2014).

2.2.2 Ergonomic Hazards

Managers in the oil and gas business have frequently received worker complaints such as chronic fatigues, back pains, headaches, upper body pains, sleep disorders, and stresses and these complaints are indications of ergonomic deficiencies in the work system from the industry (Kim, 2016). An ergonomic hazard is a physical factor within the environment that harms the musculoskeletal system and include, among others, repetitive movement, manual handling, inappropriate workplace/job/task design, uncomfortable workstation height and poor body position (International Labour Organisation, 2017). Ergonomic injuries include strains, sprains and other problems (Ezejiofor, 2014).

Workers in the oil and gas industry continuously experience the problems of noise, slippery surfaces, and numerous manual material handling exposures of carrying, lifting, lowering, pushing and pulling tasks (Kim, 2016). These injuries can be caused by performing the same motion over and over again, using physical force when lifting heavy objects or being in an awkward position like twisting your body to reach a light bulb (Ezejiofor, 2014).

There are electrical issues and fall protection challenges, as well as repetitive tasks such as valve turning, which increases the force risks to the employees (Kim, 2016). According to Ezejiofor (2014) it is recommended that one makes occasional breaks between sitting and standing and talking about shift and call duty, or prolonged working hours, there are several dimensions of this, just as there are several implications for both health and work. Workers from the oil and gas industry are largely uncovered to ergonomic – related injuries and injury risks such as repeated bending, lifting heavy items, pushing and pulling weight loads, reaching overhead, performing the same or similar tasks repetitively, and working in awkward body postures (Kim, 2016).

According to International Labour Organisation (2017) workplaces and premises for workers shall have, as far as possible, natural lighting and shall be supplied with adequate artificial or electric lighting to ensure good vision to workers. According to Kim (2016) the following examples of ergonomic solutions are suggested to successfully manage health and safety problems in the oil and gas industry, namely;

- Use ergonomic concepts and information in the designing of jobs and even choosing equipment and tools.

- Establish ergonomic policies, procedures and review programs throughout the corporation, no matter what the size of industries.
- Train workers in ergonomics for the appropriate handling and use of the special tools required during maintenance and turnaround activities.
- Ensure all workers on the location to understand the risks and dangers before starting any maintenance activities. They should be carefully informed and trained in appropriate safety procedures, including the use of safety equipment and breathing apparatus.
- Utilise ergonomics for the design and layout of control rooms to eliminate human errors and increase comfort, fit, user performance, and functionality.
- Ensure all signs and symbols are placed in areas that everyone can see and read clearly. Use larger fonts and consider both indirect as well direct glares.

According to World Health Organisation (2013) cited in Eyayo (2014) repetitive tasks and static muscular load are also common among many industrial and service occupations and can lead to injuries and musculoskeletal disorders and in many developed countries such disorders are main cause of both short term and permanent work disability and lead to economic losses amounting to as much as 5% of gross national product.

Many of the oil and gas corporations have instigated to comprise ergonomic interventions to their plants and managerial areas (Kim, 2016). Royal Dutch Shell has developed several design engineering procedures covering many aspects of ergonomics for their projects. Shell has adopted ergonomics as part of its corporate health and safety management guidelines. Chevron Texaco is upgrading its safety in design manual to integrate ergonomics and assesses subcontractors on their ability to perform in this area.

2.2.3 Chemical Hazards

According to International Labour Organisation (2017) some of the duties of the employer are to identify risk of physical or chemical reaction of hazardous chemical and ensuring the stability of hazardous chemicals, ensure that exposure standards are not exceeded, provision of information, training, instruction and supervision to workers, obtaining the safety data sheets from the manufacturer, importer or supplier of the chemical. According to Almanssoor (2008) the issue of safely producing hazardous chemicals is as important as the economics of producing and selling them. Personal factors determine the effects of a chemical and these include generic factors, age, gender, health status, hypersensitivity, personal habits, hygiene, pregnancy and lactation (Naafs, 2018).

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) once chemical hazards and workers risks are determined, the required control approach needs to be identified and implemented as follows,

- Identifying how to protect workers from the health hazards of each chemical that is on site.
- Identifying what to do in the event of an uncontrolled release, leak, or spill.
- Knowing where to go for more information.
- Knowing how to dispose of the products safely.

According to Ezejiofor (2014) some of the chemical substances recorded as hazardous in the petrochemical industry work environment include petroleum fumes, Benzene, toluene, xylene, gases such hydrogen sulphide (H_2S), Hydrogen Fluoride (HF), ammonia (NH_3), and methane, polycyclic aromatic hydrocarbons (PAH), asbestos, several salts and acids, to mention this few table 1.

Hazardous chemicals in the petrochemical industry are substances, mixtures and materials that can be classified according to their health and physico-chemical risks and dangers and such hazards include skin irritants, carcinogens or respiratory sensitizers that have an adverse effect on an employees' health as a result of direct contact with or exposure to the chemical, usually through inhalation, skin contact or ingestion (International Labour Organisation, 2017).

In the European Union alone, approximately 16 million people are exposed to carcinogenic agents at work and the most common cancers resulting from these exposures are cancers of the lung, bladder, skin, mesothelium, liver, haematopoietic tissue, bone and soft connective tissue (World Health Organisation, 2013 cited in Eyayo, 2014).

About 300 – 350 substances have been identified as occupational carcinogens and they include chemical substances such as benzene, chromium, nitrosamines and asbestos (World Health Organisation, 2013 cited in Eyayo, 2014). The hazardous effect of chemicals comes through three ways, namely: fire, explosion and toxicity and the first essential step towards greater plant health and safety is being aware of the potentially dangerous properties of the substances, i.e. whether they are flammable, explosive or toxic (Almanssoor, 2008).

Toxicology is the study of poisons and how they affect the body, and it is an inherited property of a chemical that causes bodily injury or disease to a living organism as a result of physiochemical interaction with living tissue (Naafs, 2018). Toxicity is defined as the ability of toxic (poisonous) substances, when absorbed by living tissues (either ingestion or via the skin), to cause injury or destroy life (Almanssoor, 2008).

All substances including chemicals are potentially poisons. However, all chemicals can be used safely if exposure is kept below tolerable limits (Naafs, 2018). Injuries, caused by toxic effects of chemicals, vary and occur both close to and distant from the point of release of these chemicals, especially when the correct precautions to chemical releases are ignored and injuries include eye, skin, poisoning, asphyxia and respiratory system injuries (Almanssoor, 2008).

There are various factors that influence the toxicity and the health effects of a chemical agent and these include its physical state, dose or concentration, route of absorption, duration of exposure and presence of other chemicals (Naafs, 2018).

According to Almanssoor (2008) examples of hazardous substances prevailing within the petrochemical industry are, namely;

- Gases (flammable, toxic, compressed).
- Liquids (flammable, toxic, acidic, alkaline, cryogenic).
- Solids (flammable, volatile).
- Viscous materials.
- Oxidizing, reactive and corrosive substances.

Among certain occupational groups such as asbestos sprayers, occupational cancer may be the leading factor in ill-health and mortality and due to the random character of effect, the only effective control strategy is primary prevention that eliminates exposure completely, or that effectively isolates the worker from carcinogenic exposure (World Health Organisation, 2013; Eyayo, 2014).

According to the Safety Association for Canada's Upstream Oil and Gas Industry (2012) to address the personal health and safety of workers, chemical hazard assessment need to consider the overall health and safety of the process design as well as the manner in which project activities are managed and the recommended methodology has seven steps, namely;

- Identify operations that involve chemical exposure.
    - Processes from purchasing through to disposal.
    - Type of operation.
    - Equipment design and layout.

- Identify and confirm who is responsible for chemical control and use.
    - Planning phase: The planner should assign a suitable representative to identify, assess, control, and communicate the chemical hazards as well as the planner’s standards for all work on the site.
    - Implementation phase: Those persons responsible for organising workers and ensuring that the chemical management process gets done. Implementation roles include but are not limited to supplier, supervisor, and site supervisor.
    - Execution phase: Those persons who physically manage the chemicals on the job site and therefore are directly or indirectly exposed to the chemicals. Completing effective chemical hazard assessments and implementing suitable control measures are the responsibility of every stakeholder on the work site.

- Identify the potential chemical exposure hazards.
    - Material safety data sheets are one of the most effective and efficient ways of communicating and managing chemical hazards. They should be readily available for all participants throughout the process.
    - Risk phrases, there should be full listings of risk phrases.
    - Industry knowledge and literature, additional information on hazardous substances, types of exposure, and unique chemical situations in the oil and gas industry.

- Assess the chemical hazards.
    - Properties of the chemical (e.g., flammable, health hazards)
    - Where is the chemical being used?
    - How much of the chemical is being used?
    - How long is the worker exposed to the chemical?
    - How are workers exposed?

- Evaluate and analyse the chemical hazards.
    - Quantifying the severity of the hazard.
    - Quantifying the likelihood of the hazard.
    - Using a matrix or equation to quantify the risk.

- Decide on the control approach needed to remove or reduce chemical exposure risks.
    - Selecting the appropriate control approach.
    - Identifying and applying the appropriate guidance sheets.
    - Eliminating/substituting.

    - Applying engineering controls.
    - Applying administrative controls.
    - Specifying personal protective equipment.

- Confirm that the controls work.
    - Management of change (MOC).
    - Monitoring effectiveness.
    - Informing, instructing, and training.
    - Keeping records.
    - Operations maintenance.

2.2.4 Psychosocial Hazards

According to Ezejiofor (2014) psychosocial hazards stem from overloaded work pressure, prolonged hours of work, shift duty and/or call duty schedules, and in some instances, monotomy/boredom obtainable in some sectional operations marked with repetitive schedules. Risks to psychological health due to work should be viewed in the same way as other health and safety risks and a commitment to prevention of work related stress should be included in an organisation's health and safety policies (International Labour Organisation, 2017). Psychological stress and overload have been associated with sleep disturbances, burn-out syndromes and depression (Eyayo, 2014).

Psychosocial hazards include, among others, stress, violence and substance abuse and there are circumstances in which work can have adverse consequences for health and well-being (Ezejiofor, 2014). Epidemiological evidence exists of an elevated risk of cardiovascular disorders, particularly coronary heart disease and hypertension in association with work stress (Eyayo, 2014). Risk to psychological health at work may arise from organizational or personal factors, with the major factors being poor design of work and jobs poor communication and interpersonal relationship, bullying, occupational violence and fatigue (Ezejiofor, 2014).

There is high tendency for individuals under uncontrolled stress to violate laid-down regulations in the performance of activities in their places of work and this situation, in turn, could lead to serious errors that may have disastrous consequences for the workers and the industries (Nwachukwu and Nabofa, 2014).

Severe psychological conditions (psychotraumas) have been observed among workers involved in serous catastrophes or major accidents during which human lives have been threatened or lost (Eyayo, 2014). High levels of stress are injurious to a worker's health and productivity; workers must cope with work in a petrochemical industry, which is naturally very stressful and it is therefore imperative that functional and utilizable stress management systems be out in place so as to assist workers cope with the highly stressful work conditions of the petrochemical (Nwachukwu and Nabofa, 2014).

According to the National Institute for Occupational Safety and Health in the USA causes of work related stress are,

- Improper design of tasks, which implies heavy workload, infrequent rest breaks, long working hours and shift work, hectic and routine tasks that have no inherent meaning, not utilizing workers skills and there being little sense of control.
- Management style that is not transparent precludes participation of workers in decision making and results in poor organisation of work and lack of family-friendly policies in the company.
- Career related anxieties that include, among other factors, job insecurity, lack of opportunity for advancement or promotion, little recognition, as well as rapid changes for which workers are unprepared.
- Strained interpersonal relations that are usually a sign of a poor social environment, lack of support, communication and help from supervisors and co-workers.
- Conflicting and uncertain work roles, too much responsibility, too many hats to wear, whereby individuals' need for role clarity varies.
- Unpleasant or dangerous work environment such as overcrowding, excessive noise and air pollution, or ergonomically inferior designed work places resulting in health problems.

Social conditions of work such as gender distribution and segregation of jobs and equality (or lack of) in the workplace, and relationships between managers and employees, raise concerns about stress in the workplace (Eyayo, 2014). Employees who make use of drugs or alcohol often do so in the misperception that they help to reduce the stress of work, or for mood adjustment, performance enhancement, helping to get over peer pressures, or socializing (International Labour Organisation, 2017)

Many service and public employees experience social pressure from customers, clients or public, which can increase the psychological workload and measures for improving the social aspects of work mainly involve promotion of open and positive contacts in the workplace, support of the individual's role and identity at work, and encouragement of teamwork (Eyayo, 2014).

Employees become used to their consumption as they belong to the habit – behaviours and if they are not used, anxiety increases which further increased the stress level (International Labour Organisation, 2017). Stress management systems prevent a situation where workers are exposed to protracted experience of stress, which may lead to frustrations and abnormal behaviour (Nwachukwu and Nabofa, 2014). Substance abuse generally leads to increased chances of accident, increase absenteeism, and lower productivity and general performance of the company (International Labour Organisation, 2017).

According to Eyayo (2014) organisational psychosocial factors include but not limited to the following,

- Violence and aggression
- Lone working
- Shift and night work
- Long working hours
- Time zone changes

2.3 Leadership Elements

In this research there are five leadership process health and safety elements namely leadership and commitment, training and competency, contractor management, asset integrity and effective communication explored. According to Beriha *et al.*(2012) cited in Elssayed, Hassan and Hosny (2012) occupational accidents can be reduced through effective preventative measures by investing on safety equipment, training, and educating the employees, process design, and machinery.

2.3.1 Leadership Commitment

According to Hardy (2013) it is recognised that leadership is important in the creation of a culture that supports and promotes a strong health and safety performance of an organisation. Employers and employees with good safety behaviour are particularly playing a significant role in achievement of safety compliance to occupational, safety and health improvement in industry (Fernandez, 2011; Elssayed, Hassan and Hosny, 2012). According to Agumba and Haupt (2018), there are five health and safety practices that will minimize health and safety incidents in small and medium enterprise projects in the South African construction industry, namely,

- Upper management commitment and involvement in health and safety
- Employee involvement and empowerment in health and safety
- Project supervision
- Project health and safety planning

- Communication in health and safety, health and safety resources and training

It is imperative that leadership ensures that each employee is trained in an overview of the process and in the operating procedures, emphasis on the specific safety and health hazards, emergency operations including shutdown, and safe work practices applicable to the employee's job tasks (Hardy, 2013). One of the fundamental points to note is that employers have a common law duty to ensure that a safe system of work plan is in place, prior to the work being started on site (Spillane and Oyedele, 2013). Having senior managers who take a proactive interest in establishing a health and safety culture has been considered to be a key influence on organisational health and safety performance (Hardy, 2013).

The other element that requires leadership's attention is contractor management, contractors working in petrochemical industry face a great risk during maintenance work (Othman, Jabar, Murad & Kamarudin, 2014). Safety behaviour depends directly on the communication that exists in the firm and indirectly on management's commitment (Fernandez, 2011; Elssayed, Hassan and Hosny, 2012). In order to develop a good safety culture, attitude of the workers needs to be reoriented by applying best practices, good housekeeping, change in work culture, and work practices (Beriha *et al.*, 2012; Elssayed, Hassan and Hosny, 2012).

2.3.2 Training and Competence

It is the responsibility of the employers to assure that the contractors who work in and around hazardous chemicals have the appropriate skills and knowledge to perform those tasks without compromising health and safety (Hardy, 2013). Process safety management is critical in the chemical process industry and improving organisational knowledge and knowledge management capabilities is an important means to prevent chemical accidents and improve organisations safety level (Chen, 2016).

Health and safety knowledge encompasses awareness of occupational health and safety risks, including an evaluation of occupational health and safety programmes in an organisation (Okoye, Ezeokonkwo and Ezeokoli, 2016). According to Hardy (2013), training provides employees with the knowledge and tools to fully understand the risks in working with hazardous chemicals.

Knowledge is more than information, since it involves an awareness or understanding gained through experience, familiarity or learning (Okoye, Ezeokonkwo and Ezeokoli, 2016). The employer must obtain appropriate certifications from that contractor, and should screen the contractor to assure that they can perform the tasks safety and the employer must manage the contractor to maintain control over health and safety of the work (Hardy, 2013).

According Elssayed, Hassan and Hosny (2012) in order to commit top safety management, training courses need to be further emphasised and improved to ensure better safety culture, performance and involvement of all workers in top safety management of the company. The employer shall prepare a record that contains the identity of the employee, the date of training, and the means used to verify that the employee understood the training (Hardy, 2013).

The transient nature of the construction workforce makes it difficult to train workers effectively. However, availability of trained or skilled workers directly contributes to the improvement of quality of construction work, and indirectly contributes to improve the site safety (Vitharana, De Silva and De Silva, 2015). All employees, including contractor employees and maintenance personnel, must be trained to understand the material safety data sheets, as well as safe work practices and operating procedures (Hardy, 2013). One of the leading methods to inform personnel of the various health and safety woes present on each particular construction site is through the use of site specific inductions (Spillane and Oyedele, 2013).

The employer, in consultation with the employees involved in operating the process, shall determine the appropriate frequency of refresher training (Hardy, 2013). According to Vitharana, De Silva and De Silva (2015) indicates that in the construction industry, workers have high mobility and they switch from one organisation to another, frequently. A site induction provides the initial contact with new individuals entering a construction site, the purpose of which is to provide the individuals with an overview of the various site specific safety, health and welfare requirements and associated issues (Spillane and Oyedele, 2013).

Training in emergency response, including conditions for evacuation and shelter in place and the use of personal protective equipment is critical (Hardy, 2013).

2.3.3 Contractor Management

Contractors working in processing plants, apart from the complexity of construction working condition, contractors face a great risk during maintenance tasks (Othman *et al*., 2014). Each contractor must be trained in an overview of the process and in the operating procedures and the training shall include emphasis on the specific safety and health hazards, emergency operations including shutdown, and safe work practices applicable to the employee's job tasks (Hardy, 2013). Employees are exposed to a number of inevitable hazards as most workers employed by contractors are unfamiliar with hazardous materials and more work performed under high pressure (Othman *et al.*, 2014).

According to Cooper (2006) cited in Spillane and Oyedele (2013) where there is lack of formal protocol in the development and implementation of safe system of work plans, this can result in unsafe behaviour while carrying out the hazardous task in question. Contractors could be exposed to a number of inevitable hazards: large numbers of workers- mostly employed by the contractors who are unfamiliar with the plant in a confined space; the presence of hazardous materials; large number of tasks performed under high pressure, and in various weather conditions (Othman *et al.*, 2014).

Where a safe system of work is void, there is an increased propensity for accidents or incidents to occur, therefore, it is an essential requirement, both legally and productively (Cooper, 2006; Spillane and Oyedele, 2013). Contractors and permanent employees are exposed to a number of inevitable hazards as most workers employed by contractors are unfamiliar with hazardous materials and more work performed under high pressure (Othman *et al.*, 2014). It is vital that training is done and refresher training shall be provided at least every three years, and more often if necessary, to each employee involved in operating a process to assure that the employee understands and adheres to the current operating procedures of the process (Hardy, 2013).

Contractors working in petrochemical industry face a great risk during maintenance work and the number of workers involved in a processing plant maintenance shutdown can be anywhere between 700 and 3000 at peak time (Othman *et al.*, 2014). According to Geldar (2010) cited in Elssayed, Hassan and Hosny (2012) workplaces having joint health and safety committees with greater worker involvement, both in numbers and executive capacity had lower injury rates. It is not surprising to find that the majority of some contractors do not encompass safety costs in their tender and this seems to suggest that these contractors find it difficult to develop and implement the most effective safety during the construction phase of their projects, construction is a multi-stage process as it includes conceptual, design construction, maintenance, replacement and decommissioning (Othman *et al.*, 2014).

According to Loosemore and Lee (2002) cited in Spillane and Oyedele (2013) where misinterpretations occur, there is a propensity for misguided instructions or signals, which may contribute or result in an accident or incident on site. The main concern of a contractor is how to save money and reduce costs and safety is usually considered a secondary priority in the company’s plans (Othman *et al.*, 2014).

In most projects due to limited availability of resources and time constraints, contractors are forced to select a subset of hazards recognition program elements for effective field implementation. However little is known regarding the relative influence of available methods (Albert, Hallowell and Kleiner, 2014). The construction industry consists of various parties such as clients, designer, consultants, general contractor, suppliers and subcontractors (Othman *et al.*, 2014).

The clients who demand the lowest contract costs have influenced this scenario and the contractors search for lower quality supplies and neglect safety issues (Othman *et al.*, 2014). According to Albert, Hallowell and Kleiner (2014) contractors often choose safety and hazard recognition program elements based on their subjective intuition with little regard to relative effectiveness. An additional training for the workers, which could be provided by contractors about equipment they use, before workers engage in their duty, would also help to prevent accidents (Vitharana, De Silva and De Silva, 2015). As contractors work under pressure to complete the task in a specified period, they may choose to take short cuts by using inappropriate equipment for the job (Othman *et al.*, 2014).

2.3.4 Asset Integrity

Asset integrity is a continuous process of knowledge and experience applied throughout the asset lifecycle to manage risk from design, construction, installation, operation, maintenance and finally abandonment phases of facility to maximize the benefit to the owner whilst safeguarding people, asset and environment (Ramasamy and Yusof, 2015).

It is the duty of the leadership team to ensure assets are maintained effectively and are safe to be operated at all times, mechanical equipment must be maintained to ensure that it will continue to operate correctly and safely (Hardy, 2013). According to Hought, Fowler and Grindrod (2013) effective asset integrity management programme is a prerequisite for continued safe operation of any chemical process plant and the challenge is not only to ensure that containment systems remain intact through use of appropriate inspection, testing, maintenance and repair strategies but that those strategies are implemented by competent and motivated personnel, and that they remain suited to the equipment, age and condition over time.

The objectives of asset integrity are compliance to all national regulatory bodies, company policies and standards, stay fit for purpose during operations under all circumstances, ensure all assets operate in safe manner and reliable within design parameters (Dutta and Madi (2014); Ramasamy and Yusof, 2015).

According to Hardy (2013) Process health and safety management standards require that an organisation establish and implement written procedures for maintaining equipment such pressure vessels, storage tanks, piping systems, pressure safety valves, emergency shutdown systems, and controls (monitoring devices, sensors, alarms and interlocks). In the eyes of the regulators that adherence to best practice in relation to process safety leadership, asset integrity management and competence management the ageing plants and financial global competition is a problem and these management systems are now hot topics and subjects for close examination by inspectors of high hazard manufacturing sites (Hought, Fowler and Grindrod, 2013).

An effective quality assurance program must be implemented to assure conformance to standards and codes, identify and record deficiencies and confirm that deficiencies have been corrected (Hardy, 2013). According to Hought, Fowler and Grindrod (2013) it is becoming increasingly difficult to achieve quality assurance programs for those companies that are having to operate plant well beyond planned retirement dates, with fewer people, brought about by growing financial pressures in the face of fierce global competition.

According to Hardy (2013) organisations must establish and implement written procedures to maintain the on-going integrity of facility equipment and they should include the following,

- Test and inspections on equipment following recognized and generally accepted good engineering practices, manufacturer's recommendations and operating experience for the conduct and frequency.
- Documentation of test and inspections – identifying date; name of the person performing test and inspections; serial number or other identifier; description of the inspection or test; results.
- Equipment deficiencies – correct deficiencies in equipment that are outside acceptable limits before further use or in a safe and timely manner when necessary means are taken to assure safe operation.
- New Equipment – assure that equipment as it is fabricated is suitable for the process application for which they will be used. Additionally, conduct appropriate checks and inspections to assure that equipment is installed properly and consistent with design specifications and the manufacturer's instructions.
- Material Control – assure that maintenance materials, spare parts and equipment are suitable for the process application for which they will be used.

2.3.5 Effective Communication

According to Loosemore and Lee (2002) cited in Spillane and Oyedele (2013) communication is one of the key components with regards to the management of personnel in the construction sector. Workers on a work site will only be protected with adequate chemical hazard controls in place and the necessary information about the chemicals they are working with (Safety Association for Canada upstream Oil and Gas Industry, 2012).

According to Purohit *et al.* (2018) proper management of hazards sporadically identified in the workplace can be done through effective process and individual or team who identified the hazard must ensure proper communication of the hazard to the appropriate workplace authority (manager, department head, or designated person). One of the key conclusions provided is that poor communication within work teams contributed to incidents, therefore effective means of communication, including verbally, visual and written must be adhered to at all times (Loosemore and Lee, 2002; Spillane and Oyedele, 2013).

Effective communication from all levels in an organisation is critical (Safety Association for Canada upstream Oil and Gas Industry, 2012). Petroleum refineries handle large quantities of hazardous chemicals often at extreme conditions of temperature, concentration and pressure and any mis-operation due to poor communication is prone to be a source of disaster that will cause heavy financial losses as well as casualties (Thomas and Babu, 2014). According to the Safety Association for Canada upstream Oil and Gas Industry (2012) it is vital that information feedback is available to the right people at the right time means that an effective communication system needs to be in place.

According to Eyayo (2014) occupational health and safety is a means of protecting and maintaining the physical, psychological and social health of workers and their families. The key to successful development and implementation of a chemical management process is communication and the systematic flow of information (Safety Association for Canada upstream Oil and Gas Industry, 2012).

2.4 Health and Safety Elements

Process health and safety elements investigated in this research include chemical exposure management, health and safety risk assessment, incident investigation, emergency response and audit compliance. According to Thomas and Babu (2014) petrochemical industry is a highly risk industry that involves chemical reaction, hazardous material, flammable explosion and any other risk that can occur to the permanent employees or the contractors. According to Kumar *et al.* (2017) occupational health and safety should be an integral part of production processes on an organisation, any industrial and production organisation in the oil and gas refinery should not be seen lacking in this area.

The primary objective of health and safety management system is to identify the major hazards associated with work activities and to ensure that appropriate controls are in place before work commences (Spillane and Oyedele, 2013).

Occupational health and safety can be viewed as the study of factors or conditions influencing the health and well-being of workers not only in the place of work but also at home with the aim of promoting health, safety and welfare of the workers and their family (Eyayo, 2014). It must be noted though that health and safety incidents still happen in the work place and it is important to investigate those incidents and appreciate root causes so that corrective actions can be assigned to employees that will close them and the intention is to prevent the similar incidents from happening again (Kumar *et al.*, 2017).

According to Abdelhamid and Everett (2000) occupational accidents occur due to one or more of the following,

- Failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started.
- Deciding to proceed with a work activity after the worker identifies an existing unsafe condition.
- Deciding to act unsafe regardless of initial conditions of the work environment.

2.4.1 Chemical Exposure Management

Chemicals can be classified on the base of hazards and the Globally Harmonised System divides hazardous chemicals in the workplace into different categories; physical hazards, health hazards and environmental hazards (Naafs, 2018). According to Reddy and Yarrakula (2016) chemical units include a wide range of hazards arising from the process itself, properties of the chemical and their handling, such as fire, explosion and exposure to toxic substances. However, there is a still real potential of major industrial accident with catastrophic impact. If avoidance of ignition sources is to be safely applied it is vital to be fully conversant with the details of plant and operations and it can also be important to be aware of material handling properties which are outside the scope of normal hazardous properties, but can affect what occurs on plant (Puttick, 2008).

Process safety management is critical in the chemical process industry and improving organisation knowledge and knowledge management capabilities is an important means to prevent chemical accidents and improve organisations' health and safety level (Chen, 2016). Not surprisingly, noise – induced hearing represents the most frequent occupational disease (25.3 %) in the petrochemical industry followed by the musculoskeletal diseases with (22.9%). Malignant tumors of the pleura and peritoneum follow with a proportional rate of 19%, six times higher than that recorded for the total industrial sectors (3.6%). Disease of the respiratory system are clearly proportionally more frequent (16.5%) compared to data reported from the total industrial sector (6%) (Naafs, 2018).

The major consequences of chemical disasters include impact on livestock, flora/fauna, the environment (air, soil, and water) and losses to industry (Reddy and Yarrakula, 2016). Chemical process hazards at a chemical plant can give rise to accidents that affect both workers inside the plant and members of the public who reside nearby (Chen, 2016). Biological monitoring of urine and blood provides an indication of exposure to chemicals in the workplace and is key part of health surveillance and exposure assessment (Lankulsen, Vichit - Vadakan and Taptagaporn, 2011).

According to Reddy and Yarrakula (2016) chemical disaster, though low in frequency but has the potential to cause significant immediate or long term damage, frequency and severity of chemical disasters has increased in last few years due to rapid development of chemical industries of a wider range. Urinary phenol is used as a biomarker of benzene exposure in some companies (table 4). However, urinary trans,trans-muconic acid (*t,t*-MA) or S-phenylmercapturic acid (S-PMA) is used as a biomarker of benzene exposure for much more reliable and sensitive occupational investigations (Lankulsen, Vichit - Vadakan and Taptagaporn, 2011). A small accident occurring at the local level may be a prior warning signal for impending and the disaster (Reddy and Yarrakula, 2016).

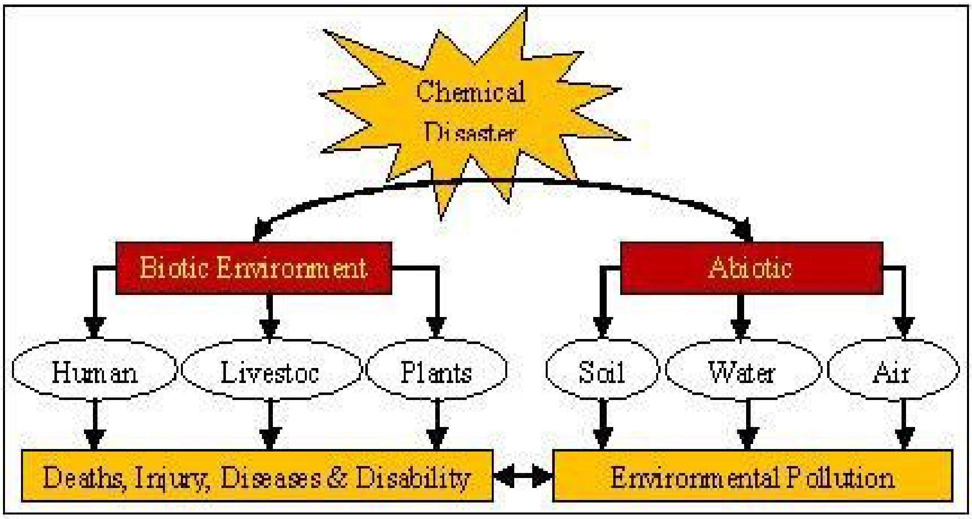

Figure 2.2 Impact of Chemical Disasters

2.4.2 Health and Safety Risk Assessment

Risk assessment is the evaluation of hazards to determine their potential to cause an accident. Identifying health and safety hazards in order to prevent and control them is very imperative to the health and well-being of the workers (Eyayo, 2014). In reality, risk assessment is something people do each and every day without giving it much thought, case in point, when driving, people assess the condition and circumstances of the roadway and adjust speed accordingly, or when caught in a rainstorm on the golf course, they assess the weather to determine if they play on or seek cover (Dunbar, 2014).

Hazard identification and risk assessment is carried for identification of undesirable events that can lead to a hazard, the analysis of hazard of this undesirable event, that could occur and usually the estimation of its extent, magnitude and likelihood of harmful effects (Purohit *et al.*, 2018).

When most people hear the term risk assessment they immediately think of insurance and indemnification (Eyayo, 2014). According to Kumar *et al.* (2017) health and safety risk assessment is a management tool that allows the workplace comply with her occupational policy, helps the workers do their jobs without damage to their health, enables the workplace meet her legal responsibilities, enables the workplace show due diligence in the protection. Promotion of health and safety of the workers, provides an auditable platform and involves the work force in protecting the health and safety of the workers. It is relatively easy for investigation programs to focus primarily on making changes to or correcting the physical environment, equipment, tools and machinery that may have contributed to the safety incident (Wachter and Yorio, 2014).

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) risk assessment reports should reflect the detail of the assessment and provide sufficient information to show how the decisions about risk and controls were made. The management of health and safety at work require employers to make a suitable and sufficient assessment of the health and safety risks to employees and non-employees, arising from their work activities (Kumar *et al.*, 2017). According to Wachter and Yorio (2014) these physical factors are typically easy to visually identify, understand and correct.

According to Dabup (2012) the risk assessment provides a systematic approach for the identification, management and reduction of the risk to an acceptable level. Risk assessment is now a common requirement of all health and safety legislation, the emphasis is now on preventing accidents and work related ill health, rather than just reacting to incidents, and making improvements after the event (Kumar *et al.*, 2017). According to Albert, Hallowell and Kleiner (2014) a critical component in health and safety risk management is to adequately identify hazards and mitigate its associated risk using safety program elements.

According Dunbar (2014) there are six-steps in the process of risk assessment, namely;

- Identification of a hazard
- Identification of the associated risk
- Assessment of the risk, which includes
    - The likelihood
    - The severity
    - Assigning a priority for correction

- Control of the risk, which includes
    - Elimination
    - Engineering a barrier
    - Administration controls
    - Personal protection equipment
- Documentation of the process
- Monitoring and review of the process.

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) hazard assessment records should include the following,

- The name of the assessor or assessment team personnel.
- Description of normal operations in the work area.
- Procedures used to assess exposure.
- Description of hazard and routes of entry to the body.
- Procedures used to assess existing control measures
- Conclusion from the assessment about whether the risk was significant or not.
- Action to be taken, including induction, training, emergency procedures, and health surveillance.
- The circumstances in which reassessment will be required.
- Signature, date, and position of assessor or assessment team.
- Signature, date, and position of the relevant person accepting the assessment.

According to Dabup (2012) risk assessment is a critical step in risk management and if done correctly, it determines the minimum level of preparedness in order to respond effectively and it involves applying qualitative or quantitative techniques to potential risks and it reduces the uncertainties in measuring risk and it usually involves frequency and severity. Hazard identification and risk analysis is a collective term that encompasses all activities involves in identifying hazards. Evaluating risk at facilities, throughout their life cycle, to make certain that risks to employees, the public or the environment are consistently controlled within the organisations risk tolerance level (Purohit *et al.*, 2018).

According to Dabup (2012) different outcomes from risk assessments are, namely;

- *Risk Aversion*: This involves a conscious commitment and decision on an organisation's part to avoid completely a particular risk by discontinuing the operation producing the risk and it presupposes that risk has been identified and evaluated.

- *Risk Acceptance*: This involves creating decision tables or standards for deciding what risks are acceptable for individuals, organisations or the society. What is acceptable may differ for each group.
- *Risk Retention*: The risk is retained in the organisation where any consequent loss is financed by the organisation.
- *Risk Transfer*: this refers to the legal assignment of the cost of certain potential losses from one party to another. The most common way of affecting such transfer is by insurance. Hence an insurance company undertakes to compensate the insured organisation against losses resulting from the occurrence of an event specified in the insurance policy.
- *Risk Reduction:* A goal of zero injuries is a challenge, but may not be credible since risk can only be reduced and not completely eradicated. Organisation can design a management system, which will reduce or eliminate all aspects of accidental loss that lead to wastage of an organisation's assets. It relies on the decline of risk within the organisation by the implementation of loss control programme whose basic aim it to protect the company's assets from wastage caused by accidental loss.

2.4.3 Incident Investigation

According to the OSHAct 85 of 1993 an incident investigation team shall be established and consist of at least one person knowledgeable in the process involved, including contract employee if the incident involved work of the contractor, and other persons with appropriate knowledge and experience to thoroughly investigate and analyse the incident. According to Hardy (2013) organisations must have an active, aggressive incident evaluation program to identify the underlying causes of these incidents and break the sequence of events that can lead to an accident and such incidents include those that could be called a near miss and incident or problem investigation should be factored back into the hazard analysis.

According to Bond (2007) the sole objective of the investigation of an accident or incident under regulations shall be the prevention of accidents and incidents. According to Oakley (2003) cited in Wachter and Yorio (2014) accident investigation programs can differ in the actual content that is focused on during the investigation. A failure to investigate the incidents and fix the root cause allows the opportunity for the incidents to reoccur (Hardy, 2013).

According to Wachter and Yorio (2014) more than 80% of accidents are still attributed to unsafe acts, it is critical that accident investigations effectively explore the reasons a worker's behaviour or performance led to an incident in an effort to correct those management system deficiencies and some of these reasons could be lack of knowledge, lack of motivation or job distractions that caused unsafe behaviours and human error to occur. ISO 18001 suggest that the process of investigating incidents should provide the collective with overlapping knowledge sets on what defined an incident for the organisation and the types of corrective actions that are applicable and it further suggests that the process must be impartial and objective.

As a primary element to any investigation, the exact casual factors that led to the safety incident must be determined in order to effectively make changes that mitigate future risk (Oakley, 2003; Wachter and Yorio, 2014). It shall not be the purpose of such an investigation to apportion blame or liability and organisations should focus on preventing accidents, not just reporting problems, and this requires root cause analysis (Bond, 2007). According to Wachter and Yorio (2014) accident investigations can vary in the length of time between the time the incident occurred and the time investigation is initiated.

According to Lerman *et al.* (2012) when evaluating an incident that may be due to fatigue, the two major steps are first to evaluate if the individual was susceptible to fatigue and second to evaluate whether the performance, behaviour, and details of the event would be consistent with inaction or inattention.

According to ISO 18001 the overall impact of accident investigation characteristics on safety performance statistics is relatively minor. A major reason to investigate quickly is to accurately record all the factors that contributed to the incident (Wachter and Yorio, 2014). Logically, there can be a resulting difference in investigation quality between investigations that are limited immediately following an incident and those that are initiated days following the incident (Wachter and Yorio, 2014).

Human error is the starting point of an investigation, not the end point and to do something about error, one must look at the system in which people work and focus must extend past "what occurred" to why do it occur (Bridger, 2015). Determining that the individual was susceptible to fatigue should not support fatigue as a cause or contributing factor to the incident unless the behaviours are also consistent with fatigue (Lerman *et al.*, 2012).

According to Vitharana, De Silva and De Silva (2015) failure to appoint a safety officer is often identified as a cause of scarcity of site safety. However effects of safety attitude of workers and safety training has not often been studied, although no willingness to follow safety norms by workers is identified as a cause of poor safety practices.

2.4.4 Emergency Preparedness and Readiness

The first step for emergency preparedness and maintaining a safe workplace is defining and analysing hazards (Purohit *et al.*, 2018). According to Hardy (2013) organisations must plan for an emergency and be prepared to respond and no matter how hard organisations try to build their systems safety, designs will be flawed, people will make mistakes, components will fail, software will do the unexpected, and environment conditions will exist that are beyond the company's control.

According to Stojkovic' (2013) practical exercises for members of the rescue group for casualty rescues in confined spaces must be maintained regularly and within the deadlines. Organisations must plan for an emergency and be prepared to respond, employers must develop an emergency action plan that includes evacuation and shelter in place instructions and training in the use of personal protective equipment (Hardy, 2013).

In case a worker in a confined space is threatened, the worker who observes should not enter unless the emergency alert informed other workers (Stojkovic', 2013). Employees must be trained to this plan for it to be effective, and alarm systems should be implemented to warn employees that emergency conditions exist (Hardy, 2013). All appropriate personal protective equipment, such as protective breathing masks, protective zones with associated rope, lamp, etc. must be ready and near the entrance to the confined space (Stojkovic', 2013). Training must accompany the operating procedures, with an emphasis on what employees should do in case of emergency (Hardy, 2013).

According to Stojkovic' (2013) a worker-observer should act in accordance with predetermined rescue mode, as follows,

- To immediately alert the surrounding workers, rescue group, party fire and health centre.
- To slip inside the tube inlet for clean air, thereby providing increased ventilation and closed the endangered area.
- Worker, which should indicate a vigilant eye, cannot enter into hazardous areas without adequate means of personal protection and if not provided workers who will watch from the doorway.
- After the rescue worker enters, other workers outside buildings urgently need to prepare all the aids to pull the killed and fingering first aid.
- Workers, observers must continuously through the inlet view monitor employee-rescuers, and in the case of invisibility must be with him regarding using agreed signals.

- If the injured worker is unconscious, it is necessary to immediately proceed with artificial respiration mouth to mouth, or using breathing apparatus. If there is a respirator at hand, in these cases the doctor does not have to always be near. When CPR must be renewed and during transport the injured health centre or hospital, and artificial respiration was discontinued as soon as the victim for consciousness returned.

2.4.5 Audit Compliance

Audit compliance is a proactive attempt to identify gaps to comply and intervene when non-compliance is ascertained (Hardy, 2013). Once the unsafe acts are discovered, then investigations are needed to understand why these behaviours occurred that led to human performance errors that often involve psychology and employee perception factors (Wachter and Yorio, 2014). Compliance audits provide a means for assuring that the procedures and practices in process health and safety management systems are being followed and are adequate (Hardy, 2013).

Compliance audits must be conducted at specific periods depending on which tier, 1, 2 or 3 (Hardy, 2013). Workplace hazards contribute significantly to the overall population's morbidity, mortality, financial and social costs, which are all principle reasons for government, private and public sector support of occupational health and safety (Ford, Haskins and Wade, 2014). The audit must be conducted by a trained individual or team, and the auditing effort should be planned to ensure success (Hardy, 2013).

2.4.6 Personal Protective Equipment

Personal protective equipment means any equipment which is intended to be worn or held by a person at work and which protects him/her against one or more risks to his/her health or safety and any additional accessory designed to meet that objective (Purohit *et al.*, 2018). Using personal protective equipment is one of the health and safety measures, and is often regarded as the last resort, supplementary to control measures, in providing protection to the employees (International Labour Organisation, 2017). According to Vitharana, De Silva and De Silva (2015) dislike to wear personal protective equipment, which are categorised under safety equipment, is often identified as the cause of poor safety practices. Personal protective equipment is usually chosen to provide protection appropriate to each of type of hazard present (Purohit *et al.*, 2018).

Low level of awareness toward using personal protective equipment is also frequently identified as a possible cause of poor safety practices (Vitharana, De Silva and De Silva, 2015). Lack of awareness about site safety and dislike to wear personal protection equipment are main causes of poor safety practices in construction sites (International Labour Organisation, 2017). Workers must be trained to use and maintain personal protective equipment properly (Purohit *et al.*, 2018). Unavailability of personal protective equipment also contributes to poor safety practices (Vitharana, De Silva and De Silva, 2015).

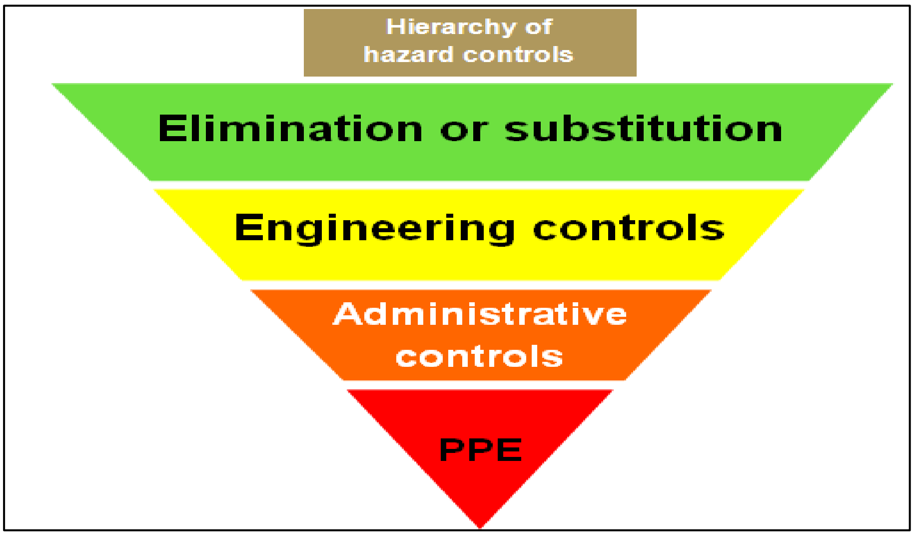

Figure 2.3 Hierarchy of Hazard Controls

According to the Safety Association for Canada's upstream oil and gas industry (2012) the hierarchy of hazard controls is as follows:

- *Eliminate or substitution*: controls the chemical hazard by removing the chemical outright from the work site. Processes are avoided or adjusted to eliminate the need for the chemical, or a safer alternative is used in place of a more hazardous chemical. If elimination or substitution is not possible, engineering controls are the next possible choice.
- *Engineering controls*: These are used to remove a hazard or place a barrier between the worker and the hazard. Engineering controls should always be considered first, where elimination or substitution is not possible. Administrative controls are often used together with engineering controls. The basic types of engineering controls are process controls, enclosure and/or isolation of emission source, and ventilation.
    - Basic engineering controls are methods that keep the chemical "in" and the worker "out" (or vice versa). Examples include basic ventilation or isolation processes that can be done on the spot without assistance, such as opening a window or door.

    - Advanced engineering controls are methods that are built into the design of a plant, equipment, or process to minimize the hazard. They include designs or modifications to plants, equipment, ventilation systems, and processes that reduce the source of exposure.
- *Administrative controls*: Involve the work process and worker, and include such measures as company policies, safe work procedures, training, work rotation, and signage.
- *Personal protective equipment*: this is the last line of defence against the hazard, and is used where the hazard cannot be eliminated or sufficiently reduced by engineering or administrative controls. Personal protective equipment does not remove the hazard; it only inserts a barrier between the work and the hazard. Personal protective equipment includes but is not limited to specified protective clothing and respiratory protective equipment.

The employer and workers must understand the limitations of the personal protective equipment (Purohit *et al.*, 2018). Personal protective equipment include hard hats, safety glasses and goggles, safety shoes, hearing protection, respiratory protection, and protective clothing such as fire resistant clothing where required and in addition, procedures should be established to assure compliance with applicable regulations and standards such as hazard communications, confined space entry and process health and safety management (Kulkarni, 2017). Personal protective equipment and clothing is used when other controls measures are not feasible and where additional protection is needed (Purohit *et al.*, 2018).

2.4.7 Fitness to Work

The increasing healthcare cost and workers' compensation expenses relating to modifiable health behaviour such as alcohol use, smoking and obesity, occupational health professionals are moving toward occupational health programs that not only address workplace hazards, but also support health lifestyle behaviours (Ford, Haskins and Wade, 2014). Problematic substance use is a social care issue and it is not just a health or criminal justice issue (Galvani, 2015).

People start using for many reasons, among these are experiences of sexual and domestic violence and abuse, feelings of low self-esteem and self-worth, as well as mental and physical distress (Galvani, 2015). People with problematic substance use will often be socially isolated and are likely to have a number of co-existing social and health care problems (Galvani, 2015).

According Ford, Haskins and Wade (2014) given the increase in the rate of obesity and the fact that employed adults spend a quarter of their lives at work, the contribution of obesity to morbidity and mortality in working populations is epidemiologically, productively and economically significant. Economically, obesity directly contributes to the rising cost of health insurance as well as workers' compensation expenses (Ostbye, Dement and Krause, 2007).

A NIOSH report reviewed studies that examined the association between long working hours and illnesses, injuries, health behaviours, and performance. In general, overtime was associated with poorer perceived general health, unhealthy weight gain, increased injury rates, more reported illnesses, increased mortality, and poorer neuropsychological test performance (Lerman *et al.*, 2012).

2.4.8 Fatigue Management

The organisation must arrange schedules of work that provide sufficient opportunities for rest, training to support fatigue management, and procedures for monitoring and managing fatigue within the organisation (Lerman *et al*., 2012). The major cause of fatigue is not having obtained adequate rest or recovery from previous *activities* and in simple terms, fatigue largely results from inadequate quantity or quality of sleep (Canada Aviation Industry, 2007).

The potential benefits of a nap in improving alertness and performance during routine operations, with a resulting increase in health and safety margin, may outweigh the potential negative effects of a short period of sleep inertia (Lerman *et al.,* 2012). The quality (how good) and the quantity (how long) of sleep are important for recovery from fatigue and maintaining normal alertness and performance (Canada Aviation Industry, 2007). Variation in work activity across a shift can help to relive fatigue, especially where the worker has a range of tasks to complete, each with differing mental and physical demands and rotating routine sedentary mental tasks with physical tasks can promote alertness or conversely help to relieve physical fatigue (Lerman *et al.,* 2012).

According to Canada Aviation Industry (2007) we live in a 24 hour society where many different work patterns have developed beyond the traditional Monday to Friday 9 to 5 routine. Safety and productivity in the workplace are intimately related to worker health (Lerman *et al.,* 2012). An increasing proportion of the workforce is engaged in shift work and non-traditional schedules and between 15-30 percent of the workforce of industrialised countries is engaged in shift work (Canada Aviation Industry, 2007).

According to Lerman *et al.* (2012) rates of absenteeism in extended hours industries range from 6% to 12% compared with the national average of about 2% and an absent worker in a 24/7 operation must either be replaced (often with someone paid overtime) or co-workers must pick up the slack (potential for fatigue, safety and morale problems). Fatigue is an experience of physical or mental weariness that results in reduced alertness (Canada Aviation Industry, 2007).

2.4.9 Housekeeping in Workplace

According to Ness (2015) effective housekeeping can eliminate some workplace hazards and assist in getting a job done healthy and safe. The unsafe conditions are usually present until corrected and they are unlike unsafe acts that require "catching" workers committing unsafe acts, which could be sporadic over time and place (Wachter and Yorio, 2014).

According to Health and Safety Ontario (2011) good housekeeping at work benefits both employers and employees alike and good housekeeping can achieve the following,

- Eliminate clutter which is a common cause of accidents, such as slip, trips and fall, fires and explosions.
- Reduce the chances of harmful materials entering the body (e.g., dusts, vapours)
- Improve productivity (the right tools and materials for the job will be easy to find)
- Improve your company's image (good housekeeping reflects a well-run business. An orderly workplace will impress all who enter it – employees, visitors, customers, etc.)
- Help your company to keep its inventory to a minimum (good housekeeping makes it easier to keep an accurate count of inventories).

One of the most common findings in workplaces is poor housekeeping i.e. untidiness, disorder, poor storage of materials and stock (Ness, 2015).

According to Health and Safety Ontario (2011) there are signs of poor housekeeping and they are,

- Cluttered and poorly arranged work areas
- Untidy or dangerous storage of materials (e.g., materials stuffed in corners, overcrowded shelves, etc.)
- Dusty, dirty floors and work surfaces
- Items that are in excess or no longer needed
- Blocked or cluttered aisles and exits
- Tools and equipment left in work areas instead of being returned to roper storage places
- Broken containers and damaged materials

- Overflowing waste bins and containers
- Spills and leaks

The smallest accidents can happen from the most innocuous activity and it is very important to keep the work area tidy from debris and from the materials and substances that are part of the everyday work process (Ness, 2015).

2.4.10 Noise Exposure Management

Exposure to noise for an extended period of time may produce subjective feelings of unpleasantness and an increase in complaints of fatigue (Lerman *et al.,* 2012). Occupational noise exposures causes between 7 and 21 percent of the hearing loss among workers in general lowest in industrial countries, where the incidence is going down and highest in the developing countries (Naafs, 2018).

Noise may ameliorate performance decline due to circadian cycle effects by increasing the general level of arousal and this effect is dependent on variables such as the nature of the noise, the nature of the task, the time of day, and on personal factors (Lerman *et al.,* 2012). According to Naafs (2018) hearing loss due to noise exposure in the workplace is a significant health problem with economic consequences.

Noise induced hearing loss is the occupational disease most frequently reported to the petrochemical safety authority (Naafs, 2018). Studies of the effects of noise on performance have been primarily conducted in laboratory settings and sound can be sedating (continuous droning/humming) or stimulating (music of varying tempos, conversation) in its effect (Lerman *et al.,* 2012).

It is difficult to distinguish between noise induced hearing loss and age-related hearing loss at an individual level and most of the hearing loss is age-related but men lose hearing more than women do (Naafs, 2018).

2.5 Technical Elements

Five technical elements are considered important in this research, namely, management of change, process hazard analysis, process health and safety information, design integrity and human errors.

2.5.1 Management of Change

Organisations should not assume that these minor changes have no impact on health and safety and many accidents have resulted from small changes that did not appear to have an effect on health and safety prior to the incident (Hardy, 2013). According to the Safety Association for Canada upstream Oil and Gas Industry (2012) employers must maintain own management of change process but must also consider chemical management and it is important to note that temporary as well as permanent changes must be considered. The changes include modifications to process equipment, procedures and processing conditions and these changes must be thoroughly evaluated to assure that health and safety in the process industry is maintained (Hardy, 2013).

The changes must be thoroughly evaluated to assure that health and safety in the process industry is maintained and the process health and safety information is critical to assist in identifying the hazards and risks associated with the process (Hardy, 2013). Accidents can take place even where process health and safety management systems exist and the probability of such occurrence increase if documentation is deficient (Tzou *et al*., 2004).

Information related to toxicity, permissible exposure limits, physical data, reactivity, corrosivity, chemical stability, thermal stability, and hazards associated with inadvertent mixing should be appreciated by all involved (Hardy, 2013). According to Tzou *et al*. (2004) managing health and safety related information inadequately has been cited as a significant factor to industrial accidents. Information on the chemicals used or produced, technology and equipment should be understood by everyone working in the process plant (Hardy, 2013).

The other vital information is material safety data sheets, maximum upper/lower limits in material of construction, relief systems, safety systems, and ventilation systems (Hardy, 2013).

Figure 2.4 ARCO Channelview Compressor Explosion

According to Ness (2015) an explosion in ARCO Channelview took place July, 1990. A waste water tank exploded during the restart of a compressor. The nitrogen purge had been significantly reduced during maintenance, and a temporary oxygen analyser failed to detect the build-up of a flammable atmosphere in the tank. When the compressor was restarted, flammable vapours were sucked into the compressor and ignited. The flashback of the flame into the headspace of the tank caused an explosion that killed 17 people and damages were estimated to be $100 million. The waste water tank was not considered part of the operating plant. Hence, the management and workers did not understand that a chemical reaction was taking place in the tank, generating oxygen. The lack of understanding enabled a series of poor decisions, such as discontinuing the nitrogen purge, poor design and location of the temporary oxygen probe, no management of change review of the decisions, and no pre-startup safety review. Key lessons in this incident are as follows,

- Ensure that proper management of change procedures are followed before any maintenance work is performed.
- In this incident, the workers did not know that a chemical reaction that could produce oxygen build up was taking place in the tank. Therefore, they did not comprehend the importance of continuing an effective nitrogen purge.

According to the Safety Association for Canada upstream Oil and Gas Industry (2012) the following changes related to chemical hazards are examples of changes that would require a technical management of change, namely;

- Replacing an original chemical with one from a different chemical supplier or following different material specifications.
- Changing equipment temporarily or permanently, which adds new exposure points e.g., adding tanks, vessels, or block/bleed valves or replacing old equipment with a different type.
- Changing the operating temperature and pressure range to exceed design and planned operating limits.
- Changing or creating products at the work site.
- Transforming or changing the formation of chemicals (may affect compatibility, flammability, toxicity).
- Using materials that are changed in a formation or produced in a process.
- Field – mixing or blending chemicals.
- Changing operating procedures that impact chemical exposure.

2.5.2 Process Hazard Analysis

According to Hardy (2013) process hazard analysis is defined as a systematic approach for identifying, evaluating and controlling the hazards of processes involving highly hazardous chemicals. The purpose of hazard identification is to highlight the critical operations of tasks, that is, those tasks posing significant risks to the health and safety of employees as well as highlighting those hazards pertaining to certain equipment due to energy sources, working conditions or activities performed (Purohit *et al.,* 2018).

The process hazard analysis is vital to the health and safety efforts as it provides information to assist management and operations team to improve health and safety by reducing risk (Hardy, 2013). Analyses examine the system, subsystems, components, and interrelationships, the elements involved are training, maintenance, operational and maintenance environments and system/component disposal (Department of Transport [USA], 2000).

Team findings and recommendations must be documented with resolutions and actions communicated to operations and maintenance along with a written schedule of when these actions are to be completed (Department of Labour [USA], 2016). Commonly used study methodologies are hazard identification (HAZID), hazard and operability (HAZOP), What-If analysis, safety integrity level (SIL), failure mode and effects analysis (FMEA) and layer of protection analysis (LOPA).

According to Department of Transport [USA] (2000) steps in performing a hazard analyses are,

- Describe the system.
- Perform functional analysis if appropriate to the system under study.
- Develop a preliminary hazard list.
- Identify contributory hazards, initiators, or any other causes.
- Establish hazard control baseline by identifying existing controls when appropriate.
- Determine potential outcomes, effects, or harm.
- Perform a risk assessment of the severity of consequence and likelihood of occurrence.
- Rank hazards according to risk.
- Develop a set of recommendations and requirements to eliminate or control risks.
- Provide managers, designers, engineers, and other affected decision makers with the information and data needed to permit effective trade-offs.
- Conduct hazard trading and risk resolution of medium and high risks. Verify that recommendations and requirements identified have been implemented.

- Demonstrate compliance with given health and safety related technical specifications, operational requirements and design criteria.

To prevent or minimize process health and safety incidents in a petrochemical industry process hazard analysis is conducted by a team with expertise in engineering and process operations, including at least one employee who has experience and knowledge on the system (Hardy, 2013). A non-critical accident that has a realistic chance of occurring may not require further study and frequency may be characterised qualitatively by terms such "frequent" or "rarely" (Department of Transport [USA], 2000). The process hazard analyses require process health and safety information to be clear and understood by all team members involved (Hardy, 2013).

2.5.3 Process Health and Safety Information

According to Chen (2016) knowledge is critical organisation asset which will create value for improving organisation competitive advantages and safety level. The relationship between knowledge and information is interactive; health and safety knowledge therefore, encompasses awareness of occupational health and safety risks, including an evaluation of occupational health and safety programmes in an organisation (Okoye, Ezeokonkwo and Ezeokoli, 2016). Among knowledge dimension, there are two kinds of knowledge, explicit knowledge and tacit knowledge, explicit knowledge consists of facts, rules, relationships, and policies that can be faithfully codified in paper or electronic form and shared without need for discussion (Chen, 2016).

Tacit knowledge represents knowledge based on the experience of individuals and tacit knowledge is knowledge housed in the human brain, such as expertise, understanding, or professional insight formed as a result of experience (Chen, 2016). Tacit knowledge is highly personal, context-specific, and therefore hard to formalise and communicate (Chen, 2016).

According to Tzou *et al.* (2004) managing health and safety related information inadequately has been cited as a significant factor to industrial accidents. There is clear distinction between data, information and knowledge and data has commonly been seen as simple facts that can be structured to become information (Chen, 2016). Accidents can still take place where process safety management systems exist and the probability of such occurrence increase if documentation is deficient (Tzou *et al.*, 2004).

Human behaviour is a major contributor to occupational health and safety issue cannot be tackle effectively without interference of employers with a particular pattern of behaviours as important criteria needed to change employee's behaviours (Zin, 2012). To enhance safety practices, once of the major needs in the construction industry is to enhance professionals' interest in active safety management and implementation of awareness programs, which must be developed and implemented among construction workers (Vitharana, De Silva and De Silva, 2015).

According to Chen (2016) knowledge is one of the most important sources to prevent accidents and guarantee process safety in the chemical process industry and there are numerous definitions of knowledge in the knowledge domain. Awareness on possible risk factors and knowledge on how to reduce these risk factors among workers and contractors will enhance site safety (Vitharana, De Silva and De Silva, 2015).

Knowledge is a fluid mix of framed experience, values expertise, contextual information and insight that provides a suitable environment and a structure for evaluating and incorporating new information and experiences (Chen, 2016). Sources of health and safety knowledge include incident investigation, teamwork, collaborations, and survey of safety culture (Okoye, Ezeokonkwo and Ezeokoli, 2016). Knowledge is more than information, since it involves an awareness or understanding gained through experience, familiarity or learning (Chen, 2016).

2.5.4 Design Integrity

Design integrity is assurance and verification function that ensure a product, process, or system meets its appropriate and intended requirements under stated operating conditions (Hardy, 2013). According to Baby (2008) cited in Ramasamy and Yusof (2015) design integrity provides assurance that facilities are design in accordance to governing standards and meet specified operating requirements without compromising on health and safety, accessibility, operability and maintainability

According to Duguid (2008) the most frequent specific problems during design for safety inadequate are, namely;

- Alarms to detect high temperatures at critical locations or loss of cooling, particularly where runaway reactions are possible. Also lack of skin thermocouples to detect high temperatures in fired heater tubes.
- High level alarms/shutdowns totally independent of the normal level control system to minimize the risk of overflow from tanks or vessels.
- Spring closed valves to remind operators to remain in attendance while draining water bottoms from equipment containing flammables or toxics to an open drain. Also installing a totally

independent low interface level shutdown system where such drainage is under automatic control.

- Over reliance on check valves to prevent reverse flow.
- Inadequate attention to design for safety when implementing modifications to plant or operation.

Process design and procedures often change in a petrochemical industry and the associated risks may increase (Hardy, 2013). Most human machine interface design principles and guidelines focus on aspects of usability, whilst usability is important for reducing the incidence of human error, more is required of a safe human machine interface (Hardy, 2013).

2.5.5 Human Factor

The human element of the system has one of the biggest potentials for either causing or preventing an accident and safe job performance by operating, maintenance personnel and contractors has a tremendous positive impact on health and safety (Karthika, 2013). Complex interaction between humans and machines is limited by the fact that whereas humans have natural intelligence, which enables us to interpret situations according to the context, this ability is absent in most machines and very restricted in even the most advanced (Hardy, 2013).

In general, software does not allow machines to adapt to unforeseen conditions, so computers are limited in their actions and cannot adapt to given situations (Hardy, 2013). Employers and employees with good health and safety behaviour are particularly playing a significant role in achievement of safety compliance to occupational health and safety improvement in industry (Zin, 2012). According to Bond (2007) it is clear that in the vast majority of accidents or near misses employees were acting with the best intentions and did not expect a serious event to occur from their actions. Human error is not the sole cause of failure, but it is a symptom of a deeper trouble (Bridger, 2015). It has to be accepted that to err is human but one can learn from these events and share with others the lessons learned (Bond, 2007).

2.6 Operational Elements

Operational elements include pre-start up and shutdown reviews, operating procedure, control of ignition source, control of confined space entry and permit to work (Hardy, 2013). The evolution of petroleum refining from simple distillation to today's sophisticated processes has created a need for health and safety management procedures and safe work practices (Kumar *et al.,* 2017).

Often accidents occur in the transition between operational phases, rather than when the process system is up and running in "steady state" mode, start up and shutting down new and existing process systems can be hazardous because changes to design or operations may be made in real time to meet schedule temperatures and pressures, potentially introducing new hazards (Hardy, 2013). Hazard identification and risk assessment studies performed once a process is near start up, during operation or before decommissioning are typical done in a plant environment (Purohit *et al.,* 2018).

A pre-start up and shutdown review is a valuable tool to assure that operating procedures are in place, hazards are understood, engineering drawings are updated, and emergency shutdown procedures have been communicated accordingly (Hardy, 2013). Human exposure to ammonia may cause the short term health effects like burn the skin and damage eyes, inhaling ammonia can irritate the nose and throat causing coughing and wheezing and higher exposures may cause a build-up of fluid in the lungs (pulmonary oedema) with severe shortness of breath (Ezejiofor, 2014).

Figure 2.5 Fertilizer Plant in Port Neal Explosion

According to Ness (2015) a massive explosion occurred in the ammonium nitrate portion of Terra Industry's fertilizer plant in Port Neal Dec 13, 1994. Ammonia may cause asthma like allergy and can cause asthma attacks and permanent lung damage (Ezejiofor, 2014).

According to Ness (2015) the explosion occurred after the process had been shut down and ammonium nitrate solution was left in several vessels. Multiple factors contributed to the explosion, including strongly acidic conditions in the neutralizer, application of 200 – psig steam to the neutralizer vessel, and lack of monitoring of the plant when the process was shut down with materials in the process vessels. Four people were killed and 18 injured. Serious damage to other parts of the plant caused the release of nitric acid into the ground and anhydrous ammonia into the air.

According to Ezejiofor (2014) ammonia acts as an alkali, and anhydrous ammonia reacts with moisture in mucosal surface (eyes, skin and respiratory tract) to produce ammonium hydroxide, which may cause injury and ammonia is a severe respiratory tract irritant with acute inhalation effects including dry mount with sore throat, and eyes, tight chest, headache, ataxia and confusion.

According to Ness (2015) the investigation concluded that the conditions that led to the explosion occurred due to lack of safe operating procedures. There were no procedures for putting the vessels into a safe state at shutdown, or for monitoring the process vessels during shutdown. The investigating team found that other producers either emptied the process vessels during a shutdown or maintained the pH above 6.0. Also, other producers either did not allow steam sparges or, if steam sparges were used, they were conducted under direct supervision of operators. The investigating team also noted that no hazard analysis had been done on the ammonium nitrate plant, and that personnel interviewed indicated they were not aware of many of hazards of ammonium nitrate. Key lessons in this incident were, namely;

- Operating procedures need to cover all phases of operation. The lack of procedures for shutdown and monitoring the equipment during shutdown led operators to perform actions that sensitized the ammonium nitrate solution and provided energy to initiate the decomposition reaction.
- Because there had been no hazard identification study, personnel did not know about the conditions that sensitise ammonium nitrate to decomposition. A hazard assessment of the shutdown step would have revealed that the pH of the neutralizer could not be measured if there was no solution flowing through the overflow line, and that the temperature of the neutralizer could not be accurately measured without any circulation in the tank. A complete hazard identification study would have covered backflow of ammonium nitrate into the nitric acid line, and better design solution could have been identified.

2.6.1 Pre-Startup and Shutdown Reviews

According to Duguid (2008) during plant shutdown and start-up operators should be reminded of the following,

- To be aware that over half of all incidents occur during shutdown, start-up, maintenance and abnormal operations.

- To be aware of the risks of runaway reactions due to changes in operations such as charging an incorrect reactant, changing the order or rate of charging, temporary shutdowns or loss of cooling.
- To be aware that they should not depart from written operating procedures without advising supervision. In emergency situations this may have to be after the event.
- To be aware of the need to only use alarms/shutdowns as a backup, rather than relying on them completely.
- To be aware of the need to physically check that equipment is de-pressured and drained in the presence of the maintenance crew directly before work on it starts. Also that the crew know exactly what they may work on.

2.6.2 Operating Procedure

Through the completion of job hazard analysis, hazards are identified and sometimes cannot be eliminated or engineered out of a particular task, safe work procedure are step by step instructions that allow workers to conduct their work safely when hazards are present (Purohit *et al.,* 2018). Operating procedures describe the tasks that must be performed, data to be recorded, and operating conditions to be maintained (Hardy, 2013).

According to Kumar *et al.* (2017) procedures should be established to assure compliance with applicable regulations and standards such as hazard communication, confined space entry and process safety management. The procedures also identify the health and safety precautions, operating procedures must be clear, concise, accurate and consistent with process safety information derived from the process hazard analysis (Hardy, 2013).

According to Ness (2015) an explosion and fire at the Formosa Plastics Corporation occurred April 23, 2004 and killed five workers and seriously injured two others. The vent destroyed most of the polyvinyl chloride manufacturing facility and ignited polyvinyl chloride resins stored in an adjacent warehouse. Concerns about the ensuing smoke from the fire forced a two-day community evacuation. On the day of the incident, the reaction and the power washing had been completed in reactor D306 and the operator went downstairs to drain the reactor. It is believed that, at the bottom of the stairway, he turned in the wrong direction, toward an identical set of four reactors that were in the reaction phase of the process. By mistake, the operator likely attempted to empty reactor D310 by opening the bottom and drain valve. The bottom valve, however, was above 10 psi. Because this tank was currently processing a batch of Polyvinyl Chloride (PVC) at high pressure, the valve did not open. In case of an emergency, operators could follow an emergency transfer procedure that required them to open the bottom valve and the transfer valve to connect the reactor to an empty reactor. However, during an emergency transfer, the reactor pressure is greater than 10 psi, and the safety interlock would prevent the opening of the bottom valve. Therefore, the company added a manual interlock bypass so that operators could open the valve and reduce reactor pressure in an emergency. The bypass incorporated quick-connect fittings on air hoses so that operators could disconnect the valve actuator from its controller and open the valve by connecting an emergency air hose directly to the reactor. It is likely that the operator thought he was at the correct reactor D306 and that its bottom valve was not functioning. When the bottom valve did not open, he switched to the backup air supply and overrode the interlock. He did not contact the upstairs reactor operator or shift foreman to check the status of the reactor before doing this. Once the bottom valve was opened, Vinyl Chloride Monomer (VCM) poured out of the reactor and the building rapidly filled with liquid and vapour. A deluge system in the building activated and a shift supervisor came to the area to investigate. The VCM detectors in the building were reading above their maximum measureable levels. The shift foreman and reactor operators took measures to slow the release, rather than evacuate. The VCM vapours found an ignition source and several explosions occurred. The root cause was that the operator overrode an interlock, which led to a release of hot, pressurised VCM. Formosa Plastics did not have comprehensive written procedure, such as requiring shift supervisor approval, for managing interlocks on the vessels. Employees were unprepared for a major accident at the facility. The reactor groupings had similar layouts. The operators on the lower levels were not given radios, which would have made communication with the reactor control operators on the upper level easier. Formosa eliminated an operator group leader position and gave its responsibilities to the shift supervisors, who were not always as available as the group leaders used to be. Key lessons learned in this incident are,

- Operators and engineers must follow operating procedures and protocols intelligently, and, when the process moves outside the operating envelope, stop work, get experienced advice as needed, and shutdown as appropriate.
- Operator should have obtained supervisory approval to override the interlock.
- Operators were not given tools (radios for communication between floors) to make it easier for them to follow their procedures. It is management's responsibility to provide the tools and controls necessary for operators to do their jobs safely.
- When Formosa plastics took over the plant, it made staffing changes, such as reductions in staff and changes in responsibilities. It did not conduct a formal management of organisational change review to analyse the impact of these changes.
- This explosion also illustrates the importance of emergency response planning. When the VCM release occurred, gas detectors in the building and a deluge system were activated. Operators

responded by trying to mitigate the release. The proper response to these activations would have been to evacuate.

Operating procedures shall be readily accessible to employees and the operating procedures shall be reviewed as often as necessary to assure that they reflect current operating practice (Hardy, 2013). According to Kumar *et al.* (2017) work practices are procedures that limit worker exposure by reducing exposure times or keeping workers away from contaminants. The procedures should be formally reviewed and updated as necessary to assure that they are consistent with existing processes (Hardy, 2013). A well-meaning "no blame" approach is not altogether desirable as it is impractical to condone reckless non-compliance with operational procedures (Bond, 2007).

According to Okoye, Ezeokonkwo and Ezeokoli (2016) health and safety have become an integral component in the workplace as employers, labour unions and other engage in trainings and procedures to ensure compliance with health and safety standards and also to keep a healthy workplace. The employer shall certify annually that these operating procedures are current and accurate (Hardy, 2013).

2.6.3 Control of Ignition Source

According to Puttick (2008) fire and explosion hazard assessment flammable and potentially flammable atmospheres must be identified and compared with the potential ignition sources present and with knowledge of the possible flammable atmospheres, their sensitivity to ignition and the possible ignition sources present and the incendivity of these sources a robust basis of safety may be selected. When heat with combustible materials reaches a combustion temperature, self-ignition and burning with flames occur (Stojkovic', 2013). Avoidance of ignition sources reliability depends on having relatively insensitive atmospheres and the main applicability will be counteracting electrostatic and some mechanical ignition sources (Puttick, 2008). Avoidance of ignition sources depends on having relatively insensitive atmospheres and the main applicability will be counteracting electrostatic and some mechanical ignition sources (Puttick, 2008).

2.6.4 Control of Confined Space Entry

The other high risk operational activity in the petrochemical industry is the confined space entry and it defined as an enclosed or partially enclosed area that is big enough for a worker to enter (Stojkovic', 2013). The hazards may not be obvious and it is imperative that the assessments must be done by a qualified person familiar with the confined space and the work to be done in that space (Karthika, 2013). According to Kumar *et al.* (2017) workers are often exposed in confined spaces, exposure levels to workplace hazards are often much higher than exposures to hazards in the general environment.

Confined space is not designed for someone to work in regularly, but workers may need to enter the confined space for tasks such as inspection, cleaning, maintenance, and repair, a small opening or a layout with obstructions can make entry and exit difficult and can complicate rescue procedures (Stojkovic', 2013).

In a workplace, hazard has been identified and the risk to health and safety assessed, an appropriate prevention or control strategy done, but many times people still get killed inside tanks and other confined spaces because of misunderstandings like entering without permission to do some job or merely put their head inside to inspect the inside (Karthika, 2013). Confined spaces may contain hazardous atmospheres, including insufficient oxygen, toxic air, and an explosive atmosphere (Stojkovic', 2013). According to Puttick (2008) preventative bases of safety (absence of flammable atmosphere and avoidance of ignition sources) are the most economic and so there will always be driver to choose them over protective bases of safety (venting, suppression and containment) and it is not always possible to use absence of flammable atmosphere due to insufficient fuel.

It is necessary to first control working conditions by an occupational safety expert and if there is danger for workers in confined space, it is necessary prior to their entry, to clean and ventilate this space (Stojkovic', 2013). According to Karthika (2013) even though accidents can never be eliminated completely, employers can prevent many of the injuries and fatalities that occur each year. Confined spaces may contain hazardous atmospheres, including insufficient oxygen, toxic air, and an explosive atmosphere and these spaces may also have physical hazards that may result, for example, in workers falling, being crushed or buried or drowning (Stojkovic', 2013). Inert brings its own set of problems, as well as expense, and possible difficulty of implementation (Puttick, 2008).

According to Stojkovic' (2013 as a worker could enter into a hazardous confined space it is necessary to execute a sequence of procedures, some of which should be allocated as follows,

- Testing of the air
- Cleaning and ventilation
- Separation, breaking links with other technological devices
- Personal protective equipment for workers
- Entry control
- Blocking of mobile devices
- Rescue plan

2.6.5 Permit to Work

A permit to work is a document which specifies the task to be performed, associated foreseeable hazards and the safety measures (Reddy and Reddy, 2015). According to Navadiya (2017) design of permit to work is very significant but most key thing is definition of roles and responsibilities of involved employees in procedure part and preparing checklist which is to be covered in synchronize way. The permit to work system has been widely used to ensure safety during maintenance and/or construction activities in almost every major hazard industry worldwide (Reddy and Reddy, 2015). Language must be simple such that it can be understood to each level of user at shop floor personnel (Navadiya, 2017).

According to Karthika (2013) major hazards arise while working and root causes regarding permit to work are,

- Wrong type of work permit used, wrong information about work required on the work permit, failure to recognise the hazards where work is carried out (e.g. flammable substances).
- Introduction of ignition source in controlled flameproof area (e.g. welding, non-spark proof tools, non-intrinsically safe equipment used in intrinsically safe zones)
- Terms of work permit not adhered to (e.g. failure to isolate plant and/or drain lines of hazardous substances) failure to hand-over plant is safe condition on completion of work/cancelling of work permit.
- Unauthorised staff performing work permits functions, poor management of the work permit system, and insufficient monitoring of the work permit system.

Effective implementation of a comprehensive permitting program certainly helps preventing several undesirable incidents. However, deficiencies in implementing a permit to work system have been a contributing factor in several catastrophic incidents (Reddy and Reddy, 2015). Defined roles and responsibilities in procedure of permit to work helps actual work to be smooth and without miss understanding that may further lead to accident (Navadiya, 2017).

According to Reddy and Reddy (2015) major steps involved in the permit system include identifying tasks requiring permit(s), develop permit forms, define roles, train and maintain competency of personnel, create work order, fill out permit forms, identify associated hazards and mitigation, execute the task within the constrained listed on the permit and adhering to specified safety measures, closeout permit, review and monitoring, main aspects generally considered for permit to work system are as follow,

- Complexity of the operation including risk involved
- Human factors including personnel skills
- Types of permits required and content of each permit.

According to Karthika (2013) normally all maintenance, repair, construction work shall be carried out with a proper work permit and jobs where work permit is required include but not limited to the following,

- Major and minor maintenance work
- Inspection
- Construction
- Alteration
- Any hot work (including use of normal battery driven equipment in operating areas)
- Entry into confined space
- Excavation
- Vehicle entry into process areas
- Work at height
- Handling of materials using mechanised means in operating areas
- Erecting and dismantling of scaffolding
- Radiography

According to Navadiya (2017) basic challenges of permit to work are,

- Steps of permit to work should be followed as per pre-defined procedure in safety management system. Deviation of one of the step may invite accident, further may damage reputation of the organisation.
- Short cuts are most dangerous in the petrochemical industry as they invite accidents. Once pre-defined procedure is established, it should be followed strictly.
- All attachments should be clearly elaborated. Lock out tag out procedure, and other related procedures.

2.7 Health and Safety Culture

Major hazard industries especially oil and gas operators are putting considerable efforts to ensure safe operations thereby protecting health and safety of workforce and the environment (Reddy and Reddy, 2015). Knowledge and compliance alone are not enough to cause behavioural changes required for safety performance but a certain aspects of health and safety culture are required and these other essential safety factors include: enforceable regulatory framework, management commitment and workers involvement (Okoye, Ezeokonkwo and Ezeokoli, 2016).

Health and safety culture combines the whole approach of reporting health and safety matters, monitoring equipment and procedures into a health and safety management system which becomes a coherent structure that becomes acceptable and comprehensible to the employees and hence to the public (Bond, 2007).

According to Albert, Hallowell and Kleiner (2014) hazard recognition program elements are,

- Pre-job safety meeting quality measurement tool – tool that evaluates the crew's hazard identification capability and communication to create hazard awareness.
- Senior leadership engagement in JSA process – a quantitative measure of the management's involvement in the JSA process through resource allocation and commitment.
- Augmented and interactive virtuality training environment – Computer based simulation tool that trains workers to identify hazards using a representative virtual environment.
- Safety situational awareness training – a worker centric program in which various potential hazards are detailed to the work crew prior to initiating work.
- JSA post kick off audit – evaluation of JSA after task completion to obtain feedback on unidentified hazards.
- Hazard identification board – a waterproof board displayed at the work site to communicate potential hazards as work progresses.
- Precursory visual cues – using visual aids such as tapes, signals, signs and LEDs to communicate hazards to the workforce proactively.
- Physical area hazard simulation – an active exercise by the crew that simulates work to be done as way of identifying associated hazards.
- Foreman one on one with employee – a one on one walkabout through the work facility, where an experienced foreman points to hazards in the environment.
- Video/Photo monitoring and feedback – a continuous feedback process received through the review of previous work captured as videos or photographs.
- Job safety/hazard analysis – a formal technique that focuses on specific work tasks as a way of identifying hazards before work in initiated.
- Task demand assessment – an evaluative method in which task difficulty is assessed and better and efficient work practices are proposed.

- What-if analyses – use of a systematic, but loosely structured form of brainstorming sessions guided by what-if questions.
- Action plan critique – a feedback mechanism involving the critiquing of established plans to improve implementation work plan.
- Recordkeeping and accident analyses – creation of a database that records lessons learned from past injuries and experiences to avoid recurrence of accidents.
- Safety checklists – survey of work area or construction process to ensure conformance to certain established criterion.
- Method statement review/work permitting – audit of written work plan elaborating on work tasks and conditions before a written permit to work is issued.
- Walk-through safety and health audit – an observational method to identify active hazardous conditions, unsafe behaviour through walkabout sessions.
- Worker to worker observation program – a peer to peer safety observation program to provide feedback on worker performance with respect to health and safety.
- Proactive safety alert systems – incorporation of detection technology into equipment that sounds an alarm, or is disabled when hazard is detected.
- Pre-use analysis and planning – a formal study conducted prior to any process modification, or the use of new equipment or chemical in the job site.

According to Holstvoogd *et al.* (2006) there is a health and safety culture ladder with five levels, namely pathological (level 1), reactive (level 2), calculative (level 3), proactive (level 4) and generative (level 5). Pathological culture level 1 is where nobody cares to understand why accidents happen and how they can be prevented and at generative culture level 5, health and safety is seen as a profit centre and it is how business is done. Reactive culture level 2 says safety is important, and people do a lot when there has been an accident while the proactive culture is where employees work safely because they intrinsically motivated to do the right things naturally. Level 3 is calculative where an organisation says there are management systems in place to manage all hazards.

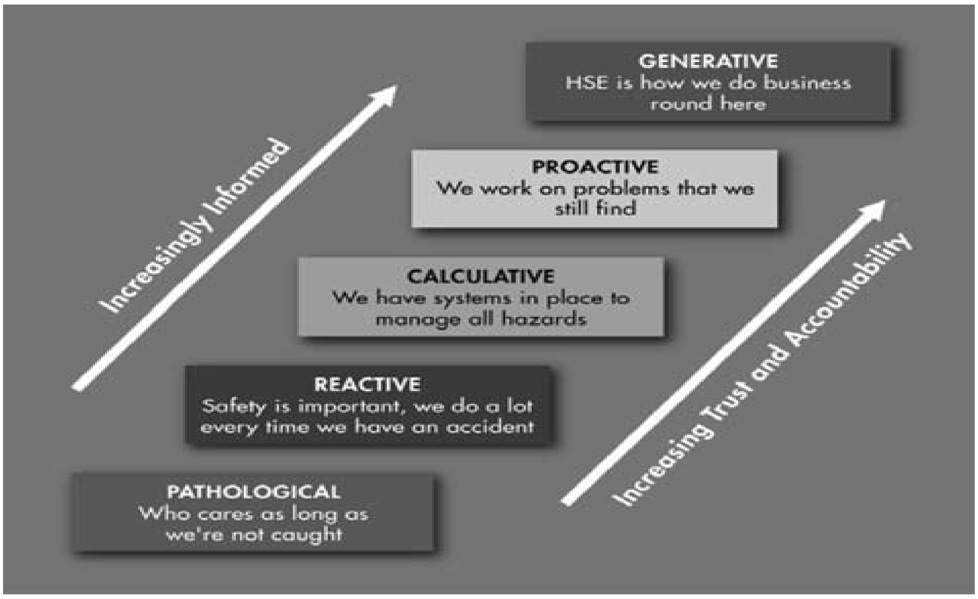

Figure 2.6 Health and Safety Culture Ladder
Adapted from Holstvoogd *et al.* (2006).

The health and safety culture ladder in Figure 2.1 shows the various levels of cultural maturity, and the change process required to achieve a lasting change in personal and organisational culture (Holstvoogd *et al.,* 2006). Health and safety knowledge automatic ensure compliance, but health and safety knowledge and compliance alone cannot substantially improve health and safety culture (Okoye, Ezeokonkwo and Ezeokoli, 2016).

2.8 Development of Conceptual Model

Models differ from theories in that the role of a theory is explanation whereas the role of a model is representation. Conceptual modelling is the abstraction of a simulation model from the part of the real world it is representing ('the real system'). The real system may, or may not, currently exist. Abstraction implies the need for simplification of the real system and for assumptions about what is not known about the real system (Robinson, 2013).

The path diagram was utilised in this study to express the model in a visual form that is easily understood. In path diagrams the observed variables are enclosed by rectangles and the latent variables are depicted in ellipses. Line with a single arrowhead represents a hypothesised relationship or direct effect of one variable on another. The two-way curved arrow with an arrowhead at each end is used to represent co-variation between two variables.

2.9 Conceptual Model

The conceptual model proposed in this research includes the following latent variables, namely,

- Generative Health and Safety Culture (Main Latent Variable)
- Leadership Commitment
- Chemical Exposure Management
- Health and Safety Risk Assessment
- Process Hazard Analysis
- Permit to Work
- Training and Competency
- Process Health and Safety Information
- Control of Confined Space Entry
- Operating Procedure
- Control of Ignition Source

In this study there are 35 observed variables as indicated in figure 2.7

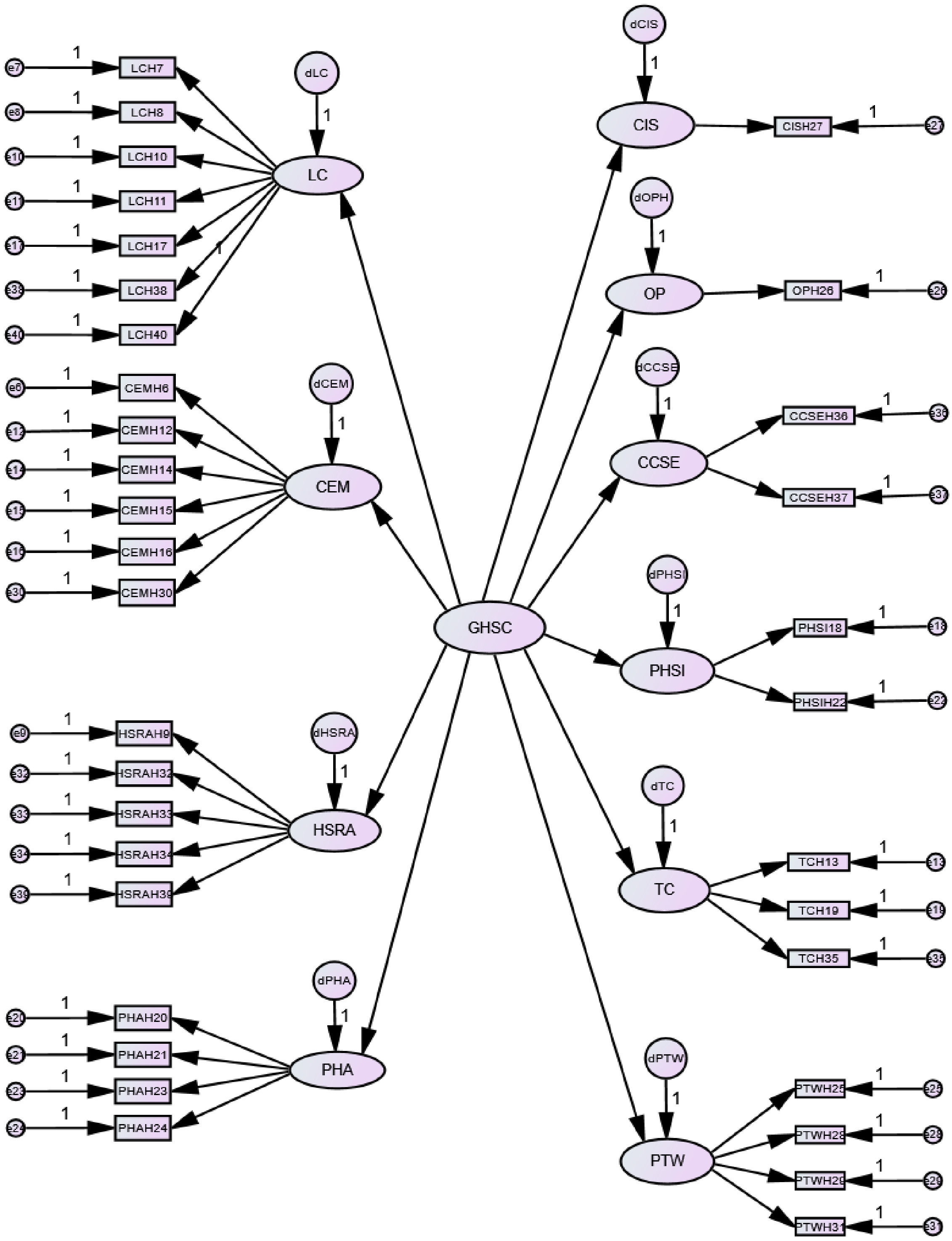

Figure 2.7 The proposed Conceptual Model

Latent Variable 1: Leadership Commitment

Leadership commitment alone can make health and safety a key business goal and provide the necessary resources to achieve health and safety objectives. If leadership commitment consistently treats health and safety as a priority, so will the rest of the work group.

LC – Leadership Commitment

dLC – Leadership Commitment Deviation

LCH – Leadership Commitment questions from the research instrument

errh – errors for all the observed variables

H_7: Senior Management prioritises Health and Safety in my organisation.
H_8: Senior Management has an open door policy on Health and Safety issues.
H_{10}: Senior Management communicates Health and Safety policy to all employees.
H_{11}: Senior Management allocates enough time to address Health and Safety concerns.
H_{17}: Senior management prioritizes mechanical/asset integrity of our processing plant.
H_{38}: Poor housekeeping in my organization is the cause for many health and safety incidents.
H_{40}: Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry.

Latent Variable 2: Chemical Exposure Management

Controlling exposures to chemical hazards and toxic substances is the fundamental method of protecting workers. It is the responsibility of every employer to ensure employee exposures to chemical hazards are maintained below local permissible exposure limits as defined by local law through the application of appropriate controls, such as engineering, administrative controls or personal protective equipment.

CEM – Chemical Exposure Management

dCEM – Chemical Exposure Management Deviation

CEMH – Chemical Exposure Management questions from the research instrument

errh – errors for all the observed variables

H_6: My organization has excellent chemical exposure management systems.
H_{12}: Most employees are aware of hazardous chemicals in their work environment.
H_{14}: Most employees know how to handle hazardous chemicals in the work place.

H_{15}: Contractor's on boarding appreciates all hazardous chemicals in my organization
H_{16}: Most contractors know how to handle hazardous chemicals in my organization.
H_{30}: All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.

Latent Variable 3: Health and Safety Risk Assessment

Health and safety risk assessment is the process of evaluation of the risks arising from a hazard, taking into account the adequacy of any existing controls and deciding whether or not the risks is acceptable. It is vital that employers know where the risks are in their organisations and control them to avoid putting in risk employees, customers and the organisation itself.

HSRA – Health and Safety Risk Assessment

dHSRA – Health and Safety Risk Assessment Deviation

HSRAH – Health and Safety Risk Assessment questions from the research instrument

errh – errors for all the observed variables

H_9: There are effective noise exposure management systems in my organization.
H_{32}: Most of the health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.
H_{33}: My organization diligently manages fatigue in both permanent employees and contractors.
H_{34}: My organization has all management systems in place to manage substance misuse.
H_{39}: Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.

Latent Variable 4: Process Hazard Analysis

A process hazard analysis is an organised effort to identify and analyse the significance of hazardous scenarios associated with a process or activity. Process hazard analysis are used to pinpoint weaknesses in the design and operation of facilities that could lead to accidental chemical releases, fires, or explosions and to provide organisations with information to aid in making decisions for improving health and safety.

PHA – Process Hazard Analysis

dPHA – Process Hazard Analysis Deviation

PHAH – Process Hazard Analysis questions from the research instrument errh – errors for all the observed variables

H_{20}: In my organization all engineering changes undergo a comprehensive management of change.
H_{21}: The organization does comprehensive process hazard analysis before engineering changes are made.
H_{23}: The organization does comprehensive process hazard analysis before engineering changes are made.
H_{24}: In my organization we have a comprehensive pre-activity start up review and pre-activity shutdown review.

Latent Variable 5: Permit to Work

Permit to work is a management system used to ensure that work is done safely and efficiently. Permit to work is an essential part of control of work, hazard identification and risk assessment. It is designed to provide protection for employees who are working in hazardous situations.

PTW – Permit to Work

dPTW – Permit to Work Deviation

PTWH – Permit to Work questions from the research instrument

errh – errors for all the observed variables

H_{25}: Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.
H_{28}: All the work activities in my organization are done after a valid permit to work has been signed by the authorities.
H_{29}: In my organization before you start excavation or entering a trench you need to obtain authorization.
H_{31}: In my organization all safety critical equipment is disabled with permission from the authorities.

Latent Variable 6: Training and Competency

Education and training are essential to an effective health and safety management system. Workers who understand the hazards and risks of the assigned tasks are far less likely to be injured or become ill from occupational disease.

TC – Training and Competency

dTC – Training and Competency Deviation

TCH – Training and Competency questions from the research instrument

errh – errors for all the observed variables

H_{13}: Employees undergo comprehensive training on health and safety in my organization.
H_{19}: The organization closed all corrective action items effectively after the root cause analysis.
H_{35}: Most of the health and safety incidents are due to human error in my organization.

Latent Variable 7: Process Health and Safety Information

Occupational Health and Safety Act requires compiling of technical information on the process and equipment prior to conducting a process hazard analysis. Occupational Health and Safety Act has three categories, namely, hazards of the chemicals and flammables in the process, information related to the technology of the process and lastly information pertaining to the equipment in the process.

PHSI – Process Health and Safety Information

dPHSI – Process Health and Safety Information Deviation

PHSIH – Process Health and Safety Information questions from the research instrument

errh – errors for all the observed variables

H_{18}: The organization closed all corrective action items effectively after the root cause analysis.
H_{22}: Most of the health and safety incidents are due to human error in my organization.

Latent Variable 8: Control of Confined Space Entry

A confined space is large enough and so configured that an employee can bodily enter and perform assigned work, it has limited or restricted means for entry or exit and it is not designed for continuous occupancy by the employee. Fatalities in confined spaces often occur because the atmosphere is oxygen deficient or toxic, confined spaces should be tested prior to entry and continually monitored.

CCSE – Control of Confined Space Entry

dCCSE – Control of Confined Space Entry Deviation

CCSEH – Control of Confined Space Entry questions from the research instrument

errh – errors for all the observed variables

H_{36}: My organization has effective management systems to manage working in confined space.
H_{37}: Most of the health and safety incidents are due to poor controls in place when working with suspended loads.

Latent Variable 9: Operating Procedure

It is the duty of an employer to develop and implement written operating procedures that provide clear instructions for safely conducting operations and maintenance. Operating procedures shall be readily accessible to employees and reviewed as often as necessary to assure that they reflect current operating practice.

OP – Operating Procedure

dOP – Operating Procedure Deviation

OPH – Operating Procedure question from the research instrument

errh – errors for all the observed variable

H_{26}: In my organization all work activities have a detailed operating procedure or work instruction.

Latent Variable 10: Control of Ignition Source

It is vital that potential ignition sources are identified, and there is feedback from operational experience back into hazard assessment process. What is required from an assessment perspective is to be able to characterise a flammable atmosphere with respect to its ignition sensitivity, and to identify potential ignition sources. Control of ignition sources is valuable and reliable basis of health and safety.

CIS – Control of Ignition Source

dCIS – Control of Ignition Source Deviation

CSIH – Control of Ignition Source question from the research instrument

errh – errors for all the observed variable

H_{27}: Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.

Main Latent Variable: Generative Health and Safety Culture

In a mature generative health and safety culture everybody has the aspiration to do all health and safety critical tasks appropriately.

GHSC – Generative Health and Safety Culture

2.10 Chapter Summary

In this research process health and safety management elements from literature to be prioritized for an effective process health and safety management system are, Leadership Commitment, Training and Competency, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Process Health and Safety Information, Operating Procedure, Control of Ignition Source, Control of Confined Space Entry and Permit to Work.

Health and safety standards and regulations reasonably cannot cover all the possible cases for different types of works in a variety of hazards in a petrochemical industry. It is the duty of health and safety experts to share as much as they can on this subject of health and safety in the petrochemical industry that can expose employees and contractors to hazardous chemicals. This chapter also presented conceptual model for this research. The proposed conceptual process health and safety elements model is based on the main latent variable (Generative Health and Safety Culture) and latent variables (Leadership Commitment, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Permit to Work, Training and Competency, Process Health and Safety Information, Control of Confined Space Entry, Operating Procedure and Control of Ignition Source) identified through literature review. The next chapter discusses the research design and methodology.

CHAPTER THREE

Research Design and Methodology

3.1 Introduction

This chapter discusses the research design and methodology to attain the research aim and objectives; the research process, paradigm and methodology as well as the sampling methodology. The qualitative and quantitative data analysis is also explained.

3.2 Research Paradigm

According to Leedy and Ormrod (2010) research is a systematic process of collecting, analysing and interpreting information in order to increase understanding of a phenomenon of interest. According to Denzil and Lincoln (2011) paradigms could be categorised by the core ontology and epistemological position embraced in the research process. These definitions imply that research is a systematic process that has objectives or purpose, aims to increase human knowledge and allows for the collection of information and evaluation of it before making a final decision (Leedy and Ormrod, 2010).

Every paradigm is based upon its own ontological and epistemological assumptions (Scotland, 2012). Researchers normally develop the research methodologies based on different ontological and epistemological assumptions and the related paradigms (Denzil and Lincoln, 2011). Ontology concerns the issues of the fundamental nature of reality and since all assumptions conjecture, the philosophical underpinnings of each paradigm can never be empirically proven or disproven (Easterby-Smith and Lowe, 2002).

The paradigm in turn commands the methodological approach to be embraced, it affords holistic insight of how the researcher views knowledge, and articulates the methodological strategies to disclose it (Denzin and Lincoln, 2011). Different paradigms inherently contain differing ontological and epistemological views, therefore, they have differing assumptions of reality and knowledge which underpin their particular research approach (Scotland, 2012).

3.2.1 Ontology

Knowledge is both socially constructed and influenced by power relations from within society and what counts as knowledge is determined by the social and positional power of the advocates of that knowledge (Scotland, 2012).

The two basic classifications within ontology are realism and nominalism; realism accepts that reality exist out there freely of people and their insights and interpretations of it, while nominalism assumes that people never openly experience the real world but through their own subjectivity and interpretations (Neuman, 2014). The ontological position of the critical paradigm is historical realism (Scotland, 2012). Internal realism assumes that the truth is out there but is challenging to spot directly, while relativism assumes that there is much truth out there, dependent on the viewpoint of the viewers (Bryman, 2016).

According to Mouton (1996) cited in Bryman and Bell (2011) historical realism is the view that reality has been shaped by social, political, cultural, economic, ethnic, and gender values, reality that was once deemed plastic has become crystallised (Scotland, 2012). Realism argues that there are in fact fundamental differences between the social and natural sciences but similarities also exist which justify the use of similar research approaches.

3.2.2 Epistemology

Epistemology is the concept that is concerned with how knowledge is gained (Malhotra, 2017). According to Scotland (2012) the belief about the nature of the world (Ontology) adopted by a researcher will affect the belief about the nature of knowledge in that world (epistemology) which in turn will influence the researchers belief as to how that knowledge can be revealed (methodology). Epistemology and methodology are intimately related: the former involves the philosophy of how we come to know the world and the latter involve the practice (Malhotra, 2017).

Epistemological assumptions are concerned with how knowledge can be created, acquired, and communicated in other words, what it means to know (Cohen, Manion and Morrison, 2007). According to Malhotra (2017) the term epistemology comes from the Greek word episteme, their term for knowledge. In simple terms, epistemology is the philosophy of knowledge or of how we come to know. Critical epistemology is one of subjectivism which is based on real world phenomena and linked with societal ideology (Scotland, 2012).

The methodology is concerned with how we come to know but is much more practical in nature and is focused on the specific ways - the methods - that we can use to try to understand our world better (Malhotra, 2017).

There are two basic paradigm groups within epistemology, namely, positivism and constructivism; positivism supports the view that truth or knowledge should be produced by way of a scientific approach (Andrew, 2012). According to Mouton (1996) cited in Bryman and Bell (2011) positivism, also referred to as ontological naturalism, suggests that social sciences are similar to natural sciences and should therefore follow the logical and rigor of natural sciences in research.

While constructivism debates that reality is composed of the perspectives and views of people and therefore reality is highly subjective and can only be inferred from viewpoints or opinions of those who have experienced reality (Andrew, 2012).

3.3 Research Philosophy

According to Scotland (2012) what knowledge is, and ways of discovering it, are subjective. The individual perception of reality affects how people gain knowledge of the world, and how people act within it. Those who believe there is a single objective truth are usually referred to as Positivist (Creswell, 2009). Each paradigm has its own ways of realizing its aims and philosophy is concerned with views about how the world works and, as an academic subject, focuses primarily on reality, knowledge and existence. The individual view of the world is closely linked to what is perceived as reality (Scotland, 2012).

According to Saunders *et al.* (2012) research philosophies are concerned with the development of knowledge (epistemology) and the nature of that knowledge (ontology). Regarding educational research, the scientific paradigm seeks to generalise, the interpretive paradigm seeks to understand, and the critical paradigm seeks to emancipate (Scotland, 2012). Research philosophies are epistemological and ontological positions or "world views" or assumptions or theoretical frameworks about how knowledge should be generated (Bryman and Bell, 2011).

If it is accepted that the understanding of reality affects the way people gain knowledge of reality, then there is a need to accept that this will affect how people actually conduct research about reality (Scotland, 2012). Epistemological philosophies determine the approach to questioning and discovery in research and ontological philosophies are concerned with the nature of reality and the assumptions made about how the world operates (Saunders *et al.,* 2012).

The ontological position of positivism is one of realism (Scotland, 2012). Realism is therefore pro-positivist in nature (Saunders *et al.,* 2012). Realism is the view that objects have an existence independent of the knower and therefore the positivist epistemology is one of objectivism (Scotland, 2012).

3.3.1 Positivism

Positivists generally assume that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments (Malhotra, 2017). According to Creswell (2009) in a scientific paradigm positivist methodology is directed at explaining relationships and positivists attempt to identify causes which influence outcomes.

According to Creswell (2009) in a scientific paradigm positivist methodology is directed at explaining relationships and positivists attempt to identify causes which influence outcomes. Positivist studies generally attempt to test the theory, in an attempt to increase the predictive understanding of phenomena. Induction strategy has its roots attached to the positivism approach where the observations analysed help in driving out the result (Malhotra, 2017). Their aim is to formulate laws, thus yielding a basis for prediction and generalisation and a deductive approach is undertaken (Creswell, 2009).

Positivism assumes an objective world hence it often searches for facts conceived in terms of specified correlations and associations among variables (Malhotra, 2017). According to Creswell (2009) positivist methodology is directed at explaining relationships and positivist attempt to identify causes which influence outcomes, such people believe there are universal truths that are waiting to be discovered. The positivist focus on experimental and quantitative methods used to test and verify hypotheses have been superseded or complemented to some extent by an interest in using qualitative methods to gather broader information outside of readily measured variables (Malhotra, 2017).

The foundation of positivism is that the reality and facts are out there; it is applicable to measure and explore them by objective methods rather than being inferred by subjective sensation, intuition or reflection (Blaikie, 2007). Based on the results of the studies, people may learn that theory doesn't fit the facts well and so they need to revise the theory to better predict reality (Malhotra, 2017). The key approach of the scientific method is the experiment, the attempt to discern natural laws through direct manipulation and observation (Malhotra, 2017).

Postpositivism is a recent evolution of positivism and postpositivism is consistent with positivism in assuming that an objective world exists but it assumes the world might not be readily apprehended and that variable relation or facts might be only probabilistic, not deterministic (Malhotra, 2017). Positivism is typically associated to quantitative methods, while constructionism is often linked with qualitative approaches (Cresswell and Clark, 2011). In a positivist view of the world, science is seen as the way to get the truth, to understand the world well enough so that people might predict and control the world (Malhotra, 2017).

Positivism philosophy is based upon the highly structured methodology to enable generalization of the results with the help of statistical methods (Williams, 2011). According to Malhotra (2017) the world and the universe are deterministic; they operated by laws of cause and effect that could discern if applied the unique approach of the scientific method and science is largely a mechanistic or mechanical affair and researchers use deductive reasoning to postulate theories that they can test

This research followed an epistemological positivist philosophy so that it can empirically test structural relationships among latent variables of generative process health and safety culture. The positivist believes in empiricism – the idea that observation and measurement is the core of scientific endeavour (Malhotra, 2017).

3.3.2 Interpretivism

Interpretive researchers start out with the assumption that access to reality is only through social constructions such as language, consciousness and shared meanings (Malhotra, 2017). The interpretive epistemology is one of subjectivism which is based on real world phenomena and the world does not exist independently of people's knowledge of it (Grix, 2004). The philosophical base of interpretive research is hermeneutics and phenomenology and interpretive studies generally attempt to understand phenomena through the meanings that people assign to them and interpretive methods of research (Malhotra, 2017).

Interpretive research does not predefine dependent and independent variables but focuses on the full complexity of human sense-making as the situation emerges (Malhotra, 2017). According to Scotland (2012) interpretive paradigm is sensitive to individual meanings that can become buried within broader generalizations. According to Mouton (1996) cited in Bryman and Bell (2011) the interpretive paradigm is also anti-positivist like the phenomenological paradigm.

Interpretive methodology is directed at understanding phenomenon from an individual's perspective, investigating interaction among individuals as well as the history and cultural contexts which people inhabit (Creswell, 2009). Interpretive research rejects a foundation base to knowledge, bringing into question its validity and cannot be judged using the same criteria as the scientific paradigm (Scotland, 2012). This research investigates how the objectives features of society emerge from depend on, and are constituted by subjective meanings of individuals and intersubjective processes such as discourses or discussions in groups (Malhotra, 2017).

If reality is subjective and differs from person to person, then research participants cannot be expected to arrive at exactly the same interpretations as researchers (Rolfe, 2006). Constructionists have also been particular concerned with the interplay of subjective, objective and intersubjective knowledge and written texts (Malhotra, 2017). Constructivist philosophy takes the stance that reality, truth, is a construction of an individual's view of their world and that constructivist research accepts the truth which is generated between the researcher and the participant (Williamson, 2006).

A key form of interpretive research is social constructionism which seeks to understand the social construction dialectic involving objective, intersubjective and subjective knowledge (Malhotra, 2017). Those who believe there is no reality other than what individuals create in their heads are known as interpretivists or contructivists (Creswell, 2009). In a sense, interpretive constructivism seeks to show how variations in human meanings and sense making generate and reflect differences in reified or objective realities (Malhotra, 2017).

3.4 Research Approach

There are two research approaches, namely, deductive and inductive approaches (Saunders *et al,* 2003). According to Mouton (1996) cited in Bryman and Bell (2011) deductive reasoning works from the general truth or theory to logically arrive at a specific conclusion to test a hypothesis and it is used when testing hypotheses from existing theories. The deductive approach is when a theory and hypothesis or hypotheses are developed and a research strategy is designed to test the hypothesis (Saunders *et al,* 2003). It begins explicitly with a tentative hypothesis or set of hypotheses that form a theory which could provide a possible answer or explanation for a particular problem, then proceeds to use observations to rigorously test the hypotheses (Malhotra, 2017).

According to Judd *et al.* (1986) cited in Saunders *et al.* (2012) inductive reasoning works from a specific observation to propose a generalisation or hypothesis or theory based on the observation. The inductive approach is when data is collected and a theory is developed from the data analysis (Saunders *et al,* 2003).

3.4.1 Deductive Approach

Deductive approach is concerned with developing a hypothesis (or hypotheses) based on existing theory, and the designing a research strategy to test the hypothesis (Creswell and Plano Clark, 2007).

According to Malhotra (2017) the deductive argument moves from premises, at least one of which is a general or universal statement, to a conclusion that is a singular statement.

Deductive means reasoning from the particular to the general (Creswell and Plano Clark, 2007). According to Malhotra (2017) the deductive argument moves from premises, at least one of which is a general or universal statement, to a conclusion that is a singular statement. Deductive propositions form a hierarchy from theoretical to observational; from abstract to concrete, the deductivist accepts that observation is guided and presupposed by the theory (Malhotra, 2017).

3.4.2 Inductive Approach

Inductive approach starts with the observations and theories are proposed towards the end of the research and when following an inductive approach, beginning with a topic, a researcher tends to develop empirical generalisations and identify preliminary relationships (Creswell and Plano Clark, 2007).

According to Malhotra (2017) the inductive strategy assumes that all science starts with observations which provide a secure basis from which knowledge can be derived and claims that reality impinges directly on the senses, hence there is a correspondence between sensory experiences, albeit extended by instrumentation, and the objects of those experiences.

There is no hypothesis at the initial stages of the research and the researcher is not sure about the type and nature of the research findings until the study is finished (Creswell and Plano Clark, 2007). The conclusion of an inductive argument makes claims that exceed what is contained in the premises and so promises to extend knowledge by going beyond actual experience (Malhotra, 2017).

3.5 Research Methodology

Research methodology in principle is focused around the problems to be studied in a research study and therefore varies according to the problems explored (Scotland, 2012). The literature review plays a major role in justifying the research and identifying the purpose of the study in quantitative research and can be used to identify the questions to be asked and to inform the hypotheses (Creswell and Plano Clark, 2007). Identifying the research methodology that best suits a research in hand is vital as it will serve establishing the credibility of the work (Scotland, 2012).

Research philosophy, approach, strategy, and techniques are inherent components of the research methodology (Scotland, 2012). Literature reviews in quantitative research are more comprehensive and more detailed than is the case in qualitative research (Creswell and Plano Clark, 2007). In quantitative research, the researcher and what is being researched are viewed as independent of each other, whereas in the qualitative research, they are interactive and inseparable (Teddlie and Tashakkori, 2009). The literature review is typically brief and does not usually guide the research questions to the same extent as literature reviews in quantitative research does (Creswell and Plano Clark, 2007). Quantitative researchers believe that reality is single and tangible, whereas qualitative researchers view reality as constructed and hence multiple (Teddlie and Tashakkori, 2009).

In qualitative research, the literature review is used to provide evidence for the purpose of the study and to identify the underlying problem that will be addressed by the inquiry and this is done to ensure that the literature does not limit the types of information the researcher will learn from the participants (Creswell and Plano Clark, 2007). Differences in ontology and epistemology mean that different research methods have been employed, with quantitative researchers using deductive approaches, whereas, in contrast, qualitative researchers have tended to use inductive approaches (Teddlie and Tashakkori, 2009).

3.5.1 Quantitative Research

A quantitative approach endorses the view that psychological and social phenomena have an objective reality that is independent of the subjects being studied (Yilmaz, 2013). The quantitative research design is used to examine relationships among variables using statistical analyses, it uses either experimental or survey research strategies with questionnaires, structured interviews or structured observation (Saunders *et al.*, 2012). Quantitative research emphasises the measurement and analysis of causal relationship between isolated variables within a framework which is value – free, logical, reductionistic, and deterministic, based on a priori theories (Yilmaz, 2013).

Quantitative methods require the researcher to use a pre – constructed standardised instrument or pre-determined response categories into which the participants varying perspectives and experiences are expected to fit (Yilmaz, 2013). Accordingly to Trochim (2006) quantitative research often translates into the use of statistical analysis to make the connection between what is known and what can be learned through research. Quantitative methods generally demand randomly selected large representative samples in order for researchers to generalise their findings from the sample (Yilmaz, 2013).

The major advantage of Quantitative methods is that it allows one to measure the responses of number of participants to a limited set of questions, thereby facilitating comparison and statistical aggregation of the data (Yilmaz, 2013). Collecting and analysing data using quantitative strategies requires an understanding of the relationships among variables using either descriptive or inferential statistics (Trochim, 2006). Quantitative research is informed by objectivist epistemology and thus seeks to develop explanatory universal laws in social behaviours by statistically measuring what it assumes to be a static reality (Yilmaz, 2013).

3.5.2 Qualitative Research

Unlike quantitative studies which are concerned with outcomes, generalisation, prediction, and cause-effect relationship through deductive reasoning, qualitative studies are concerned with process, context, interpretation, meaning or understanding through inductive reasoning (Yilmaz, 2013). According to Hox and Boeije (2005) qualitative researchers examine how people learn about and make sense of themselves and others and how they structure and give meaning to their daily lives. Therefore, methods of data collection are used that are flexible and sensitive to the social context.

According to Yilmaz (2013) qualitative research is based on a constructivist epistemology and explores what it assumes to be a socially constructed dynamic reality through a framework which is value-laden, flexible, descriptive, holistic and context sensitive. According to Creswell (2005) qualitative research is often said to employ inductive thinking or induction reasoning since it moves from specific observations about individual occurrences to broader generalisations and theories. According to Yilmaz (2013) qualitative research tries to understand how social experience is created and given meaning, in qualitative research reality or knowledge is socially and psychologically constructed.

A popular method of data collection is the qualitative interview in which interviewees are given the floor to talk about their experiences, views and so on. Instead of a rigidly standardised instrument, interview guides are used with a range of topics or themes that can be adjusted during the study (Hox and Boeije, 2005). The aim is to describe and understand the phenomenon studies by capturing and communicating participants' experiences in their own words via observation and interview (Yilmaz, 2013).

According to Hox and Boeije (2005) another widely used method is participant observation, which generally refers to methods of generating data that involve researchers immersing themselves in a research setting and systematically observing interactions, events and so on. The qualitative paradigm views the relationship between the knower and the known as inextricably connected (Yilmaz, 2013).
Qualitative research can be defined as a study which is conducted in a natural setting (Creswell, 2005).

According to Yilmaz (2013) in making use of the inductive approach to research, the researcher begins with specific observations and measures, and then moves to detecting themes and patterns in the data. This allows the researcher to form an early tentative hypothesis that can be explored (Yilmaz, 2013).

The research, in effect, becomes the instrument for data collection it is up to the researcher to gather the words of the participants and to analyse them by looking for common themes, by focusing on the meaning of the participants, and describe a process using both expressive and persuasive language (Creswell, 2005). Other well-known methods of qualitative data collection are the use of focus (guided-discussion) groups, documents, photographs, film, and video (Hox and Boeije, 2005). The results of the exploration may later lead to general conclusions or theories and qualitative findings are far longer, more detailed and variable in content than quantitative ones (Yilmaz, 2013).

3.5.3 Mixed Approach

According Driscoll *et al.* (2007) mixed methods designs can provide pragmatic advantages when exploring complex research questions. According to Youngshin *et al.* (2017) when combining qualitative and quantitative data in a study there are four principles, namely,

- To determine the kind of data needed about the problem and the relevance of the problem to the method chosen should be evident.
- The strengths and weaknesses of each method employed should complement each other.
- Methods should be selected on the basis of their relevance to the nature of the phenomena of interest
- The methodological approach employed should be continually monitored and evaluated to ensure that the first three principles are being followed.

The qualitative data provide a deep understanding of survey responses, and statistical analysis can provide detailed assessment of patterns of responses (Driscoll *et al.,* 2007). According to Youngshin *et al.* (2017) in a measurement context, combining qualitative and quantitative data within a study can be useful in developing a scale.

The analytic process of combining qualitative and survey data by quantitizing qualitative data can be time consuming and expensive and thus may lead researchers working under tight budgetary or time constraints to reduce sample sizes or limit the time spent interviewing (Driscoll *et al.,* 2007).

According to Youngshin *et al.* (2017) triangulation refers to combining multiple methods when studying the same phenomena, to minimise systematic bias in study findings and triangulation may help not only in the development of an instrument, but also with respect to insight about the meaning of concepts.

3.6 Research Methods

The research was planned to first explore the concepts by qualitative research methods, such as in depth literature review. The quantitative data collection and analysis is based on a quantitative research method involving questionnaire survey and statistical data analysis methods. The validation of the findings and related conclusions rely on the results from both qualitative and quantitative research methods. The mixed method was considered the best option for this study as it assisted to leverage the advantages of both quantitative and qualitative research methods in achieving the research objectives.

3.7 Research Strategies

According to Malhotra (2017) a research method is a strategy of enquiry which moves from the underlying philosophical assumptions to research design and data collection and the choice of research method influences the way in which the researcher collects data. The research strategy is an action plan to achieve the research objectives and respond to the research questions and therefore links the research philosophy with the methods for collection and analysis of the data (Saunders *et al.,* 2012). Research strategy provides the overall direction of the research including the process by which the research is conducted (Malhotra, 2017).

Research strategies are influenced by the general direction which a research study may follow, namely, exploratory or formulative, descriptive, and explanatory (Saunders *et al.,* 2012; Sekaran and Bougie, 2010; Thakur, 1993). Specific research methods imply different skills, assumptions, and research practices (Malhotra, 2017). Case study, ethnographic study, ground theory study, phenomenological study, experimental study, archival research, and action research are examples for such research strategies (Malhotra, 2017).

3.7.1 Case Study

The word case means an instance of and the central feature of case study research design is the investigation of the one or more specific instances of something that comprise the cases in the study (Yin, 2003). Case studies are commonly associated with qualitative research and qualitative data but this need not be so and quantitative data can readily be incorporated into a case study where appropriate (George and Bennet, 2005). Case study research can also facilitate a holistic perspective on causality because it treats the case as a specific whole and thereby offers the possibility of investigating casual complexity where there are many relevant factors but few observations (Yin, 2009).

The case study method in research demands a high degree of depth, breadth and rigour, with careful attention to showing the way in which evidence supports the conclusions reached (George and Bennet, 2005). Case studies can also be used to research questions about process because the use of multiple data sources supports the retrospective investigation of events (Yin, 2009). Research questions should make it clear what aspects of the cases are of interest, it will not be feasible to investigate every aspect of chosen cases (Yin, 2009).

In explanatory research, for instance, case studies offer the possibility of investigating casual mechanisms and the specific contexts in which they are activated (George and Bennet, 2005). A case can be something relatively concrete such as an organisation, a group or an individual, or something more abstract such as an event, a management decision or a change programme (Yin, 2003). Case studies involve the intensive examination of a single entity but can also take a comparative form when they focus on more than a single entity (Murray, 2003; Thakur, 1993).

3.7.2 Ethnographic Study

The other research strategy investigated in this research is Ethnographic Study. According to Angrosino (2007) ethnographic study is conducted on site or in a naturalistic setting in which real people live and it is personalised since the researcher are both observer and participant in the lives of those people. The ethnographic research comes from the discipline of social and cultural anthropology where and ethnographer is required to spend a significant amount of time in the field (Malhotra, 2017).

According to Williamson (2006) ethnography follows constructivist philosophical principals because ethnographic researchers gather data by studying people in their everyday contexts or by participating in social interactions with them in order to understand their world. Ethnography also collects data in multiple ways for triangulation over an extended period of time and the process is inductive, holistic and requires a long term commitment (Angrosino, 2007). Ethnographers immerse themselves in the lives of the people they study and seek to place the phenomena studied in their social and cultural context (Malhotra, 2017). Ethnography is dialogic since conclusions and interpretations formed through it can be given comments or feedback from those who are under study (Angrosino, 2007).

3.7.3 Grounded Theory

Ethnography and grounded theory studies begin with the same a posteriori principle that truth is found through experience and grounded theory naturally fits with a constructivist philosophy because that can also be used to understand people's thoughts and behaviour (Charmaz, 2006). According to Malhotra (2017) grounded theory is a research method that seeks to develop a theory that is grounded in data systematically gathered and analysed. According to Charmaz (2006) grounded theory encourages reflexivity when analysing data to check for events and reactions that may have happened due to the presence of the researcher and therefore a grounded theory study is more appropriate for a study with time constraints.

Grounded theory is an inductive theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data (Malhotra, 2017). According to Williamson (2006) selecting a sample frame for grounded theory and for ethnographic studies does not involve random sampling for research participants and either method is concerned with statistical representation; instead groups or individuals are targeted who represent the important characteristics that researchers consider of interest to the study.

The major difference between grounded theory and other methods is its specific approach to theory development and grounded theory suggests that there should be a continuous interplay between data collection and analysis (Malhotra, 2017).

Grounded theory was initially devised as a set of explicit procedures for qualitative data analysis in order to construct useful middle range theories from data (Charmaz, 2006). Both grounded theory and ethnography seek to understand different people's perceptions and other realities, seeing events and actions through the eyes of the participants (Fetterman 2010; Charmaz 2006). Grounded theory approaches are becoming increasingly common in the research literature because the method is extremely useful in developing context-based, process-oriented descriptions and explanations of the phenomenon (Malhotra, 2017).

3.7.4 Phenomenological Study

Phenomenology as a philosophical research tradition emerged within the early part of the 20th century and was built on the work of either philosophers who discussed human experience as a starting point for philosophy (Trodres and Holloway, 2006). The researchers that believe there is no objective reality, but that reality is constructed by individuals and therefore reality is subjective use phenomenology research approach (Rolfe, 2006). The fundamental aim of phenomenological philosophy is to develop a greater understanding of individual's experiencer and by adopting this approach, the theory is that it will allow human beings to be understood from inside their subjective experience (Todres and Holloway, 2006).

Phenomenology argues that differences between social science and natural science are so fundamental that the same methods for research would not suffice (Bryman and Bell 2011; Mouton, 1996). The main emphasis of phenomenological research is to describe or interpret human experience as lived by the experiencer in a way that can be used as a source of qualitative evidence (Todres and Holloway, 2006).

Based on the philosophy of phenomenology, research approaches in the social world should take cognisance of the difference with the natural world occasioned by human behaviour by employing an epistemology which acknowledges and capitalises on the differences and should be empathetic of the research participants (Bryman and Bell, 2011; Saunders *et al.,* 2012).

3.8 Research Instrument

There are various procedures of collecting data: tests, questionnaires, interviews, classroom observations, diaries and journals (Zohrabi, 2013). The process of recruiting participants for quantitative research is quite different from that of qualitative research and sample bias is a major failing in research design and can lead to inconclusive, unreliable results (Zikmund, 2003). Many researchers have focused on instrument development to measure health phenomena and as a result, appropriate instruments can be easily found for use in research and practice (Youngshin, Youn-Jung and Doonam, 2015).

Quite often, quantitative designs use tests and closed ended questionnaires in order to gather, analyse and interpret the data. However, the qualitative methods mostly make use of interviews, diaries, journals, classroom observations and open-ended questionnaires to obtain, analyse and interpret the data (Zohrabi, 2013). Use of existing instruments may provide the advantage of cost-effective and knowledge accumulation, however, instruments should be used in the same way that they were designed, to fit the situation in terms of place, time and population (Youngshin *et al.,* 2015).

The researcher should focus on the format of the questionnaire with attention to layout, readability, time demands on respondents, logic and clarity of content (Youngshin *et al.,* 2015). The researcher can revise the instrument as needed based on feedback provided and prepare a protocol for implementing the questionnaire (Youngshin *et al.,* 2015).

If a distortion of the measurement occurs because respondents' answer are falsified or misrepresented, either intentionally or inadvertently, the sample bias that occurs is a response bias (Zikmund, 2003). In this research the questionnaire had mostly closed ended questions. This meant there was little or no possibility of misinterpreting the response.

Nonresponses can affect the quality of the survey separately or jointly and increase the total number of survey errors (Toepoel and Schonlau, 2017). Non-response error is always a potential problem with mail surveys and individuals who are interested in the general subject, the survey are more likely to respond than those with less interest or little experience (Zikmund, 2003). Nonresponse can stem from the inability to contact potential respondents, from the unit's refusal or lack of cooperation, or from language or technical difficulties (Toepoel and Schonlau, 2017).

If some groups are misrepresented (in a way that is not corrected by applying sampling weights to adjust for unequal probability of selection), and if these groups behave differently with respect to the investigated question, then nonresponse is selective and results are biased (Toepoel and Schonlau, 2017). Despite the methodological challenges encountered by nonresponse follow-ups, compliance to the measurement invariance and non-respondents representativity, they are good tools to comprehend the nonresponse and nonresponse mechanism (Vandenplas *et al.,* 2015).

In practice, indicators measuring the representativeness of the collected data help overcome possible nonresponse biases and post survey adjustment techniques can then be implemented to help reduce nonresponse biases (Toepoel and Schonlau, 2017). Identifying good participation indicators is a key step in detecting and treating nonresponse and nonresponse bias (Vandenplas *et al.,* 2015). Preventing nonresponse also passes through devising the questionnaire acceptable to the respondents (Toepoel and Schonlau, 2017).

There are many different types of bias and participation in questionnaire must be on a voluntary basis, if only those people with strong views about the topic being researched volunteer then the results of the study may not reflect the opinions of the wider population creating a bias (Zikmund, 2003). According to Toepoel and Schonlau (2017) post survey adjustment techniques, including imputation and weighting, are devised to reduce nonresponse biases.

Imputation methods rely on information available on individuals for other variables than those to impute and missing values can be replaced by the mean of the variable to impute or by values forecast in a regression by other explanatory variables (Toepoel and Schonlau, 2017). Missing values due to attrition can be reduced by extrapolating from previous waves and deterministic imputation methods tend to underestimate the variances (Toepoel and Schonlau, 2017). The introduction of a random component, which increases the variances, has the merit to counterbalance this effect and different imputation techniques are commonly used to contain the biases introduced by a specific technique (Toepoel and Schonlau, 2017).

According to Leeuw, Hox and Huisman (2003) three main patterns can be discerned in item missing data, namely;

- The data are missing systematically by design
- All the data are missing after a certain point in the questionnaire (partial nonresponse)
- Data are missing for some items for some respondents (Item nonresponse).

According to Toepoel and Schonlau (2017) there are techniques to deal with nonresponse biases, namely;

- Post stratification consists of distributing the population into groups using auxiliary common variables such as sex, age and education so that the auxiliary variables are distributed as in the whole population. This is achieved by dividing the population percentage of a post stratification cell by the sample percentage in that cell and using the ratio as weight.
- Linear regression involves neither joint nor marginal distributions but helps adjust sample estimates to population parameters. The estimate from the sample is equated to the population total output. The weights are chosen to fit the population totals and can be viewed as regression coefficients.
- Adjustment by propensity score is devised to modify the mean values of the auxiliary variables in the sample closer to those estimated from a higher-quality sample of reference. The common procedure is to regress the indicator variable of the sample versus the sample of reference on attitudinal or web-related variables. Inverse propensity scores can be used as weights. The quality of the adjustment depends on the relevance of auxiliary variables to the question under study and to their correlations with the response biases.

3.9 Questionnaire Design

Questionnaire design is more of an art than science and the importance during the process of the questionnaire design is attention to the purpose of the questionnaire (Youngshin *et al.*, 2015). Before designing the survey questions, some features and format of the survey should also be touched upon as the look of the questionnaire survey will affect the respondents' reaction to it (Dillman, 2007). The flow of items should be clear and easy to understand in order to gather precise information and when using an existing questionnaire and performing cultural adaptation, psychometric properties and cultural equivalence should be initially evaluated (Youngshin *et al.*, 2015). A pilot test will help to evaluate preliminary questions prior to administration to avoid later mistakes (Youngshin *et al.*, 2015).

According Youngshin *et al.* (2015) most respondents have the tendency to respond to questionnaires without considering how missing responses will be analysed, how they will contribute to answering research questions and how researchers will account for questionnaires that are not returned.

Most researchers experience issues related to non-response when self-report questionnaires are used and the literature has offered suggestions on how to avoid those problems and how to develop questionnaires to measure psychological constructs more concisely (Youngshin *et al.*, 2015).

The questionnaire used in this research had two parts. Part one was the particulars of respondents and part two was the research questions. The research questions used a Likert scale. The neutral option was used to accommodate participants that preferred not to comment or were puzzled about the statement. The five options were presented to the participants to choose the answer that express their feelings most accurately about the statement. The respondents were requested to use any type of indication be it a cross, or a tick or they could circle in the relevant answer.

Validity of Likert scale is driven by the applicability of the topic concerned, in context of respondents understanding and judged by creator of the response item and when the topic concerned is relevant to the respondents' context provision of more option, may add to the content & construct validity of the scale (Joshi *et al.*, 2015).

According to Vannette (2014) questions should be worded to be as follows,

- Be simple, direct, comprehensible
- Not use jargon
- Be specific and concrete
- Avoid ambiguous words
- Avoid negations
- Avoid leading questions
- Include filter questions
- Be sure questions read smoothly aloud
- Avoid emotionally charged words
- Avoid prestige names

- Allow for all possible responses

According to Youngshin *et al.* (2015) the process and steps for developing a scale vary depending on what is being measured in a study and the eight steps in creating a questionnaire for a successful epidemic study are, namely;

- Identify the leading hypotheses about the source of the problem
- Identify the information needed to test the hypotheses
- Identify the information needed for the logistics of the study and to examine confounding factors.
- Write the questions to collect this information
- Organise the questions into questionnaire format
- Test the questionnaire
- Revise the questionnaire
- Train interviewers to administer the questionnaire

3.9.1 Scales and Measurement

According to Joshi *et al.* (2015) Likert scale was devised in order to measure 'attitude' in a scientifically accepted and validated manner. An attitude can be defined as preferential ways of behaving/reacting in a specific circumstance rooted in relatively enduring organisation of belief and ideas (around an object, a subject or a concept) acquired through social interactions. According to Boone and Boone (2012) to properly analyse Likert data, one must understand the measurement scale represented by each and numbers assigned to Likert-type items express a "greater than" relationship, however, how much greater is not implied and because of these conditions, Likert –type items fall into the ordinal measurement scale.

This is clear from this discourse mentioned above that thinking (cognition), feeling (affective) and action (psychomotor) all together in various combination/permutation constitute delivery of attitude in a specified condition (Joshi *et al.*, 2015). The issue is how to quantify these subjective preferential thinking, feeling and action in a validated and reliable manner (Joshi *et al.*, 2015).

The difficulty of measuring attitudes, character, and personality traits lies in the procedure for transferring these qualities into a quantitative measure for data analysis purposes and the recent popularity of qualitative research techniques has relieved some of the burden associated with the dilemma, however, many social scientists still rely on quantitative measures of attitudes, character and personality traits (Boone and Boone, 2012). According to Joshi *et al.* (2015) psychometrics techniques are being developed, instituted and refined in order to meet the quantification of traits like ability, perceptions, qualities and outlooks – the requirement of social sciences and educational researches.

According to Joshi *et al.* (2015) psychometrics operates through two ways, namely;

- The first is to formulate approaches (theoretical construct) for measurements, followed by development of measuring instruments and their validation. Stanford Binet test (measures human intelligence) and Minnesota Multiphasic Personality) are the example for the same. The content in such instruments are rather 'pre – fixed'.
- The other path is same up to formulation of theoretical construct for the measurement. This conceptualization is followed by operational assembly of abstract ideas/experiences/issues under investigation into some statements (items) largely guided by the aim of the study. This permits the contents (items) in such scales/modes to be rather flexible and need based. Rasch measurement model (use for estimation of ability), Likert scale (measures human attitude) are the examples of such scales in Psychometrics used widely in the social science and educational research.

Descriptive statistics recommended for ordinal measurement scale items include a mode or median for central tendency and frequencies for variability, additional analysis procedures appropriate for ordinal scale items include the chi-square measure of association (Boone and Boone, 2012).

According to Joshi *et al.* (2015) if one wishes to combine the items in order to generate a composite score (Likert scale) of set of items for different participants, then the assigned scale will be an interval scale. Likert scale data are analysed at the interval measurement scale and Likert scale items are created by calculating a composite score (sum or mean) from four or more type Likert – type items, therefore, the composite score for Likert scale should be analysed at the interval measurement scale (Boone and Boone (2012). According to Joshi *et al.* (2015) the methods adopted for Likert scale analysis largely depends on the item response variable assignment into ordinal or interval scale which in turn depends on the construct of research instrument.

The measures for central tendency and dispersion for an interval scale are mean and standard deviation, this data set can be statistically treated with Pearsons' correlation coefficient (r), analysis of variance (ANOVA) and regression analysis (Joshi *et al.*, 2015). Descriptive statistics recommended for interval scale items include the mean for central tendency and standard deviations for variability, additional data analysis procedures appropriate for interval scale items would include the Pearson's coefficient, t-test, ANOVA, and regression procedures (Boone and Boone, 2012).

Construct of research instrument can be derived from objectives of study and objectives are the operational form of theoretical construct of phenomenon under inquiry and designing of instruments based upon objectives and frameworks of study decided further statistical treatment (Joshi *et al.*, 2015).

3.9.2 Questionnaire Administration

In this research a questionnaire was used as a research instrument. Questionnaire are divided into two different types, self-administered and interviewer administered (Saunders *et al.,* 2003). According to Youngshin *et al.* (2015) self-administration is the most popular method of administering questionnaires in survey studies and self-administered questionnaires can be collected via post, email or electronically. This research used a self-administered questionnaire. Self-administered questionnaires are easy to implement, cost-effective, and protect confidentiality (Youngshin *et al.*, 2015).

Self-administered surveys of all types typically cost less than personal interviews (Cooper and Schindler, 2005). Moreover, they can be completed at the respondent's convenience and administered in standard manner (Youngshin *et al.,* 2015).

Interview administered questionnaires allow participation by illiterate people and clarification of ambiguity and the best method for administered questionnaires depends on who the respondents are (Youngshin *et al.,* 2015).

In this research, the questionnaire was distributed personally and the explanation was done face to face with the respondents. The questionnaire was pilot tested first with 20 permanent and contractor employees to find out completion time, any unclear questions, and other concerns from the questionnaire. The workmates were invited to a 30 minutes engaging session during working hours after receiving permission from the supervisors and managers. The questionnaire was handed over to the randomly selected potential participants in groups of 15 – 20 per engaging session. The participants included all different levels in the organization from senior management, junior management, supervisors, engineers, inspectors, technicians, fitters, artisans, operators and others.

The challenges encountered in this research were to persuade people to spend 20 or less minutes of their time answering the research questionnaire. The other problem was to get the managers and supervisors to release the employees during working hours, especially those that are doing physical labour. There was no incentive provided to employees that answered the questionnaire, may be if there was an incentive, employees would have been attracted to participate. Employees that were systematic selected in this research varied from top management of the organisations to the hard labour in the petrochemical industry KwaZulu-Natal Province.

3.10 Sampling

According to Creswell (2015) cited in Guetterman (2015) sampling in quantitative research typically follows random sampling procedures and researchers calculate the required sample size before beginning the study and that size remains a constant target throughout the study. According to Alvi (2016) the process through which a sample is extracted from a population is called sampling and in investigation it is impossible to assess every single element of a population, so a group of people (smaller in number than the population) is selected for the assessment. Qualitative sampling is not a single planning decision and a reflexive researcher then makes adjustments and considers the implications of sampling on interpretation (Emmel, 2013; Guetterman, 2015).

Sample population was selected using systematic sampling amongst permanent employees and contractors permanently onsite. A systematic sample is designed to be an easy alternative to simple random sampling and it is taken by deciding on what fraction of the population is to be sampled (Cooper and Schindler, 2005). According to Alvi (2016) the inferences are drawn for the population and the more the sample is representative of the population, the higher is the accuracy of the inferences and better is the results (generalizable). A simple random sample is a sample taken in such a way that each combination of individuals in the population has an equal chance of being selected and the simple random sample is the simplest sampling plan to execute if one has a list of the population (Cooper and Schindler, 2005).

A sample is representative when the characteristics of elements selected are similar to that of entire target population. Sampling process may encounter the problem of systematic errors and sampling biases (Alvi, 2016). Systematic errors can be defined as incorrect or false representation of the sample and there are two main sampling categories, namely, probability sampling methods and non-probability sampling methods (Alvi, 2016).

3.10.1 Probability Sampling Methods

According to Alvi (2016) probability sampling is also called random sampling or representative sampling. In probability sampling every member of the population has a known (non-zero) probability of being included in the sample. Some form of random selection is used. The probabilities can be assigned to each unit of the population objectively. These techniques need population to be very precisely defined. They cannot be used for the population that is too general a category found almost everywhere in the world. If target population is defined as college students, it means person studying at any college of the world is an element of population.

Advantages

- This sampling technique reduces the chance of systematic errors.
- The methods minimize the chance of sampling biases.
- A better representative sample is produced using probability sampling technique.
- Inferences drawn from sample are generalizable to the population.

Disadvantages

- The techniques need a lot of efforts.
- A lot of time is consumed.
- The techniques are expensive.

According to Alvi (2016) there are five methods used for probability sampling, namely;

- Simple Random Sampling
- Systematic Random Sampling
- Stratified Random Sampling
- Cluster Sampling
- Multistage Sampling

(a) Simple Random sampling: In this type of sampling each and every element of the population has an equal chance of being selected in the sample. The population must contain a finite number of elements that can be listed or mapped. Every element must be mutually exclusive i.e. able to distinguish from one another and does not have any overlapping characteristics. The population must be homogenous i.e. every element contains same kind of characteristics that meets the described criteria of target population.

(b) Systematic Random Sampling: This type of sampling is also used for homogenous population. Unlike simple random sampling, there is no equal probability of every element to be included. The elements are selected at a regular interval; it may be in terms of time, space or order. This regularity and uniformity in selection makes the sampling systematic.

(c) Stratified Random Sampling: this type of sampling method is used when population is heterogeneous i.e. every element of population does not match all the characteristics of the predefined criteria. Sub groups are formed that are homogenous and they are called strata. The common criterions used for stratification are gender, age, ethnicity, socioeconomic status. However, the criterion varies greatly from investigation to investigation. The sample is selected from each stratum randomly. There are two techniques that are used to allocate sample from strata: proportional allocation technique and equal allocation technique. For proportional allocation technique the sample size of stratum is made proportional to the number of elements present in the stratum. For equal allocation technique same number of participants is drawn from each stratum regardless of the number of elements in each stratum.

(d) Cluster Sampling: the group of elements in one geographical region is called a cluster and sampling of cluster is called cluster sampling. This sampling technique is used when the elements of population are spread over a wide geographical area. The population is dived into sub-groups called clusters on the basis of their geographical allocation. The clusters ought to be homogenous.

(e) Multistage Sampling: it is a sampling technique where two or more probability techniques are combined. It is used when elements of population are spread over wide geographical region and it is not possible to obtain a representative sample with only one aforementioned technique.

3.10.2 Non - Probability Sampling Methods

According Alvi (2016) every unit of population does not get an equal chance of participation in the investigation and no random selection is made; the selection of the sample is made on the basis of subjective judgement of the investigator.

According Alvi (2016) these techniques do not need the population to be very precisely defined and they can be used for both types of population: the population that is too general category, and the population that is a specific category (precisely defined).

Non – probability sampling is well suited for exploratory research intended to generate new ideas that will be systematically tested later (Alvi, 2016) and the following are advantages and disadvantages;

Advantages

- Techniques need less effort.
- These techniques need less time to finish up.
- They are not much costly.

Disadvantages

- The sampling techniques are prone to encounter with systematic errors and sampling biases.
- The sample cannot be claimed to be a good representative of the population.
- Inferences drawn from sample are not generalizable to the population.

According to Alvi (2016) there are seven methods used for non-probability sampling, namely;

- Volunteer Sampling
- Convenient Sampling
- Purposive Sampling
- Quota Sampling
- Snowball Sampling
- Matched Sampling
- Genealogy Based Sampling

(a) Volunteer Sampling: the members of the sample self-selected themselves for being the part of the study. It is not the investigator who approaches the participants rather participants themselves reach the investigator.

(b) Convenient Sampling: it is also called accidental sampling or opportunity sampling. The researcher includes those participants who are easy or convenient to approach. The technique is useful where target population is defined in terms of very broad category. The target population may be girls and boys, men and women, rich and poor.

(c) Purposive Sampling: it is not a mutually exclusive category of sampling technique rather many other non-probability techniques is purposive in nature. In purposive sampling the sample is approached having a prior purpose in mind. The criteria of the elements who are to include in the study is predefined

(d) Quota Sampling: This type of sampling method is used when population is heterogeneous i.e. every element of population does not match all the characteristics of the predefined criteria. The elements differ from one another on a characteristic. The participants are selected non-randomly from each group on the basis of some fixed quota.

(e) Snowball Sampling: The investigator selects a person who matches the criteria of the research. The first participant is now asked to refer the investigator to another person who meets the same criteria. The second participant approached is asked to refer the researcher to another one and in this way a chain is made.

(f) Matched Sampling: this technique is used in experimental researches. The main purpose of this sampling is to take a control group to assess the effects of an intervention. The groups of elements that resemble on a variety of variables are selected. Intervention is introduced on only one group. The other group is used to compare with the first one to see what impacts the intervention produced.

(g) Genealogy Based Sampling: This sampling technique has been mostly used for taking samples from rural areas. Using this technique, instead of selecting household in an area, the members of the entire families are selected (whether or not living in the same house). It gives a reasonable cross section of the community by age and gender.

3.11 Data Collection

Most research begins with an investigation to learn what is already known and what remains to be learned about a topic, including related and supporting literature, but one should also consider previously collected data on the topic and data may already exist that can be utilised in addressing the research questions (Creswell, 2009).

There are two types of data available, primary and secondary data. Secondary data is information collected by others and primary data is information collected by the researcher (Ghauri and Gronhaung, 2002). The focus of this research was on the primary collected data. According to Hox and Boeije (2005) primary data are data that are collected for the specific research problem at hand, using procedures that fit the research problem best.

On every occasion that primary data are collected, new data are added to the existing store of social knowledge (Hox and Boeije, 2005).

According to Hox and Boeije (2005) increasingly, this material created by other researchers is made available for reuse by the general research community; it is then called secondary data and data may be used for, namely;

- The description of contemporary and historical attributes
- Comparative research or replication of the original research
- Reanalysis (asking new questions of the data that were not original addressed)
- Research design and methodological advancement
- Teaching and learning

According to Hox and Boeije (2005) the other established primary data collection strategy is the interview survey, a large and representative sample of an explicitly defined target population is interviewed.

Characteristically, a large number of standardised questions are asked and the responses are coded in standardised answer categories and a survey is carried out when researchers are interested in collecting data on the observations, attitudes, feelings, and experiences, or opinions of a population (Hox and Boeije, 2015). Information on subjective phenomena can be collected only by asking respondents about these (Hox and Boeije, 2015).

In conducting research, the area of investigation and the research questions determine the method that the researcher follows and the research method consists of how the researcher collects, analyses, and interprets the data in the study (Creswell, 2009). Social scientists who intend to study a particular theoretical problem or a specific policy issue have the choice to collect their own data or to search for existing data relevant to the problem at hand (Hox and Boeije, 2005).

The most important advantage of collecting one's own data is that the operationalization of the theoretical constructs, the research design and data collection strategy can be tailored to the research question, which ensures that the study is coherent and that the information collected indeed helps to resolve the problem (Hox and Boeije, 2005).

According to Froelicher (2009) cited in Johnston (2014) the use of existing data sets can accelerate the pace of research because some of the most time consuming steps of a typical research project, such as measurement development and data collection are eliminated. The most important disadvantage of collecting one's own data is that it is costly and time-consuming, if relevant information on the research topic is accessible, reusing it gains benefits (Hox and Boeije, 2005).

The disadvantage of using secondary data is that the secondary researcher did not participate in the data collection process and does not know exactly how it was conducted (Johnston, 2014). The other disadvantage of using secondary data is that the data were originally collected for a different purpose and therefore may not be optimal for the research problem under consideration or, in the case of qualitative data, may not be easy to interpret without explicit information on the informants and the context; the advantage of using secondary data is a far lower cost and faster access to relevant information (Hox and Boeije, 2005). The secondary researcher does not know how well it was done and if data are affected by problems such as low response rate or respondent misunderstanding of specific survey questions (Johnston, 2014).

3.12 Data Analysis

According to Ozgur *et al.* (2017) MegaStat can perform a multitude of statistical operations: descriptive statistics, frequency distributions, probability, confidence intervals and sample size, hypothesis tests, ANOVA, regression, time series/forecasting, chi-square, nine nonparametrics tests, quality control process charts, and generate random numbers. SPSS and SAS, for example, have more advanced options, especially in the area of multivariate statistics.

Statistical Packages for Social Science (SPSS) version (25) was used to analyse the data collected through the surveys. The research applied the structural equation modelling (SEM) technique and utilised AMOS version (25) tools to test the hypotheses among the variables in the model. Structural equation modelling (SEM) is a statistical technique that allows the researcher to examine multiple interrelated dependence relationships in a single model. Structural equation modelling is a popular method in social science research, it has flexibility for interpreting the theory to be tested and the sample data (Alshetewi *et al.,* 2015). Descriptive statistics used in this research are median, standard deviation, standard error of the mean, and correlations between variables.

SPSS, originally termed Statistical Package for Social Science, was released in 1968 as software designed for social sciences and a series of companies subsequently acquired SPSS, ending with International Business Machines (IBM), the current owner, during which time the product's user base was expanded (Ozgur *et al.,* 2017). There, its former acronym was replaced with Statistical Product and Services Solutions to reflect the greater diversity of its clients (Ozgur *et al.,* 2017). Along with Minitab, it is one of the leading statistical packages used in the social and behavioural sciences (Ozgur *et al.,* 2017).

Quantitative methods were used to analyse the data by means of statistical package SPSS. Frequency plots were used to calculate the percentages. The mean and standard deviation were computed and the main deficiencies were decided on when the mean was greater than 2.3. The mean that is greater than 2.3 was considered to be more towards disagree and strongly disagree. The person correlation was used to assess relationships. A correlation coefficient (r) was used to quantify the strength of the relationship between different process health and safety elements that affected generative health and safety culture in the petrochemical industry. Pearson's coefficient has a value +1 and -1 in statistics (Waters, 2001). Correlation and experimentation are used to reduce complex interactions (Grix, 2004).

According to Waters (2001) a value of $r = 1$ shows that the two variables have a perfect linear relationship with no noise at all, and as one increases so does the other. A lower positive value of r shows that the linear relationship is getting weaker. A value of $r = 0$ shows that there is no correlation at all between the two variables and lo linear relationship. A lower negative value of r = shows that the linear relationship is getting stronger. A value of r = -1 shows that the two variables have a perfect linear relationship and as one increases the other decreases. The above values of r were used in this research as a guide to decide whether the relationship between the variables was strong or weak. The relationship between the factors with correlation coefficients (r) less than 0.3 and greater than -0.3 are taken as statistically not related. Correlation coefficient (r) less than 0.7 and greater than or equal to 0.3 or greater than -0.7 and less or equal to -0.3, are taken as statistically having weaker positive and negative correlations respectively. Correlation coefficients greater or equal to 0.7 and less or equal to 0.7 are taken as statistically having strong positive and negative correlations respectively (Waters, 2001).

3.13 Data Screening

The data from the survey questionnaire was analysed using the following methods:

- Assessment of internal consistency using SPSS
- Confirmatory Factor Analysis using SPSS
- Structural Equation Modelling using AMOS

Data screening and preparation was carried out as follows, namely;

- Consideration for sample size
- Examination for missing data
- Evaluating univariate and multivariate normality
- Consideration of outliers, and
- Item parcelling

3.13.1 Sample Size

In most areas in life, it is very difficult to work with populations and hence researchers choose to work with samples (Gogtay, 2010). The most important consideration in sampling is the planning of appropriate technique to be used considering the situation on ground, and determination of sample size adequate to ensure confidence on the inference made out of the results of the study within the limitations under which the study (sampling) was conducted (Dahiru *et al*., 2006). According to Arthur *et al*. (2014) it is clever to determine efficient sample size before the data collection as the studies generally estimate the characteristics of large population and many determinants command the sample size including object variability, sample type, estimation precision, the degree of confidence and the availability of time and budget (Kuncel *et al.*, 2005).

Sample size calculations begin with an understanding of the type of data and distribution dealt with and very broadly, data are divided into quantitative (numerical) and categorical (qualitative) data (Goptay, 2010). In practice, this means that before carrying out any investigation one should have an idea of what kind of change from the null hypothesis would be regarded as practically important and the smaller the difference regarded as important to detect, the greater the sample size required (Cornish, 2006).

Sample size calculations enable researchers to draw strong robust conclusions from the limited amount of information and also permit generalisation of results and it is however important to remember that since it is very difficult to predict the outcome of any study, sample size calculations will always remain approximate (Gogtay, 2010). According to Cornish (2006) one crucial aspect of study design is deciding how big sample should be and if sample size is increased the precision of estimates increases, which means that, for any given estimate/size of effect, the greater the sample size the more "statistically significant" the result will be.

If an investigation is too small then it will not detect results that are in fact important and if a very large sample is used, even tiny deviations from the null hypothesis will be significant, even if these are not, in fact practically important (Cornish, 2006). It should be borne in mind that sample size calculation is based on estimates and assumptions that can be inaccurate and is therefore subject to error (Patino and Ferreira, 2016).

According to Arthur *et al*. (2014) the sample size can be computed by statistical formula with three determinants, namely, the degree of confidence (historically 95 percent), the level of precision (acceptable error), and the variability of the object (standard deviation).
The sample size was computed in the following equation:

$$n = \{[z^2 \text{ x } \sigma (1 - \sigma)]/e^2\}/ \{1 + [z^2 \text{ x } \sigma (1- \sigma)/e^2N]\} \quad \textbf{(3.1)}$$

Where:

z: is Z-score which is equal to 1.96 associated with 95% confidence level
σ: is population standard deviation which usually uses 0.5 for safe decision
e: is margin of error with respect to a confidence level
N: is the population.

For the former, information on the mean responses in the two groups' μ1 and μ2 are required as also the common standard deviation for the two groups and for categorical data, ρ1 and ρ2 or information on proportions of successes in the two groups is needed (Goptay, 2010).

It is also important to be realistic when choosing the estimates employed in calculating the sample size (Patino and Ferreira, 2016). Highly optimistic choices about the effect size increase the risk of calculating an insufficient number of participants for the sample, whereas highly pessimistic choices can make the study unviable by resulting in a sample size that is too large to be practical (Patino and Ferreira, 2016).

According to Cornish (2006) In most studies, particularly those involving humans, there is likely to be a certain amount of data "lost" (or never gathered) from the original sample and this could be for a variety of different reasons, non-response, subjects deliberately withdrawing from a study or getting "lost" in some other way (e.g cannot be traced), subjects in clinical trial not following their allocated treatment, or missing data (e.g on a questionnaire).

Allowance should be made for this when determining the sample size. The sample size should be increased accordingly. The extent to which this is needed should be guided by previous experience or a pilot study (Cornish, 2006).

Choosing the correct size of sample is not a matter of preference, it is a crucial element of the research process without which the researcher may well be spending months trying to investigate a problem with a tool which is either completely useless, or over expensive in terms of time and other resources (Fox, Hunn and Matters, 2009). It is very important and mandatory that sample sizes are determined based on the study design and the objectives of the study. Failure to calculate size of sample with reference to particular study design may lead to incorrect results and conclusions (Dahiru, Aliyu and Kene, 2006).

3.13.2 Missing Data

Missing data is a problem because nearly all standard statistical methods presume complete information for all the variables included in the analysis and a relatively few absent observations on some variables can dramatically shrink the sample size (Soley-Bori, 2013). According to Tabachnick & Fidel (2013); Hair *et al.* (2010) cited in Harinarain (2013) considering the relatively few missing values in the dataset and the random pattern of missingness the researcher deemed it acceptable to ignore the missing data As a result, the precision of confidence intervals is harmed, statistical power weakens and the parameter estimates may be biased (Soley-Bori, 2013).

According to Tabachnick & Fidel (2013); Hair *et al.* (2010) cited in Harinarain (2013) if the data is missing in a random pattern the choice off procedure to handle missing values is not important since most procedures will yield comparable results.

Appropriately dealing with missing data can be challenging as it requires a careful examination of the data to identify the type and pattern of missingness, and also a clear understanding of how the different imputation methods work (Soley-Bori, 2013). Sooner or later all researchers carrying out empirical research will have to decide how to treat missing data (Soley-Bori, 2013).

In survey, respondents may be unwilling to reveal some private information, a question may be inapplicable or the study participant simply may have forgotten to answer it (Soley-Bori, 2013).

According Soley - Bori (2013) there are different assumptions about missing data mechanisms:

- Missing completely at random (MCAR): suppose variable Y has some missing values. Say these values are MCAR if the probability of missing data on Y is unrelated to the value of Y itself or to the values of any other variable in the data set. However, it does allow for the possibility that on Y is related to the missingness on some other variable X.
- Missing at random (MAR) a weaker assumption than MCAR: The probability of missing data on Y is unrelated to the value of Y after controlling for other variables in the analysis (say X).
- Not missing at random (NMAR): missing values do depend on unobserved values.

3.13.3 Univariate and Multivariate Normality

According Kline (2011); Schumacher & Lomax (2004) cited in Harinarain (2013) structural equation modelling estimation methods assumes multivariate normality, which means that (1) all the univariate distributions are normal (2) the joint distribution is bivariate normal and (3) bivariate scatterplots are linear.

According to Kline (2011); Pallant (2010); Raykov & Marcoulides (2006); Schumacker & Lomax (2004); Tabachnick & Fedel (2013) cited in Harinarain, (2013) skewness describes the symmetry of a distribution, whereas kurtosis describes the shape of the distribution. Positive skew indicates that most of the scores are below the mean, and negative skew indicates most of the scores are above the mean. Positive kurtosis indicates heavier tails and a higher peak described as leptokurtic and negative kurtosis indicates lighter tails and lower peak

According to Rousseeuw and Hubert (2011) multivariate *M*-estimators have a relatively low breakdown value due to possible implosion of the estimated scatter matrix. More recently, robust estimators of multivariate location and scatter include *S*-estimators, MM-estimators, and the orthogonalised Gnanadesikan-Kettenring (OGK) estimator.

3.13.4 Outliers

An outlier is a data point that is significantly different from the remaining data. Outliers are also referred to as abnormalities, discordants, deviants, or anomalies in the data mining and statistics literature (Aggarwal, 2016).

In most applications, the data is created by one or more generating processes, which could either reflect activity in the system or observations collected about entities and when the generating process behaves unusually, it results in the creation of outliers (Aggarwal, 2016). Outlying observations may be error, or they could have been recorded under exceptional circumstances, or belong to another population, consequently they do not fit the model well and it is very important to be able to detect these outliers (Rousseeuw and Hubert, 2011).

An outlier often contains useful information about abnormal characteristics of the systems and entities that impact the data generation process and the recognition of such unusual characteristics provides useful application-specific insights (Aggarwal, 2016).

There are many trade-offs associated with model choice, a highly complex model with too many parameters will most likely over fit the data, and will also find a way to fit the outliers (Rousseeuw and Hubert, 2011).

A simple model, which is constructed with a good intuitive understanding of the data (and possibly also and understanding of what the analyst is looking for), is likely to lead to much better results and on the other hand, an oversimplified model, which fits the data model, is perhaps the most crucial one in outlier analysis (Aggarwal, 2016). When analysing data, outlying observations cause problems because they may strongly influence the results. Robust statistics aims at detecting the outliers by searching for the model fitted by the majority of the data (Rousseeuw and Hubert, 2011).

SPSS defines outliers if they extend more than 1.5 box – lengths from the edge of the box. Extreme points are those that extend more than three box – lengths from the edge of the box and are indicated with an asterisk (Harinarain, 2013).

In practice, one often tries to detect outliers using diagnostics starting from a classical fitting method, classical methods can be affected by outliers so strongly that the resulting fitted model does not allow detecting the deviating observations (Rousseeuw and Hubert, 2011). This is called the masking effect. In addition, some good data points might even appear to be outlier, which is known as swamping and to avoid these effects, the goal of robust statistics is to find a fit that is close to the fit that would have been found without the outliers (Rousseeuw and Hubert, 2011).

According to Jung Kim (2017) practitioners often "toss out" such anomalous points, which may or may not be a good idea and if it is clear that an outlier is the result of a mishap or a gross recording error, then this may be acceptable and on the other hand, if no such basis may be identified, the outlier may, in fact, be a genuine response.

There are other aspects to robust statistics apart from outlier detection (Rousseeuw and Hubert, 2011). For instance, robust estimation can be used in automated settings such as computer vision, another aspect is statistical inference such as the construction of robust hypothesis tests, ρ – values, confidence intervals, and model selection (e.g., variable selection in regression) (Rousseeuw and Hubert, 2011).

According to Jung Kim (2017) there are strategies to deal with outliers and the suggestions are as follows,

- Delete outliers and redo the analysis (new outliers may surface).
- Sometimes the purpose of the experiment is just to identify the outliers. In this case there is no need to redo the analysis.
- Check the experimental circumstances surrounding the data collection for the outlying cases.
- Report the analysis both with and without the analysis and let the reader decide.

3.13.5 Item Parcelling

According to Sterba and MacCallum (2010) when the conservative unidimensionalty requirements for the use of item parcels are met, there can be substantial variability in parameter estimates and fit indexes, due to different allocations of items to parcels from a 12 item scale.

According to Brown (2006) cited in Harinarain (2013) the advantage of using parcels when specifying models, is a more parsimonious model as fewer parameters need to be estimated and the distribution of these parcels more closely resemble normal distribution than the original items. Item parcelling can therefore be used as a remedial approach to address non-normality and the one disadvantage of parcelling is that parcelling depends on the unidimensionality of the items being combined (Bandalos, 2002; Brown, 2006; Harinarain, 2013).

According to Marsh *et al.* (2013) it is recommended to,

- Avoid using parcels to camouflage method effects, cross loadings, and other sources of misspecification at the item level. It is better to systematically model the misspecification at the item level. Failure to do so might turn out to be substantively important and will typically bias interpretations of substantively important parameter estimates.
- The use of item parcels is only justified when there is good support for the unidimensionality of all the constructs at the item level for the particular models and sample being considered. Tests for this requirement should be conducted for the complete model at the item level – not simply the evaluation of each construct separately, which is likely to ignore many forms of misspecification.
- If parcels are used, then applied researchers should use homogeneous rather than distributive parcel strategies that confound sources of misfit with allocation items to parcels. They should make explicit the parcelling strategy used, its justification, and particularly if sampling variability is large. Justification for the use of item parcels should be accompanied by at least a summary of the corresponding results based on item analyses and any substantively important difference between the two.
- Applied researchers will continue to argue, sometimes with good justification, that there are situations in which it is not reasonable to replicate fully the analyses based on parcels with models based on items.

It is almost always preferable to evaluate latent variable models based on item-level data, particularly when the sample size is appropriate (Marsh *et al.*, 2013). A priori use of item parcels (an extreme pragmatist perspective) is never justified without clear support for the a priori model at the item level and unidimensionality in relation to the models and data under consideration (Marsh *et al.*, 2013).

Expedient compromises between parsimony and accuracy in applied research when sample sizes are modest (e.g., the use of parcel scores) are likely to be biased under typical conditions (Marsh *et al.*, 2013). They should be avoided unless there is clear evidence that the very restrictive unidimensinality assumptions upon which they are based are met, or that the sizes of biases are trivially small and substantively unimportant (Marsh *et al.*, 2013).

3.14 Reliability and Validity

According to Zohrabi (2013) one of the main requirements of any research process is the reliability of the data and findings. Reliability means consistency or the degree to which a research instrument measures a given variable consistently every time it is used under the same condition with the same subjects (Yilmaz, 2013). Reliability refers to the extent to which our measurement process provides consistent or repeatable results and it indicates how closely the results of repeated measurements of the same concept agree: a reliable measurement of quantify known not to have changed that is performed twice with the same person will produce the same value both times (Zohrabi, 2013). The same is true where two different people are involved who do not differ on the measured characteristic.

It is important to note that reliability applies to data not to measurement instruments and from different perspectives or approaches, researchers can evaluate the extent to which their instruments provide reliable data (Yilmaz, 2013).

Cronbach's alpha test is the most generally used measurement to test the reliability or internal consistency of the data collection instruments, while internal consistency normally tells how well the items in the test measure the same construct (Zohrabi, 2013). The two essential elements to assess the instrument are validity and reliability, an instrument measurement cannot be authenticated without reliability (Yilmaz, 2013). The reliability and validity of the constructs must be scrutinized and assessed before using them in the structural model (Schreiber *et al.,* 2006).

The research used the questionnaire survey to gather the data, and the reliability of the questionnaire was tested in order to produce validated and reliable results. Cronbach's alpha test was used in the data analysis to measure the internal consistency of the items in the questionnaires.

The concept of validity in quantitative study corresponds to the concept of credibility, trustworthiness, and authenticity in qualitative study which means that the study findings are accurate or true not only from the standpoint of the researcher but also from that of the participants and the readers of the study (Cresswell & Miller, 2000; Yilmaz, 2013). The concept of reliability in quantitative study is comparable, but not identical, with the concept of dependability and auditability in qualitative study, which means that the process of the study is consistent over time and across different researchers and different methods Yilmaz, 2013).

Validity refers to the extent to which our measurement process is measuring what we intend to be measuring and there is content validity that confirms how well the sample of questions reflects the domain of possible questions (Vannette, 2014). According to Lipsey (2009), a study with both strong internal validity and strong external validity would require: a relatively large research sample randomly drawn from the relevant population (external validity), randomly assignment to intervention and control conditions with attrition (internal validity).

Criterion - related validity looks at what is the strength of the empirical relationship between question and criterion, the construct validity is more on how closely does the measure behave like it based on established measures or the theory of the underlying construct (Vannette, 2014). Construct validity is concerned with the question on how much the construct measured by the research reveals the hypothesised construct (Mona and Martin, 2016).

When considering the validity of a research study, there is a need to ask two basic questions. First, does the study have sufficient controls to ensure that the conclusions drawn are truly warranted by the data? And second, can what is observed be used in the research situation to make generalisations about the world beyond that specific situation? The answers to these two questions address the issues of internal validity and external validity, respectively (Leedy and Ormrod, 2005).

Validity is the extent to which an instrument measures what it is supposed to measure and performs as it is designed to perform and it is rare, if nearly impossible, that an instrument be 100% valid, so validity is generally measured in degrees (Vannette, 2014).

Internal validity is concerned with how much the variations in the dependent variables is caused by independent variables (Grajo *et al.,* 2016). To attain high internal validity, consideration should centre on no significant related data being overlooked and suitable methods should be nominated (Schick and Vaughn, 2002).

As a process, validation involves collecting and analysing data to assess the accuracy of an instrument (Vannette, 2014). Survey design should begin with a data analysis plan that can provide structure and help to avoid many problems, every question must have a purpose, and every question should produce the best possible data for the purpose of the study (Vannette, 2014).

The measurement indicators or variables have different correlations or loading values as the indicators measure the latent construct in different degrees. Measurement indicators having low loadings should be eliminated since they offer small explanatory power to the model (Aibinu and Al-Lawati, 2010). A common acceptable threshold value for a good indicator is having a loading higher than 0.5. The value of Cronbach's alpha ranges from 0 to 1 as the value become closer to 1 the higher reliability of the items. The reliability test should be conducted before the construct validity analysis is commenced. Constructs are considered reliable when Cronbach's alpha is 0.7 or higher (Alshetewi *et al.,* 2015). The lack of researcher's faithfulness can cause the significance of the information gathered to be partial, raising doubts regarding its reliability and validity (Vannette, 2014).

3.15 Regression Analysis

According to Campbell and Campbell (2008) regression analysis is a statistical method to determine the linear relationship between two or more variables and regression is primarily used for prediction and casual inference. In its simplest (bivariate) form, regression shows the relationship between one independent variable (X) and a dependent variable (Y), as in the formula below:

$$Y = \beta_0 + \beta_1 X + u \qquad \textbf{(3.2)}$$

The magnitude and direction of that relation are given by the slope parameter (β_1), and the status of the dependent variable when the independent variable is absent is given by the intercept parameter (β_0), an error term (u) captures the amount of variation not predicted by the slope and intercept terms, the regression coefficient (R^2) shows how well the values fit the data (Campbell and Campbell, 2008).

According to Rousseeuw and Hubert (2011) the multiple linear regression model assumes that in additional to the ρ independent x – variables also a response variable y is measured, which can be explained by a linear combination of the x – variables.

According to Campbell and Campbell (2008) a regression analysis is usually centred on describing and evaluating the relationship between a given variable Y (dependent variable) and one or more other variables $X_1, X_2, \ldots.. X_n$ (independent variable). Regression models include more than one independent variables are called multi regression models. One of the vital assumptions for regression analysis is that there is a linear relationship between the dependent variable and independent variable.

According to Jung Kim (2017) regression is one of the most widely used statistical technique, estimates relationships among variables and models provide a very flexible framework for describing and testing hypotheses about relationship between explanatory variables and a response variable.

According to Jung Kim (2017) typically, a regression analysis is used for the following purposes, namely;

- Modelling the relationship between variables.
- Prediction of the target variable (forecasting).

- Testing of hypotheses.

The basis of regression analysis is the linear model. The model can be characterised as follows. Where there are *n* sets of observations $\{X_{1i}, X_{2i}, \ldots, X_{pi}, Y_i\}$, i = 1, …., n, which represent a random sample from a larger population. It is assumed that these observations satisfy a linear relationship

In this research the relationships between the process health and safety elements was tested against generative health and safety culture. According to Jung Kim (2017) the regression analysis can deliver a simple understanding of the relations. Algorithms for exploratory factor analysis include principal component analysis, and an algorithm for structural equation modelling using the analysis of a moment structures (AMOS).

3.16 Principal Component Analysis

According to Rousseeuw and Hubert (2011) cited in Zhao (2017) principal component analysis is a very popular dimension – reduction method and it tries to explain the covariance structure of the data by a small number of components. According to Zhang *et al.* (2013) cited in Zhao (2017) the principal component regression methods combine linear regression with principal component analysis and it transfers a set of highly correlated independent variables into a set of uncorrelated independent principal components.

These components are linear amalgamations of the original variables and often allow for an interpretation and a better understanding of the different sources of variation and PCA is often the first step of the data analysis, followed by other multivariate techniques (Rousseeuw and Hubert, 2011; Zhao 2017).

The principal component analysis not only litigates the multicollinearity problem but also reveals which independent variables should be predictors (Zhang *et al.*, 2013; Zhao, 2017).

According to Zhang *et al.* (2013) cited in Zhao (2017) the spatial pattern' new variables remove the properties caused by multicollinearity after principal component analysis, as the ideal predictors to use in a regression analysis and the new variables are mutually orthogonal and uncorrelated which are linear combinations of the original variables.

In the classical approach, the first principal component corresponds to the direction in which the projected observations have the largest variance. The second component is then orthogonal to the first and again maximises the variance of the data points projected on it (Rousseeuw and Hubert, 2011; Zhao, 2017).

Continuing in this way produces all the principal components, which correspond to the eigenvectors of the empirical covariance matrix, but unfortunately, both the classical variance matrix (which is being decomposed) is very sensitive to anomalous observations. Consequently, the first components from classical PCA are often attracted toward outlying points and may not capture the variation of the regular observations (Rousseeuw and Hubert, 2011; Zhao, 2017).

According to Zhang *et al.* (2013) cited in Zhao (2017) the number of principal components is often reduced due to only several eigenvectors being used where their corresponding eigenvalues are greater or equal to 1 and this is why the principal component analysis can reduce the number of independent variables.

According to Zhang *et al.* (2013) cited Zhao (2017) principal components are linear combinations of the original variables, but they are orthogonal, the percentage of total variance in the original data is represented by each principal component is the reasonable number of principal components that are selected depends on the cumulative variance being over 85 – 90%.

$$\lambda_i a_i = V a_i \qquad \textbf{(3.3)}$$

Where:

λ is the eigenvalue of V
a_i is the corresponding eigenvector

The principal components can be computed in

$$PC_t\,(i) = a_i\, X_t, \qquad i = 1,2,\ldots\ldots,p \qquad \textbf{(3.4)}$$

The percentage of total variance in the original data represented by each principal component is calculated as follows:

$$L_i = \lambda_i/(\Sigma_{i=1}\,\lambda_i) \text{ x } 100\% \qquad \textbf{(3.5)}$$

Where:

λ_i represents the ration of the component i to the total components
p is the total number of components
L_i represents the variance of component i

According to Tabachnick and Fidell (2007) cited in Yong & Pearce (2013) principal component analysis is used to extract maximum variance from the data set with each component thus reducing a large number of variables into smaller number of components. Principal components analysis is data reduction technique and the issues of whether it is truly a factor analysis technique has been raised (Costello & Osborne, 2005; Yong & Pearce, 2013).

Researchers may use Principal Component Analysis as the first step to reduce the data, then follow-up with a true factor analysis technique, the factor loadings are fairly similar and will need to perform rotation regardless of the extraction technique (Tabachnick & Fidell, 2007; Yong & Pearce 2013). It is best to pick the extraction technique based on research question and the ease of interpretation (Yong & Pearce, 2013).

3.17 Structural Equation Modelling

Structural Equation Modelling is an attempt to model casual relations between variables by including all variables that are known to have some involvement in the process of interest and the first step in structural equation modelling is to specify a model (Raykov, 2006; Zhao, 2017). Structural equation modelling can be engaged to capture complex relationships between one or more dependent and independent variables that can be sources from qualitative or quantitative data (Hox and Kleiboer, 2007; Zhao, 2017).

A model is simply a statement or set of statements about the relations between variables and structural equation modelling combines multiple regression analysis and factor analysis together to analyse the relationship between measured variables and latent variables (Raykov, 2006; Zhao, 2017). Structural equation modelling while resembling the regression analysis mostly, is a very powerful statistical technique that models interactions, it can cope with non-linear situations and lets correlation among independent variables (Hox and Kleiboer, 2007; Zhao, 2017).

Missing data is a serious issue in SEM and must be discussed in any article. Also, given new technologies, more options can handle missing data, such as maximum likelihood estimation (Schreiber *et al.,* 2006). Although the problem of missing values is not unique to structural modelling, estimating a successful model necessitates the appropriate handling of missing data from a methodological, as well as conceptual, perspective (Schumaker & Lomax, 1996).

Reliance on pairwise deletion can result in a nonpositive covariance matrix, and other methods, including replacement with the mean, may result in heteroscedastic error (Schumaker & Lomax, 1996).

Structural Equation modelling estimates the degree to which a hypothesized model fits the data and in a confirmatory factor analysis, goodness of fit indexes is estimated for each latent variable as a distinct structural model (Schreiber *et al.,* 2006).

The structural equation modelling normally encompasses the latent variables, the measures variable and regression paths, the latent variable can be identified as an eclipse or circle, while the measured or observed variable is showed as a rectangular shape while the regression path is expressed by an arrow (Child, 2006; Young and Pearce, 2013).

According to Schreiber *et al.* (2006) although it is wise and appropriate for one to measure items found in other studies to form a certain construct, it is not appropriate to assume that a certain group of items found to form a valid and reliable construct in another study will form an equally valid and reliable construct when measured in a different set of data.

Constructs tested on a national data set are valid in a new study in the rare instance when the new study uses the identical observations analysis in the same data with the same theoretical under pinning. Divergent choices addressing the problem of missing data will normally change construct validity results such that a new confirmatory analysis is appropriate (Schreiber *et al.,* 2006).

According to Byrne (2012) there three types of structural equation modelling analysis, namely;

- **Strictly confirmatory**: The researcher postulates a single model based on theory, collects the appropriate data, and then tests the fit of the hypothesised model to the sample data. The results of this test, the researcher either rejects or fails to reject the model. No further modifications to the model are made.
- **Alternative models**: The researcher proposes several alternative or competing models, all of which are grounded in theory. Following analysis of a single set of empirical data, the researcher selects one model as most appropriate in representing the sample data.

- **Model generating**: The researcher postulate and reject a theoretically derived model on the basis of its poor fit to the sample data, proceeds in an exploratory rather than confirmatory fashion to modify and re-estimate the model. The primary focus, in this instance, is to locate the source of misfit in the model and to determine a model that better describes the sample data.

The two main factor analysis techniques are Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) and it attempts to confirm hypotheses and used path analysis diagrams to represent variables and factors, whereas EFA tries to uncover complex patterns by exploring the dataset and testing predictions (Child, 2006; Young and Pearce, 2013).

3.17.1 Exploratory Factor Analysis

According to Yong and Pearce (2013) factor analysis is used to identify latent constructs or factors and it is commonly used to reduce variables into a smaller set to save time and facilitate easier interpretations. Exploratory factor analysis is used when a researcher wants to discover the number of factors influencing variables and to analyse which variables go together (DeCoster, 1998; Yong and Pearce, 2013).

A basic hypothesis of EFA is that there are m common latent factors to be discovered in the dataset, and the goal is to find the smallest number of common factors that will account for the correlations (McDonald, 1985; Yong and Pearce, 2013). There are many extraction techniques such Principal Axis Factor and Maximum Likelihood and factor analysis is mathematically complex and the criteria used to determine the number and significance of factors are vast (Yong and Pearce, 2013).

There are two types of rotation techniques – orthogonal rotation and oblique rotation and orthogonal rotation (e.g., Varimax and Quartimax) involves uncorrelated factors whereas oblique rotation (e.g., Direct Oblimin and Promax) involves corrected factors (Yong and Pearce, 2013).

According to Yong and Pearce (2013) the interpretation of factor analysis is based on rotated factor loadings, rotated eigenvalues, and scree test and in reality, researchers often use more than one extraction and rotation technique based on pragmatic reasoning rather than theoretical reasoning.

3.17.2 Confirmatory Factor Analysis

According to Schreiber *et al.* (2006) confirmatory factor analysis and structural equation modelling are statistical techniques that one can use to reduce the number of observed variables into a smaller number of latent variables by examining the covariation among the observed variables. Confirmatory factor analysis allows for the testing and refining of research constructs in relation to a theoretical framework (Yale *et al.,* 2015). Confirmatory factor analysis is carried out to test whether the measure of a latent construct corresponds with the study of the nature of the individual factor and at this stage, the indicator elimination and model re-specification are performed for each latent construct (Schreiber *et al.,* 2006).

Confirmatory factor analysis and structural equation modelling can each be an iterative process by which modifications are indicated in the initial results, and parameter constraints altered to improve the fit of the model, if such changes are warranted theoretically (Schreiber *et al.*, 2006). CFA is a theoretically driven process as opposed to EFA which is data driven (Byrne, 2006). If parameter is freed on the basis of a high modification index value, the researcher is called on to theoretically defend the change indicated so that the final model does not deviate from the initial theoretical model (Schreiber *et al.*, 2006).

Confirmatory factor analysis was adopted to test the strength and appropriateness of the relationship between latent constructs and corresponding measurement. CFA is also known as a measurement model as it can be used to assess the fit between the collected data and the conceptual relationship between process health and safety elements (Leadership Commitment, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Permit to Work, Training and Competency, Process Health and Safety Information, Control of Confined Space Entry, Operating Procedure and Control of Ignition Source) identified through literature review and the latent variable (Generative Health and Safety Culture).

3.18 Path Modelling Process

According to Schumacker & Lomax (2004) cited in Harinarain (2013) Path models and structural models can be conducted through five basic steps, namely;

- Model Specification
- Model Identification
- Model Estimation
- Model Testing
- Model Modification

(a) Step 1: Research Model Specification

According to Schumacker and Lomax (2010) involves using all of the available relevant theory, research and information to develop a theoretical model and prior to any data collection or analysis, the researcher specifies a particular model that should be confirmed using variance –covariance data.

Model specification involves determining every relationship and parameter in the model that is of interest to the researcher and is usually the first step in path models, structural equation modelling and regression models as it determines every relationship and parameters (Schumacker and Lomax, 2004; Harinarain 2013).

This is usually the hardest part of modelling as it involves developing a theoretical model and in order to avoid misspecification the theoretical model needs to be consistent with the true model which requires the specification of all relevant variables (Schumacker and Lomax, 2004; Harinarain 2013). Model specification was the first step performed in this research. Path modelling was used since this study has observed dependent variables.

(b) Step 2: Research Model Identification

During model identification process the researcher has to determine if there is sufficient information to obtain a unique solution for the parameters to be estimated by the model (Byrne, 2012; Harinarain, 2013). Model identification was the second step done in this research. According to Brown (2006); Byrne (2012); Hair *et al.* (2010); Kaplan (2000); Kline (2011); Schumacker & Lomax (2004) cited in Harinarain (2013) there are three types of model identification, namely;

- Under –identified models: where one or more parameters cannot be estimated or uniquely determined in the matrix due to lack of information and has negative degrees of freedom. This type of model can be unstable and should be looked at with scepticism as it is difficult to determine unique values for the model coefficients.
- Just-identified: (also referred to as a saturated model) models where all of the parameters are uniquely determined because there is just enough information in the matrix. This model contains zero degrees of freedom. The model perfectly reproduces the data resulting in a perfect fit.
- Over-identified models: these are the most preferred type of identification, when there is more than one way of estimating a parameter/s because there is more than enough information in the

matrix and the model has positive degrees of freedom. (Brown, 2006; Byne, 2012; Hair *et al.,* 2010).

(c) Step 3: Research Model Estimation

According to Kline (2011) cited in Harinarain (2013) during the estimation process the model fit is evaluated, the parameter estimates are interpreted and equivalent or near-equivalent models are considered. Model estimation was the third step done in this research. The aim of estimation is to generate numerical values for free parameters within the model that produces the implied matrix such that the parameter values yield a matrix as close as possible to the sample covariance matrix (Kline, 2011; Schumacker & Lomax, 2004; Harinarain, 2013).

(d) Step 4: Research Model Testing

Model testing is the fourth step that determines how well the data fits the model. Various authors have cautioned against the use of goodness-of-fit indices as rules of thumb or golden standards (Ho, 2006; Hu and Bentler, 1999; Schmitt, 2011; Harinarain, 2013). This is because all research is unique and sample sizes differ. These authors believe that consideration should be given to the adequacy of model parameters and complexity and therefore the model fit statistics should be used as guidelines as they only provide information on a models lack of fit and do not reflect the extent to which the model is plausible. Even if a model fits well, data can never confirm a model, they can only fail to disconfirm a model (Kline, 2011; Harinarain, 2013).

(e) Step 5: Research Model Modification

According to Schumaker and Lomax (2010) if the fit of the implied theoretical model is not as strong as one would like (which is typically the case with an initial model), then the next step is to modify the model and subsequently evaluate the new modified model. Model modification is carried out in order to improve the model so that a better fitting model and/or more parsimonious model which were substantively more interpretable can be obtained (Kline, 2011; Harinarian, 2013).

According to Kline (2011) cited in Harinarain (2013) model modification should be guided by theoretical considerations and not just determined by statistical results, because adjusting a model after initial testing increases the chance of making a type 1 error.

3.19 Chapter Summary

This chapter outlined the steps followed in the research as a research design and methodology. There were different research designs and methodologies that were examined in this chapter to simplify this research. The research approaches and methods that were best suited to the research topic were selected. The type of data used was mainly primary data for the quantitative research. A questionnaire was used as a research instrument to collect primary data and the literature review was used for the secondary data.

CHAPTER FOUR

Presentation of Results

4.1 Introduction

This chapter analyses the data that has been obtained from the respondents to establish relationships that are available in the data and cross-examining that with the literature review. The data analysis aims to identify the main factors that need senior management's attention to improve the behaviour and mind-set of employees to generative health and safety culture.

4.2 Questionnaire Administration

The questionnaire was piloted with about 30 employees within a petro-chemical organization to find out completion time and any concerns from the questionnaire. The completion time established be between 15 and 25 minutes depending on each respondents speed. The questionnaire was handed over to the randomly selected potential participants in groups of 15 to 30 per engaging session. The participants included all different levels in the organisations, senior management, junior management, supervisors, engineers, inspectors, technicians, fitters, artisans, operators and administration employees. The questionnaire was explained to the group and employees were allowed to decide whether they are willing to participate to the research or not. Those that were willing to participate in the research were then allowed to answer the questionnaire and those that opted out were allowed to leave. The potential participants received the questionnaire and 5 to 10 minutes was spent to explain the reason for the survey and the potential respondents were given a week to return the answered questionnaire.

4.3 Questionnaire Responses

According to Fincham (2008), a survey response rate helps to ensure that survey results are representative of the target population. Response rates are calculated by dividing the number of usable responses returned by the total number eligible in the sample chosen. The study was conducted by distributing 400 questionnaires manually to potential participants within a single petrochemical organization and therefore considered a convenience sample. The targeted population was 800 employees. The employees to whom questionnaires were handed during health and safety talks and production meetings were then requested to remain behind for an explanation. The duly completed questionnaires were 259, and were analysed using SPSS version 25. The response rate was computed to be 64.75%.

4.4 Demographic Information of Participants

Table 4.1 Age and Years of Service

	Minimum	Maximum	Median
Age	22	66	38
Years of Service	1	46	11

From Table 4.1 it is evident that the median age of participants was 38 with a minimum age of 22 years and a maximum age of 66 years. Further, the median number of years of service was 11 years with a minimum of 1 year and a maximum of 46 years. The participants were therefore considered matured with considerable years of experience in the petrochemical industry. This aspect increases the reliability of the responses received from the participants in terms of their accuracy and completeness.

Table 4.2 Gender, Marital Status and Department

Gender (%)	
Male	80,6
Female	19,4
Total	**100,0**
Marital Status (%)	
Single	37,2
Married	61,6
Divorced	1,2
Total	**100,0**
Department (%)	
Health, Safety and Environment	8,2
Operations	50,6
Maintenance	24,1
Technical	12,5
Others	4,7
Total	**100,0**

Table 4.2 indicates that 80.6% of the participants were males, 61.6% were married and most of the respondents were from the Operations Department (50.6%), followed by the Maintenance Department (24.1%).The results show that the petrochemical industry in the case of the sample organization is still male dominated. Operations and maintenance generally have more employees that are exposed to health and safety risks in petrochemical industry.

4.5 Quantitative Data Analysis

A quantitative research methodology and the deductive research approach in the form of questionnaire instrument was used to collect the data. The observed variables were measured using a Likert scale where 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree and 5=Strongly Disagree

4.5.1 Leadership Commitment

Table 4.3 Leadership Commitment Construct

Leadership Commitment	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
LCH10	64.5	32.4	1.9	1.2	0.0	1.40	0.591	1
LCH7	61.2	32.2	4.3	1.9	0.4	1.48	0.707	2
LCH40	57.1	30.1	9.3	1.5	1.9	1.61	0.866	3
LCH11	51.0	37.5	9.3	2.3	0.0	1.63	0.748	4
LCH8	50.8	37.6	9.3	1.9	0.4	1.64	0.763	5
LCH17	37.6	36.0	18.6	6.6	1.2	1.98	0.966	6
LCH38	8.5	25.2	31.0	26.4	8.9	3.02	1.103	7

Table 4.3 shows the responses to statements about leadership commitment. It is evident that LCH10 (Senior Management communicates Health and Safety policy to all employees) with a mean of 1.40 ranked highest out of the seven statements presented to the participants. Further, LCH 7 (Senior Management prioritises health and safety in my organisation) with a mean of 1.48 ranked second highest.

LCH40 (Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry), LCH11 (Senior Management allocates enough time to address Health and Safety concerns), LCH8 (Senior Management has an open door policy on health and safety issues), LCH17 (Senior Management prioritises mechanical/asset integrity of our process plant), and LCH38 (Poor housekeeping in my organisation is the cause for many health and safety incidents) ranked 3rd to 7th within the leadership commitment latent variable.

4.5.2 Chemical Exposure Management

Table 4.4 Chemical Exposure Management Construct

Chemical Exposure Management	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
CEMH30	71.0	24.7	2.7	1.5	0.0	1.35	0.612	1
CEMH6	47.9	44.4	6.2	1.2	0.4	1.62	0.692	2
CEMH14	42.6	42.2	12.8	2.3	0.0	1.75	0.766	3
CEMH12	42.1	44.4	9.7	3.9	0.0	1.75	0.783	4
CEMH15	22.0	40.4	32.2	5.1	0.4	2.22	0.858	5
CEMH16	15.5	28.3	40.3	13.2	2.7	2.59	0.991	6

Table 4.4 shows the responses to statements about chemical exposure management. It is evident that CEMH30 (All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.) with a mean of 1.35 ranked highest out of the six statements presented to the participants. Further, CEMH6 (My organisation has excellent chemical exposure management systems.) with a mean of 1.62 ranked second highest.

CEMH14 (Most permanent employees know how to handle hazardous chemicals in the work place.), CEMH12 (Most employees are aware of hazardous chemicals in their work environment.), CEMH15 (Contractor's on boarding appreciates all hazardous chemicals in my organisation.), and CEMH16 (Most contractors know how to handle hazardous chemicals in my organisation.) ranked 3rd to 6th within the chemical exposure management latent variable.

4.5.3 Health and Safety Risk Assessment

Table 4.5 Health and Safety Risk Assessment Construct

Health and Safety Risk Assessment	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
HSRAH9	43.6	45.2	8.5	2.7	0.0	1.70	0.737	1
HSRAH34	45.7	42.2	8.5	3.1	0.4	1.70	0.784	2
HSRAH33	22.9	32.6	29.5	10.5	4.7	2.41	1.092	3
HSRAH39	14.0	32.2	22.1	24.8	7.0	2.79	1.169	4
HSRAH32	15.1	25.5	27.8	24.7	6.9	2.83	1.166	5

Table 4.5 shows the responses to statements about health and safety risk assessment. It is evident that HSRAH9 (There are effective noise exposure management systems in my organisation.) with a mean of 1.70 and standard deviation of 0.737 ranked highest out of the five statements presented to the

participants. Further, HSRAH34 (My organisation has all management systems in place to manage substance misuse.) with a mean of 1.70 and standard deviation of 0.784 ranked second highest.

HSRAH33 (My organisation diligently manages fatigue in both permanent employees and contractors.) HSRAH39 (Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.) and HSRAH32 (Most of health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.) ranked 3rd to 5th within the health and safety risk assessment latent variable.

4.5.4 Process Hazard Analysis

Table 4.6 Process Hazard Analysis Construct

Process Hazard Analysis	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
PHAH24	58.8	35.0	4.7	1.2	0.4	1.49	0.680	1
PHAH21	43.2	45.6	9.3	1.5	0.4	1.70	0.732	2
PHAH20	44.4	42.9	9.3	3.1	0.4	1.72	0.787	3
PHAH23	8.2	12.5	38.5	32.3	8.6	3.21	1.038	4

Table 4.6 shows the responses to statements about process hazard analysis. It is evident that PHAH24 (In my organisation we have a comprehensive pre-activity start up review and pre-activity shutdown review.) with a mean of 1.49 ranked highest out of the four statements presented to the participants. Further, PHAH21 (The organisation does comprehensive process hazard analysis before engineering changes are made.) with a mean of 1.70 ranked second highest.

PHAH20 (In my organisation all engineering changes undergo a comprehensive management of change.) and PHAH23 (Most of the health and safety incidents are due to poor engineering design integrity.) ranked 3rd to 4th within the process hazard analysis latent variable.

4.5.5 Permit to Work

Table 4.7 Permit to Work Construct

Permit to Work	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
PTWH29	82.6	15.8	1.2	0.0	0.4	1.20	0.478	1
PTWH28	72.8	23.0	2.7	0.8	0.8	1.34	0.648	2
PTWH31	68.1	22.2	6.6	2.7	0.4	1.45	0.770	3
PTWH25	6.2	18.7	36.6	30.7	7.8	3.15	1.018	4

Table 4.7 shows the responses to statements about permit to work. It is evident that PTWH29 (In my organisation before you start excavation or entering a trench you need to obtain authorisation.) with a mean of 1.20 ranked highest out of the four statements presented to the participants. Further, PTWH28 (All the work activities in my organisation are done after a valid permit to work has been approved by the authorities.) with a mean of 1.34 ranked second highest.

PTWH25 (Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.) and PTWH31 (In my organisation all safety critical equipment is disabled with permission from the authorities.) ranked 3rd to 4th within the permit to work latent variable.

4.5.6 Training and Competence

Table 4.8 Training and Competence Construct

Training and Competence	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
TCH13	40.9	45.2	9.7	3.9	0.4	1.78	0.805	1
TCH19	38.2	42.5	15.4	2.7	1.2	1.86	0.856	2
TCH35	15.5	39.5	32.2	9.7	3.1	2.45	0.970	3

Table 4.8 shows the responses to statements about training and competence. It is evident that TCH13 (Employees undergo comprehensive training on health and safety in my organisation.) with a mean of 1.78 ranked highest out of the three statements presented to the participants. Further, TCH19 (The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite.) with a mean of 1.86 ranked second highest. TCH35 (Most of the health and safety incidents are due to human error in my organisation.) ranked 3rd within the training and competence latent variable.

4.5.7 Process Health and Safety Information

Table 4.9 Process Health and Safety Information Construct

Process Health and Safety Information	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
PHSIH22	51.7	38.2	8.1	1.5	0.4	1.61	0.736	1
PHSIH18	55.2	32.8	6.6	3.5	1.9	1.64	0.897	2

Table 4.9 shows the responses to statements about process health and safety information. It is evident that PHSIH22 (The organisation has all process health and safety information available to all employees.) with a mean of 1.61 ranked highest out of the two statements presented to the participants. Further, PHSIH18 (The organisation communicates effectively all lessons learned after the occupational health and safety incidents.) with a mean of 1.64 ranked second highest.

4.5.8 Control of Confined Space Entry

Table 4.10 Control of Confined Space Entry Construct

Control of Confined Space Entry	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
CCSEH36	63.8	29.2	4.3	2.3	0.4	1.46	0.723	1
CCSEH37	8.5	20.2	29.8	30.2	11.2	3.16	1.129	2

Table 4.10 shows the responses to statements about control of confined space entry. It is evident that CCSEH36 (My organisation has effective management systems to manage working in confined space.) with a mean of 1.46 ranked highest out of the seven statements presented to the participants. Further, CCSEH37 (Most of the health and safety incidents are due to poor controls in place when working with suspended loads.) with a mean of 3.16 ranked second highest.

4.5.9 Operating Procedure

Table 4.11 Operating Procedure Construct

Operating Procedure	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
OPH26	55.2	36.3	5.8	2.3	0.4	1.56	0.741	1

OPH26 (In my organisation all work activities have a detailed operating procedure or work instruction.)

4.5.10 Control of Ignition Source

Table 4.12 Control of Ignition Source Construct

Control of Ignition Source	Str Agree%	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
CISH27	10.5	23.6	31.4	25.2	9.3	2.99	1.133	1

CISH27 (Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.)

4.6 Discussion

The frequency of responses were used to determine the major deficiencies existing in process health and safety management systems when dealing with hazardous chemicals. The mean and standard deviation were computed and the main deficiencies were decided on when the mean was greater than 2.3. The mean that is greater than 2.3 was considered to be more towards disagree and strongly disagree.

Table 4.13 Main Deficiencies

Observed Variables	Str Agree %	Agree %	Neutral %	Disagree %	Str Disagree %	Mean	Std Dev	Rank
PHAH23	8.2	12.5	38.5	32.3	8.6	3.21	1.038	1
CCSEH37	8.5	20.2	29.8	30.2	11.2	3.16	1.129	2
PTWH25	6.2	18.7	36.6	30.7	7.8	3.15	1.018	3
LCH38	8.5	25.2	31.0	26.4	8.9	3.02	1.103	4
CISH27	10.5	23.6	31.4	25.2	9.3	2.99	1.133	5
HSRAH32	15.1	25.5	27.8	24.7	6.9	2.83	1.166	6
HSRAH39	14.0	32.2	22.1	24.8	7.0	2.79	1.169	7
CEMH16	15.5	28.3	40.3	13.2	2.7	2.59	0.991	8
TCH35	15.5	39.5	32.2	9.7	3.1	2.45	0.970	9
HSRAH33	22.9	32.6	29.5	10.5	4.7	2.41	1.092	10

It is evident in Table 4.13 that most of the health and safety incidents are due to poor engineering design integrity with a mean of 3.21 and standard deviation of 1.038 ranked highest out of the ten statements identified as process health and safety deficiencies. Further, it is revealed that most of the health and safety incidents are due to poor controls in place when working with suspended loads with a mean of 3.16 and standard deviation of 1.129 ranked second highest.

Poor controls when working at heights, Poor housekeeping, Poor controls of source of ignition, Verifying energy isolation before start working on equipment, Poor health and safety risk assessments, Effective handling of hazardous chemicals, Human error and Fatigue management for both permanent employees and contractors were ranked 3rd to 10th within the key process health and safety management deficiencies.

Many construction sites involve working at height. This is a major cause of accidents and caused almost half of all construction site deaths over the last five years. Hazards from working at heights include lack of guardrails, inadequate edge protection, unsecured ladders and loose tools. According to Department of Labor (USA) in out of 4 779 workers fatalities in private industry in calendar year 2018, 1008 (21.1%) were in construction industry. The leading cause of private sector worker deaths in the construction industry were falls when working at heights (33.5%), followed by struck by object (11.1%), electrocution (8.5%) and caught in/between objects (5.5%). The main deficiencies revealed in this research confirm some of the recent incident statistics.

4.7 Chapter Summary

This chapter presented the results of this research and outlined the major deficiencies that require senior management's attention to prevent process health and safety incidents when dealing with hazardous chemicals. Descriptive statistics in the form of median, minimum, maximum, percentage and cumulative percentage were calculated using SPSS (version 25). The ten observed variables were assessed to be main deficiencies that require senior management's attention reduce process health and safety incidents. This chapter is responding to the following research question, namely, what are the major deficiencies that should be priorities by top management to prevent process health and safety incidents when handling hazardous chemicals? The next chapter discusses the model development.

CHAPTER FIVE

Model Development

5.1 Introduction

There are several statistical analysis tools considered in this research study with an intention to select an appropriate analysis approach. Structural Equation Modelling (SEM) has been chosen over other multivariable analysis tools due to its ability to consider the measurement errors inherent in subjective operational measurement and to develop and explore the entire set of hypothesised relationships in the model.

According to Molwus *et al.* (2017), the development of a SEM research model includes some basic steps, namely;

- Define and identify the model components that include the latent constructs and measurement indicators sourced from literature theory and empirical studies.
- Set up the hypothetical relationship depending on the aim and objectives of the study.
- Develop the initial model by using the data collected from the questionnaire survey.
- Verification of the model by evaluating the model estimates and goodness-of-fit GOF measures.
- Validation of the model based on theoretical and empirical justification.

5.2 Model Development using SEM

The study reviewed the process health and safety elements from the literature and then grouped the observed variables. The questionnaire survey was designed and disseminated to petrochemical industry employees (permanent and contractors) to collect the data and then test data to fit the hypothesis

In SEM, a variable can be an independent variable or exogenous variable and a dependent variable or endogenous variable in a chain of casual hypotheses (Groanland and Stalpers, 2012; Zhao, 2017). The adoption of SEM for research and studies in the construction management –related field is increasing in the recent years (Shanmugapriya and Subramanian, 2016; Zhao, 2017). In SEM, the explained variance of the endogenous latent variables are estimated by assessing model relationships in an iterative sequence of maximum likelihood regression (Hair *et al*., 2010; Zhao, 2017). SEM consists of a measurement model that identifies the relationship between a latent variable, measurement attributes, indicators and a structural model that identifies the relationship between latent variables (Molenaar and

Washington, 2000; Zhao, 2017). AMOS 25 software was used to analyse the research model and test the reliability and validity of the research model. The required data were entered into SPSS version 25 software that links with AMOS version 25 software.

5.2.1 Structural Equation Modelling

Structural Equation Modelling is an effort to model casual relations between observed variables by including all observed variables that are known to have connection in the process of curiosity. The first step in structural equation modelling is to stipulate a model. A model is basically a statement or set of statements about the relations between observed variables. According to Maydeu-Olivares and Garcia-Forero (2010) Goodness of Fit has been more extensively developed in SEM than in other areas and new developments in GOF assessment for multivariate discrete data are strongly related to SEM procedures, and expect further developments on GOF assessment procedures for multivariate discrete data along the lines of SEM developments.

SEM combines multiple regression analysis and factor analysis together to analyse the relationship between measured variables and latent constructs or factors (Raykov, 2006). Basically, it provides a quantitative method to test a hypothesised model (Byrne, 2016). SEM can be employed to capture complex relationships between one or more dependent variables that can be sourced from qualitative or quantitative data (Hox and Kleiboer, 2007). The fit of the correlation matrix of the hypothesised model to that from data gathering is analysed and assessed by SEM analysis, and then creates a set goodness of fit index that indicates how well the hypothesised model fits the data (Raykov, 2006).

Missing data is a serious issue in SEM and must be discussed in any article. Also, given new technologies, more options can handle missing data, such as maximum likelihood estimation (Schreiber *et al.,* 2006). Although the problem of missing values is not unique to structural modelling, estimating a successful model necessitates the appropriate handling of missing data from a methodological, as well as conceptual, perspective. Reliance on pairwise deletion can result in a nonpositive covariance matrix, and other methods, including replacement with the mean, may result in heteroscedastic error (Schumaker & Lomax, 1996).

SEM estimates the degree to which a hypothesized model fits the data. In a confirmatory factor analysis, goodness of fit indexes are estimated for each latent variable as a distinct structural model. Although it is wise and appropriate for one to measure items found in other studies to form a certain construct, it is not appropriate to assume that a certain group of items found to form a valid and reliable construct in another study will form an equally valid and reliable construct when measured in a different set of data. Similarly, constructs tested on a national data set are valid in a new study in the rare instance when the new study uses the identical observations analysis in the same data with the same theoretical under pinning. Divergent choices addressing the problem of missing data will normally change construct validity results such that a new confirmatory analysis is appropriate (Schreiber *et al.,* 2006).

5.2.2 SEM Analysis Selection

According to Hair *et al*. (2011) cited in Zhao (2017) there are two approaches to SEM modelling. The first is the covariance – based SEM (CB-SEM) method; the other is the partial least squares SEM (PLS-SEM). CB-SEM aims to reproduce the theoretical covariance matrix that matches the sample covariance matrix; the objective of the PLS-SEM approach is to maximise the explained variance of dependent latent constructs and both are suitable to test the hypothetical causal relationships between latent constructs (Zhao, 2017).

Although a growing number of studies use PLS-SEM, this approach is not as rigorous as the CB-SEM approach (Hair, 2017; Zhao, 2017). Therefore, it is less reliable when examining the relationships between latent constructs (Zhao, 2017). Few researchers view the PLS-SEM approach as a robust analytical approach for dealing with SEM challenges for reasons such as adequacy of sample size, normality and homoscedasticity (Wong, 2016; Zhao, 2017). According to Rigdon (2016) PLS-SEM does not provide the calculation for goodness-of-fit (GOF) measures which provide a reliable tool for examining the goodness-of-fit of the proposed model to the empirical dataset. Without this goodness-of-fit assessment for the model, there will be no basis for concluding that the model is valid (Barrett, 2007). PLS-SEM use in such a situation is not model-specific and might result in an unreliable estimate of the sample size requirement. The ratio of measurement indicators to the latent constructs is a more reliable approach to computing the minimum sample size required for CB-SEM application (Westland, 2010; Zhao, 2017).

$$n \geq 50r^2 - 450r + 1100 \qquad \textbf{(5.1)}$$

Where
n is the number of samples
r is the ratio of indicators to latent constructs

Using Equation 5.1, the minimum number of samples for this research was calculated as 138 with 35 being the number of observed variables and ten latent constructs as shown in Table 5.1. The value of r in Equation 5.1 is 35/10 = 3.5; then Equation 5.1 evaluates $n = [(50 * 3.5^2) - (450 * 3.5) + 1100] = 138$; this is less than the 259 samples used in this research (i.e. 259 > 138). Therefore, qualifying the use of covariant based structural equation modelling (CB-SEM) in place of partial least squares structural equation modelling (Westland, 2010; Zhao, 2017).

According to Maydeu-Olivares and Garcia-Forero (2010) GOF is a very active area of research in structural equation modelling and in classical SEM applications, multivariate models for continuous data are estimated from some summary statistics. PLS-SEM does not offer the computing for goodness of fit (GOF) measures which provide a reliable tool for analysing the goodness-of-fit of the proposed model to the empirical dataset (Rigdon, 2016, Zhao, 2017). It is essential to assess how well the model fits the data as a key decider on the appropriateness of the research structural equation modelling model developed from the dataset (Barrett, 2007; Zhao, 2017). Without this GOF assessment for the model, there will be no basis for concluding that the model is valid (Barrett, 2007; Zhao, 2017).

CB-SEM technique draws from its stringent requirements in meeting the assumption about the observed variables to be multivariate and normally distributed. Accordingly to Byrne (2010) cited in Zhao (2017) this is imperative to SEM estimation, particularly for Generalised Least Squares (GLS) and Maximum Likelihood (ML) estimating subroutines of the CB-SEM analysis. Violation of this assumption might lead to inaccurate calculations for the Chi-square and t-test. According to Hair *et al*. (2011) cited in Zhao (2017) if the assumptions of the CB-SEM are satisfied with respect to the minimum sample size and data distribution, the CB-SEM is a better option; otherwise, PLS-SEM is a good approximation of CB-SEM. Satisfaction of the above strict requirements of the CB-SEM by the empirical data attributes warranty the use of CB-SEM in this research in place of a PLS-SEM approach.

5.2.3 Reliability Checks

Mean ratings of observed variables, principal component factor analysis and Cronbach's alpha test were conducted in this research. The mean ratings of the observed variables were obtained to check the acceptance of them by the participants; principal component factor analysis was carried out to check the commonality within the data set; and Cronbach's alpha test was performed to test the reliability of the data set. SEM with AMOS version 25 software was employed to test the hypothesised relationship between the observed variables, latent variables and generative health and safety culture.

In a research study, the reliability and validity of the data are vital. The Cronbach's Alpha is a high-quality test widely used for reliability testing and an important test for assessing a research instrument (Zhao, 2017). The appropriateness of the categories was confirmed by reliability test. The quality of the observed variables attributes and the indicators for corresponding latent constructs in the model should be examined and evaluated (Zhao, 2017). Cronbach's Alpha test is extensively –used method to test the internal consistency of observed variables, based on the correlations between indicators (Zhao, 2017).

5.2.4 Principal Component Analysis

Table 5.1 Principal Component Analysis with all loading

Rotated Component Matrix[a]

Observed Variables	Latent Constructs: PTW	PHA	LC	HSRA	CEM	TC	PHSI	CCSE	OP	CIS
PTWH29	0.779									
PTWH28	0.687									
PTWH31	0.661									
CCSEH36	0.649		**0.304**							
PHAH24		0.630								
PHSIH22		0.587			**0.395**					
PHAH20		0.564				**0.447**				
PHAH21		0.504			**0.305**	**0.425**				
OPH26		0.586								
PHSIH18	**0.486**					**0.375**				
HSRAH34	**0.420**		**0.309**			**0.404**				
LCH8			0.726							
LCH10			0.725							
LCH11			0.698			**0.364**				
LCH7	**0.305**		0.660							
TCH13			0.547		**0.401**					
HSRAH9	**0.373**		0.524		**0.317**					
LCH17			0.519			**0.432**				
LCH40	**0.333**			←←←←←←←		0.587				
TCH19	**0.392**					**0.478**				
CCSEH37				0.833						
HSRAH32				0.788						
PTWH25				0.785						
CSIH27				0.739						
PHAH23				0.690						
LCH38				0.598						**0.564**
HSRAH39				0.573						**0.536**
HSRAH33					←←←←	0.637				
TCH35						←←←←←←←←←←←←←←←				0.769
CEMH30	0.735		→→→→→→→→→→							
CEMH6	**0.413**		0.604		**0.310**					
CEMH16					0.763					
CEMH15					0.731					
CEMH14					0.695					
CEMH12					0.654					

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 6 iterations.

It is evident in Table 5.1 that five latent constructs were eliminated after principal component analysis, namely;

- Training and Competency (TC)
- Process Health and Safety Information (PHSI)
- Control of Confined Space Entry (CCSE)
- Operating Procedure (OP)
- Control of Ignition Source (CIS)

The above five latent constructs were eliminated due to no observed variable allocated to it or because the loading was less than 0.5. There are observed variables that were relocated from original latent constructs to other latent constructs as shown Table 5.2 for reliability analysis after principal component analysis.

According Zohrabi (2013) one of the main requirements of any research process is the reliability of the data and findings. The reliability and validity of the data are vital for a research study. The Cronbach's Alpha is a high-quality test extensively used for reliability testing and a vital test for assessing a questionnaire instrument. The quality of the measurement attributes and indicator for corresponding constructs in the model should be analysed and assessed. Cronbach's Alpha test is an extensively used method to test the internal consistency of measurement indicators, based on the correlations between indicators.

Table 5.2 Reliability Analysis before Principal Component Analysis for Constructs

Latent Constructs	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	10 (LCH7, LCH8, LCH9, LCH10, LCH11, LCH13, LCH17, LCH19, LCH34, LCH40)	0.873
Chemical Exposure Management (CEM)	6 (CEMH6, CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.797
Health and Safety Risk Assessment (HSRA)	9 (HSRAH23, HSRAH25, HSRAH27, HSRAH32, HSRAH33, HSRAH35, HSRAH37, HSRAH38, HSRAH39)	0.829
Process Hazard Analysis (PHA)	5 (PHAH20, PHAH21, PHAH22, PHAH24, PHAH26)	0.810
Permit to Work (PTW)	5 (PTWH18, PTWH28, PTWH29, PTWH31, PTWH36)	0.774

It is evident in Table 5.2 that the all latent constructs have Cronbach's Alpha above 0.7, which confirms reliability of the data.

5.2.5 Consistency Test Results

The consistency tests are imperative to the study as they ensure the reliability and validity of the data set. The mean ratings of all the measurement indicators by the participants are used to determine the acceptance of them by the participants.

Table 5.3 Leadership Commitment

Leadership Commitment	(Str Agree and Agree)%	Neutral%	(Str Disagree and Disagree)%	Mean	Std Dev
LCH7	93.4	4.3	2.3	1.48	0.707
LCH8	88.4	9.3	2.3	1.64	0.763
LCH9	88.8	8.5	2.7	1.70	0.737
LCH10	96.9	1.9	1.2	1.40	0.591
LCH11	88.4	9.3	2.3	1.63	0.748
LCH13	86.1	9.7	4.2	1.78	0.805
LCH17	73.6	18.6	7.8	1.98	0.966
LCH19	80.7	15.4	3.9	1.86	0.856
LCH34	88.0	8.5	3.5	1.70	0.784
LCH40	87.3	9.3	3.4	1.61	0.866

From Table 5.3 it is evident that the mean ratings for leadership commitment construct range between 1.40 (LCH10) to 1.98 (LCH17) and the standard deviation is between 0.591 (LCH 10) to 0.966 (LCH17) for the ten observed variables.

Table 5.4 Chemical Exposure Management

Chemical Exposure Management	(Str Agree and Agree)%	Neutral %	(Str Disagree and Disagree)%	Mean	Std Dev
CEMH6	92.2	6.2	1.6	1.62	0.692
CEMH12	86.5	9.6	3.9	1.75	0.783
CEMH14	84.9	12.8	2.3	1.75	0.766
CEMH15	62.4	32.1	5.5	2.22	0.858
CEMH16	43.8	40.3	15.9	2.59	0.991
CEMH30	95.8	2.7	1.5	1.35	0.612

From Table 5.4 it is evident that the mean ratings for chemical exposure management construct range between 1.35 (CEMH30) to 2.59 (CEMH16) and the standard deviation is between 0.612 (CEMH30) to 0.991 (CEMH16) for the six observed variables.

Table 5.5 Health and Safety Risk Assessment

Health and Safety Risk Assessment	(Str Agree and Agree)%	Neutral%	(Str Disagree and Disagree)%	Mean	Std Dev
HSRAH23	20.6	38.5	40.9	3.21	1.038
HSRAH25	24.9	36.6	38.5	3.15	1.018
HSRAH27	34.1	31.4	34.5	2.99	1.133
HSRAH32	40.5	27.8	31.7	2.83	1.166
HSRAH33	55.4	29.5	15.1	2.41	1.092
HSRAH35	55	32.2	12.8	2.45	0.970
HSRAH37	28.7	29.8	41.5	3.16	1.129
HSRAH38	33.7	31	35.3	3.02	1.103
HSRAH39	46.1	22.1	31.8	2.79	1.169

From Table 5.5 it is evident that the mean ratings for health and safety risk assessment construct range between 2.41 (HSRAH33) to 3.21 (HSRAH23) and the standard deviation is between 0.970 (HSRAH35) to 1.169 (HSRAH39) for the nine observed variables.

Table 5.6 Process Hazard Analysis

Process Hazard Analysis	(Str Agree and Agree)%	Neutral%	(Str Disagree and Disagree)%	Mean	Std Dev
PHAH20	87.2	3.5	9.3	1.72	0.787
PHAH21	88.8	9.3	1.9	1.70	0.732
PHAH22	90.0	8.1	1.9	1.61	0.736
PHAH24	93.8	4.6	1.6	1.49	0.680
PHAH26	91.5	5.8	2.7	1.56	0.741

From Table 5.6 it is evident that the mean ratings for process hazard analysis construct range between 1.49 (PHAH24) to 1.72 (PHAH20) and the standard deviation is between 0.680 (PHAH24) to 0.787 (PHAH20) for the five observed variables.

Table 5.7 Permit to Work

Permit to Work	(Str Agree and Agree)%	Neutral%	(Str Disagree and Disagree)%	Mean	Std Dev
PTWH18	88.0	6.6	5.4	1.64	0.897
PTWH28	95.7	2.7	1.6	1.34	0.648
PTWH29	98.4	1.2	0.4	1.20	0.478
PTWH31	90.3	6.6	3.1	1.45	0.770
PTWH36	93.0	4.3	2.7	1.46	0.723

From Table 5.7 it is evident that the mean ratings for permit to work construct range between 1.20 (PTWH29) to 1.64 (PTWH18) and the standard deviation is between 0.478 (PTWH29) to 0.897 (PTWH18) for the five observed variables. Having inveterate the acceptance, commonality, and reliability of all the measurement indicators, the confirmatory factor analysis would be conducted to test the measurement model.

5.2.6 Structural Equation Modelling Specification

According to Gainey and Klass (2003); Molenaar *et al.* (2000); Zhao (2017) a SEM specification should first be developed based on the theoretical framework. The initial SEM specification followed the research model, the main key factors influencing generative health and safety culture were found to be leadership commitment, chemical exposure management, health and safety risk assessment, process hazard analysis and permit to work. The model denotes a theoretical framework where the five constructs were selected from the 10 constructs in the original conceptual framework. These five constructs were selected because of loadings higher than 0.5 after principal component analysis and reliability test computed above 0.7 for all observed variables in each latent variable.

5.2.7 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) and SEM can each be an iterative process by which modifications are indicated in the initial results, and parameter constraints altered to improve the fit of the model, if such changes are warranted theoretically (Schreiber *et al.,* 2006). If a parameter is freed on the basis of a high modification index value, the researcher is called on to theoretically defend the change indicated so that the final model does not deviate from the initial theoretical model (Schreiber *et al.,* 2006).

In this research CFA was adopted to test the strength and appropriateness of the relationship between latent constructs and corresponding measurement indicators. CFA is also acknowledged as a measurement model as it can be used to evaluate the fit between the collected data and the conceptual relationship between measurement and latent variables. According to Schreiber *et al.* (2006) CFA and SEM are statistical techniques that one can use to reduce the number of observed variables into a smaller number of latent variables by examining the covariation among the observed variables.

5.2.8 Model Modification

CFA is done to test whether the measure of latent construct corresponds with the study of the nature of the individual factor and at this stage, the indicator elimination and model re-specification are performed for each latent construct (Zhao, 2017). The reliability and validity of the constructs must be examined and evaluated before using them in the following structural model (Shanmugapriya and Subramanian, 2016; Zhao, 2017). The measurement model includes all latent constructs and specifies the measurement indicators and attributes for corresponding constructs. The measurement indicators or variables have different degrees. Measurement indicators having low loadings should be eliminated since the offer small explanatory power to the model (Aibinu and Al-Lawati, 2010; Zhao, 2017). A common acceptable threshold value for a good indicator is having a loading higher than 0.5 (Rahman *et al.*, 2013; Zhao, 2017).

Table 5.8 Final Principal Component Analysis

Rotated Component Matrix[a]					
Observed Variables	Component				
	PTW	**PHA**	**LC**	**HSRA**	**CEM**
Permit to Work (PTWH29)	0,779				
Permit to Work (PTWH28)	0,687				
Permit to Work (PTWH31)	0,661				
Permit to Work (PTWH36)	0,649				
Process Hazard Analysis (PHAH24)		0,630			
Process Hazard Analysis (PHAH22)		0,587			
Process Hazard Analysis (PHAH20)		0,564			
Process Hazard Analysis (PHAH21)		0,504			
Process Hazard Analysis (PHAH26)		0,586			
Leadership Commitment (LCH8)			0,726		
Leadership Commitment (LC10)			0,725		
Leadership Commitment (LCH11)			0,698		
Leadership Commitment (LCH7)			0,660		
Leadership Commitment (LCH13)			0,547		
Leadership Commitment (LCH9)			0,524		
Leadership Commitment (LCH17)			0,519		
Leadership Commitment (LCH6)			0,604		
Leadership Commitment (LCH40)			0,587		
Health and Safety Risk Assessment (HSRAH37)				0,833	
Health and Safety Risk Assessment (HSRAH32)				0,788	
Health and Safety Risk Assessment (HSRAH25)				0,785	
Health and Safety Risk Assessment (HSRAH27)				0,739	
Health and Safety Risk Assessment (HSRAH23)				0,690	
Health and Safety Risk Assessment (HSRAH38)				0,598	
Health and Safety Risk Assessment (HSRAH39)				0,573	
Health and Safety Risk Assessment (HSRAH33)				0,637	
Health and Safety Risk Assessment (HSRAH35)				0,769	
Chemical Exposure Management (CEMH30)					0,735
Chemical Exposure Management (CEMH16)					0,763
Chemical Exposure Management (CEMH15)					0,731
Chemical Exposure Management (CEMH14)					0,695
Chemical Exposure Management (CEMH12)					0,654

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 6 iterations.

Convergent validity confirms that a set of indicators measure one and the same latent construct and not another construct. Squared multiple correlations (SMC) is used as a criterion of convergent validity and the cut-off value of 0.5 is considered as an acceptable indicator (Azen and Sass, 2008; Zhao, 2017).

Table 5.9 Reliability Analysis after Principal Component Analysis for Constructs

Latent Construct	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	9 (LCH6, LCH7, LCH8, LCH9, LCH10, LCH11, LCH13, LCH17, LCH40)	0.867
Chemical Exposure Management (CEM)	5 (CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.781
Health and Safety Risk Assessment (HSRA)	9 (HSRAH23, HSRAH25, HSRAH27, HSRAH32, HSRAH33, HSRAH35, HSRAH37, HSRAH38, HSRAH39)	0.829
Process Hazard Analysis (PHA)	5 (PHAH20, PHAH21, PHAH22, PHAH24, PHAH26)	0.810
Permit to Work (PTW)	4 (PTWH28, PTWH29, PTWH31, PTWH36)	0.749

It is evident from Table 5.9 that the five latent constructs that are drivers to generative process health and safety culture are Leadership Commitment (0.867), Chemical Exposure Management (0.781), Health and Safety Risk Assessment (0.829), Process Hazard Analysis (0.810) and Permit to Work (0.749), and which all have Cronbach's Alpha above 0.7, which confirms reliability of the data.

5.3 Model Fit

A range of established fit indices should be introduced to decide upon the goodness of fit (GOF) between the research model and empirical data. Broadly, fit indices can be classified into three categories: overall model fit, goodness-of-fit, and badness-of-fit (Green, 2016, Zhao, 2017). The overall model fit is measured by a chi-square statistic that is used to examine whether the statistical significance exists between the observed and estimated variance-covariance matrix (Bagozzi & Yi, 2012; Zhao, 2017). However, chi-square statistics are sensitive and artificially inflated by sample size (Iacobucci, 2010; Zhao, 2017).

5.3.1 Goodness-of-Fit (GOF)

The concept of goodness of fit is used for identification of statistical model for different analysis, in research area this concept is used in almost all the fields directly or indirectly (Jha *et al.,* 2011). The goodness of Fit (GOF) of a statistical model pronounces how well it fits into a set of observations. GOF indices summarize the inconsistency between the observed values and the values expected under a statistical model (Jha *et al.,* 2011). GOF statistics are GOF indices with known sampling distributions, usually obtained using an asymptotic methods, that are used in statistical hypothesis testing. There are numerous methods used for goodness of fit test and most important among them are, namely, Kolmogorov - Smirnov, Anderson - Darling and Chi – Squared (Jha *et al.,* 2011).

The overall model fit is measured by a chi-square statistic that is used to examine whether the statistical significance exists between the observed and estimated variance-covariance matrix (Bagozzi and Yi, 2012; Zhao, 2017). However, chi-square statistics are insufficient to determine the merit of a model which is where goodness-of-fit and badness-of-fit indices should be introduced. Goodness-of-fit indices include comparative and absolute fit indices (Green, 2016; Zhao, 2017).

Comparative indices comprises Comparative Fit Index (CFI) whilst absolute fit indices consist of Tucker-Lewis Index (TLI), adjusted Goodness of Fit Index (AGFI), Incremental Fit Index (IFI) and Normed Fit Index (NFI) (Bagozzi, 2010; Zhao, 2017). Badness-of-fit indices are indicated by the root-mean-square error of approximation (RMSEA) with a 90% confidence interval (90% CI) and the standardised root-mean-square residual (RMSR) (Hu and Bentler, 1999; Zhao, 2017).

Parsimonious fit indices were developed to penalise for model complexity because complex, nearly saturated models are dependent on the sample during estimation. Non-parsimonious or complex models are models which contain few paths. Complex models create a less rigorous theoretical model that produces better fit indices. Parsimonious indices include the Parsimony Goodness-of-fit (PGFI), the Parsimony Adjusted Normed Fit Index (PNFI) and the Parsimony Adjusted Comparative Fit Index (PCFI). There are no widely accepted minimum thresholds of acceptance. Often values of 0.50 are obtainable even when other indices exceed the 0.90 threshold, it is recommended to report them with other indices.

Table 5.10 Threshold Limits for Model Fit Indices

Model Fit Index	Acceptable Threshold	Interpretation	References
Absolute Fit Indices			
Relative Normed Chi-Square Value	< 2	Good Fit	Tabachnick and Fidell (2013)
Root Mean Square Error of Approximation	Value < 0.05	Good Fit	Brown (2006); Hoe (2008); Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999); Schreiber *et al.* (2006); Schumacker and Lomax (2004).
	Value is 0.06 - 0.08	Acceptable Fit	
Incremental Fit Indices			
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95	Good Fit	Brown (2006); Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999); Schreiber *et al.* (2006); Schumacker and Lomax (2004).
	Value is 0.90 - 0.95	Acceptable Fit	
Incremental Fit Index (IFI)	Value ≥ 0.95	Good Fit	Brown (2006); Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999); Schreiber *et al.* (2006); Schumacker and Lomax (2004).
	Value is 0.90 - 0.95	Acceptable Fit	
Normed Fit Index (NFI)	Value ≥ 0.95	Good Fit	Brown (2006); Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999); Schreiber *et al.* (2006); Schumacker and Lomax (2004).
	Value is 0.90 - 0.95	Acceptable Fit	
Tucker - Lewis Index (TLI)	Value ≥ 0.95	Good Fit	Brown (2006); Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999); Schreiber *et al.* (2006); Schumacker and Lomax (2004).
	Value is 0.90 - 0.95	Acceptable Fit	
Parsimonious Fit Indices			
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.90	Good Fit	Hooper *et al.* (2008)
	Value > 0.50	Acceptable Fit	
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.90	Good Fit	Hooper *et al.* (2008)
	Value > 0.50	Acceptable Fit	

In this research there was no threshold limit for Chi-square values as this fit statistic varies according to the design complexity of the model. The results of the model fit and its interpretation will be presented for each latent construct in order to assess model fit for the dependent variables.

5.3.2 Leadership Commitment Goodness-of-Fit

Table 5.11 Leadership Commitment Construct Goodness-of-Fit

Leadership Commitment Construct					
Model Fit Index	**Threshold**	**First SEM**	**Acceptability**	**Final SEM**	**Acceptability**
Absolute Fit Indices					
CMIN/df	< 2	2.394	Not Accepted	2.151	Marginal Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	0.073	Accepted	0.067	Accepted
Incremental Fit Indices					
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.956	Accepted	0.971	Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.957	Accepted	0.972	Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.928	Accepted	0.949	Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.926	Accepted	0.948	Accepted
Parsimonious Fit Indices					
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.50	0.557	Accepted	0.527	Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.50	0.573	Accepted	0.540	Accepted

It is evident in Table 5.11 that RMSEA = 0.067, CMIN/df = 2.151 indicates that the theoretical model of leadership commitment fitted the empirically data satisfactory. The CFI (0.971), IFI (0.972), NFI (0.949) and TLI (0.948) was indicative of good fit and therefore suggested acceptable fit. When considering the construct validity, leadership commitment observed variables were strong and statistically significant. Parsimony was assessed using PNFI and PCFI. The indices exceeded the threshold of 0.50 suggested by Hooper *et al.* (2008) at PNFI (0.527) and PCFI (0.540). However, it may be argued that the general threshold index of 0.9 which is widely accepted for all other indices might be more appropriate. The model presented is not so parsimonious, but still acceptable. The researcher decided to eliminate LCH40 to improve CMIN/df from 2.394 to 2.151 which was then marginally accepted.

5.3.3 Chemical Exposure Management Goodness-of-Fit

Table 5.12 Chemical Exposure Management Construct Goodness-of-Fit

Chemical Exposure Management Construct					
Model Fit Index	**Threshold**	**First SEM**	**Acceptability**	**Final SEM**	**Acceptability**
Absolute Fit Indices					
CMIN/df	< 2	4.957	Not Accepted	7.244	Not Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	0.124	Not Accepted	0.156	Not Accepted
Incremental Fit Indices					
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.942	Accepted	0.960	Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.944	Accepted	0.961	Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.931	Accepted	0.955	Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.827	Not Accepted	0.798	Not Accepted
Parsimonious Fit Indices					
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.50	0.310	Not Accepted	0.191	Not Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.50	0.314	Not Accepted	0.192	Not Accepted

It is evident in Table 5.12 that RMSEA = 0.156 and CMIN/df = 7.244 was indicative of poor model fit for the theoretical model of chemical exposure management. The CFI (0.960), IFI (0.961), NFI (0.955) was indicative of good fit but TLI (0.798) suggested not acceptable fit. When considering the construct validity, chemical exposure management observed variables were not strong and statistically not significant. Parsimony was assessed using PNFI (0.191) and PCFI (0.192) and thus the model presented is not so parsimonious. The researcher decided to eliminate CEMH30 to improve incremental fit indices CFI, IFI and NFI to acceptable threshold. Due to lack of construct validity, any interpretations based on the chemical exposure management latent variable needs to be inferred carefully.

5.3.4 Health and Safety Risk Assessment Goodness-of-Fit

Table 5.13 Health and Safety Risk Assessment Construct Goodness-of-Fit

Health and Safety Risk Assessment Construct					
Model Fit Index	**Threshold**	**First SEM**	**Acceptability**	**Final SEM**	**Acceptability**
Absolute Fit Indices					
CMIN/df	< 2	2.729	Not Accepted	3.666	Not Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	0.082	Marginal Accepted	0.102	Not Accepted
Incremental Fit Indices					
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.933	Accepted	0.944	Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.935	Accepted	0.945	Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.901	Accepted	0.926	Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.889	Marginal Accepted	0.888	Marginal Accepted
Parsimonious Fit Indices					
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.50	0.541	Accepted	0.463	Marginal Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.50	0.560	Accepted	0.472	Marginal Accepted

In Table 5.13, RMSEA = 0.082 and CMIN/df = 2.729 was indicative of marginally acceptable theoretical model fit for health and safety risk assessment construct. The CFI (0.933), IFI (0.935), NFI (0.901) was indicative of good fit and TLI (0.889) suggested marginal acceptable fit. When considering the construct validity, health and safety risk assessment construct observed variables were strong and statistically significant. Parsimony was assessed using PNFI (0.541) and PCFI (0.560) and thus the model presented is not so parsimonious, but still acceptable. The researcher did not accept the first SEM model and attempted to improve the model for this construct by eliminating HSRAH33 and HSRAH35. RMSEA = 0.102 and CMIN/df = 3.666 and was not accepted. However the CFI (0.944), IFI (0.945), NFI (0.926) improved from the first SEM was indicative of good fit but TLI (0.888) remained marginal acceptable fit. The elimination of HSRAH33 and HSRAH35 improved the overall model. Parsimony assessment was marginally acceptable PNFI (0.463) and PCFI (0.472).

5.3.5 Process Hazard Analysis Goodness-of-Fit

Table 5.14 Process Hazard Analysis Construct Goodness-of-Fit

Process Hazard Analysis Construct			
Model Fit Index	**Threshold**	**Final SEM**	**Acceptability**
Absolute Fit Indices			
CMIN/df	< 2	10.263	Not Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	0.189	Not Accepted
Incremental Fit Indices			
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.895	Marginal Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.897	Marginal Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.887	Marginal Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	0.684	Not Accepted
Parsimonious Fit Indices			
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.50	0.296	Not Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.50	0.298	Not Accepted

It is evident in Table 5.14 that RMSEA = 0.189 and CMIN/df = 10.263 indicates that the theoretical model of the process hazard analysis construct did not fit the empirical data satisfactorily. The CFI (0.895), IFI (0.897), NFI (0.887) were indicative of marginal accepted fit and TLI (0.684) suggested poor model fit. Parsimony was assessed using PNFI (0.296) and PCFI (0.298) and therefore the model presented is not so parsimonious. The researcher decided to eliminate three observed variables, namely, PHAH22, PHAH24 and PHAH26 to improve the final model. Process hazard analysis construct had only 2 observed variable in the final research model, namely, PHAH20 and PHAH21.

5.3.6 Permit to Work Goodness-of-Fit

Table 5.15 Permit to Work Construct Goodness-of-Fit

Permit to Work Construct				
Model Fit Index	**Threshold**	**Interpretation**	**Final SEM**	**Acceptability**
Absolute Fit Indices				
CMIN/df	< 2	Good Fit	1.651	Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	Good Fit Acceptable Fit	0.050	Accepted
Incremental Fit Indices				
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.995	Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.995	Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.988	Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.975	Accepted
Parsimonious Fit Indices				
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.50	Acceptable Fit	0.198	Not Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.50	Acceptable Fit	0.199	Not Accepted

It is evident in Table 5.15 that RMSEA = 0.05, CMIN/df = 1.651 indicates that the theoretical model of permit to work construct fitted the empirically data satisfactory. The CFI (0.995), IFI (0.995), NFI (0.988) and TLI (0.975) was indicative of good fit and therefore suggested acceptable fit. When considering the construct validity, permit to work observed variables were strong and statistically significant. Parsimony was assessed using PNFI and PCFI. The indices did not exceed the threshold of 0.50 suggested by Hooper *et al.* (2008) at PNFI (0.198) and PCFI (0.199). The model presented is not so parsimonious.

5.3.7 Generative Process Health and Safety Culture Model Goodness-of-Fit

Table 5.16 Generative Process Health and Safety Culture Model

Generative Health and Safety Culture Final Model						
Model Fit Index	**Acceptable Threshold**	**Interpretation**	**First SEM**	**Acceptability**	**Final SEM**	**Acceptability**
Absolute Fit Indices						
CMIN/df	< 2	Good Fit	2.341	Not Accepted	1.758	Accepted
Root Mean Square Error of Approximation	Value < 0.05 Value is 0.06 - 0.08	Good Fit Acceptable Fit	0.072	Accepted	0.054	Accepted
Incremental Fit Indices						
Bentler Comparative Fit Index (CFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.824	Not Accepted	0.925	Accepted
Incremental Fit Index (IFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.827	Not Accepted	0.927	Accepted
Normed Fit Index (NFI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.733	Not Accepted	0.846	Marginal Accepted
Tucker - Lewis Index (TLI)	Value ≥ 0.95 Value is 0.90 - 0.95	Good Fit Acceptable Fit	0.795	Not Accepted	0.908	Accepted
Parsimonious Fit Indices						
Parsimony Adjusted Normed Fit Index (PNFI)	Value > 0.90	Good Fit	0.630	Accepted	0.689	Accepted
Parsimony Adjusted Comparative Fit Index (PCFI)	Value > 0.90	Good Fit	0.708	Accepted	0.755	Accepted

It is evident in Table 5.16 that the model fit indices for the refined model met the acceptable threshold limits. The absolute fit was assessed using the relative normed Chi-square and the RMSEA. The CMIN/df and RMSEA met the recommended acceptable limits with 1.758 and 0.054 respectively. The relative normed Chi-square is recommended to be less than 2.00 (Tabachnick and Fidell, 2013) and RMSEA is recommended to be less than 0.05 (Hu and Bentler, 1999), however it is still acceptable when it is less than 0.08. The RMSEA is used to measure the square root of the residual that is the difference between the collected data and model prediction (Anderson and Gerbing, 1984). It ranges between 0 and 1 with the value smaller than limit value of 0.08 perceived as an acceptable fit Kline, 2005).

Incremental indices assessed were the CFI, IFI, NFI and the TLI. The CFI compares the fit of the hypothesised model to the collected data with the fit of baseline model to the data (Iacobucci, 2010). The IFI is the ratio of the difference of Chi-square between the hypothesised model and the baseline model and the difference of the degree of the freedom of the two models (Bentler, 1990). The TLI compares the discrepancy and degrees of freedom of the baseline model with that of the hypothesised model (Bentler and Bonett, 1980).

The CFI (0.925), IFI (0.927) and TLI (0.908) all met the minimum threshold suggested by Hooper *et al.* (2008) and Hu and Bentler (1999). However, the NFI (0.846) fell below the 0.90 threshold. The three of four incremental fit indices assessed fell above the acceptable threshold to provide support for acceptable model fit and therefore the model has acceptable incremental fit. Parsimony was assessed using PNFI (0.689) and PCFI (0.755). The indices exceeded the threshold limit of 0.50 recommended by Hooper *et al.* (2008). It may be argued that the general acceptable index limit of 0.90 which is widely accepted for all other indices might be more appropriate. Due to complexity of the model assessed, it was expected that these indices would be lower than the widely accepted limits of 0.90 and thus the model presented is not parsimonious.

5.4 Model Refinement

The model was refined by eliminating awkward constructs and observed variables as recommended by Hooper *et al*. (2008). In this research there are five latent constructs that were eliminated after principal component analysis, namely, Training and Competency (TC), Process Health and Safety Information (PHSI), Control of Confined Space Entry (CCSE), Operating Procedure (OP) and Control of Ignition Source (CIS). The above five latent constructs were eliminated due to no observed variable allocated to it or because the loading was less than 0.50.

There were three observed variables that were eliminated since their loadings were less than 0.5 and they are namely, TCH18 - The organisation communicates effectively all lessons learned after the occupational health and safety incidents. PTW19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite). TCH34 - My organisation has all management systems in place to manage substance misuse. Other Observed variables were allocated to different latent variables after principal component analysis.

Leadership commitment is the latent construct that had nine observed variables and only LCH40 was eliminated to improve CMIN/df from 2.394 to 2.151 which was then marginally accepted. Under chemical exposure management there was original five observed variables and only CEMH30 was eliminated to improve incremental fit indices CFI, IFI and NFI to acceptable threshold. Health and safety risk assessment is the latent construct that had nine observed variables and two HSRAH33 and

HSRAH35 were eliminated to improve incremental fit indices CFI, IFI and NFI for the final research model.

Process Hazard Analysis is the latent construct had five observed variables, namely, PHAH20 – In my organization all engineering changes undergo a comprehensive management of change. PHAH21 – The organization does comprehensive process hazard analysis before engineering changes are made. PHAH22 – The organization has all process health and safety information available to all employees. PHAH24 – In my organization we have a comprehensive pre-activity start up review and pre-activity shutdown review. PHAH26 – In my organization all work activities have a detailed operating procedure or work instruction. The final model eliminated PHAH22, PHAH24 and PHAH26 and remained with only PHAH20 and PHAH21.

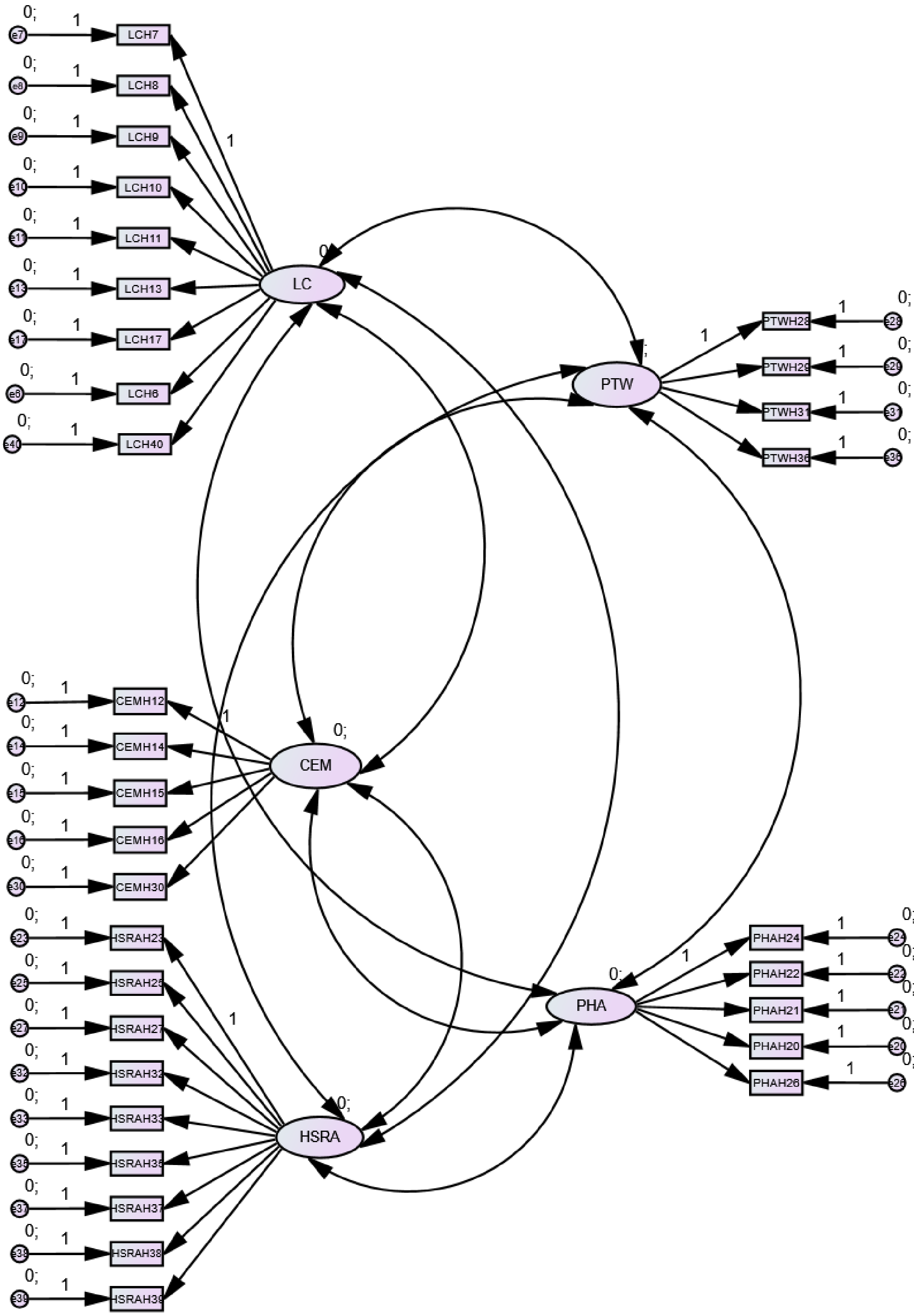

Figure 5.1 Initial Measurement Model

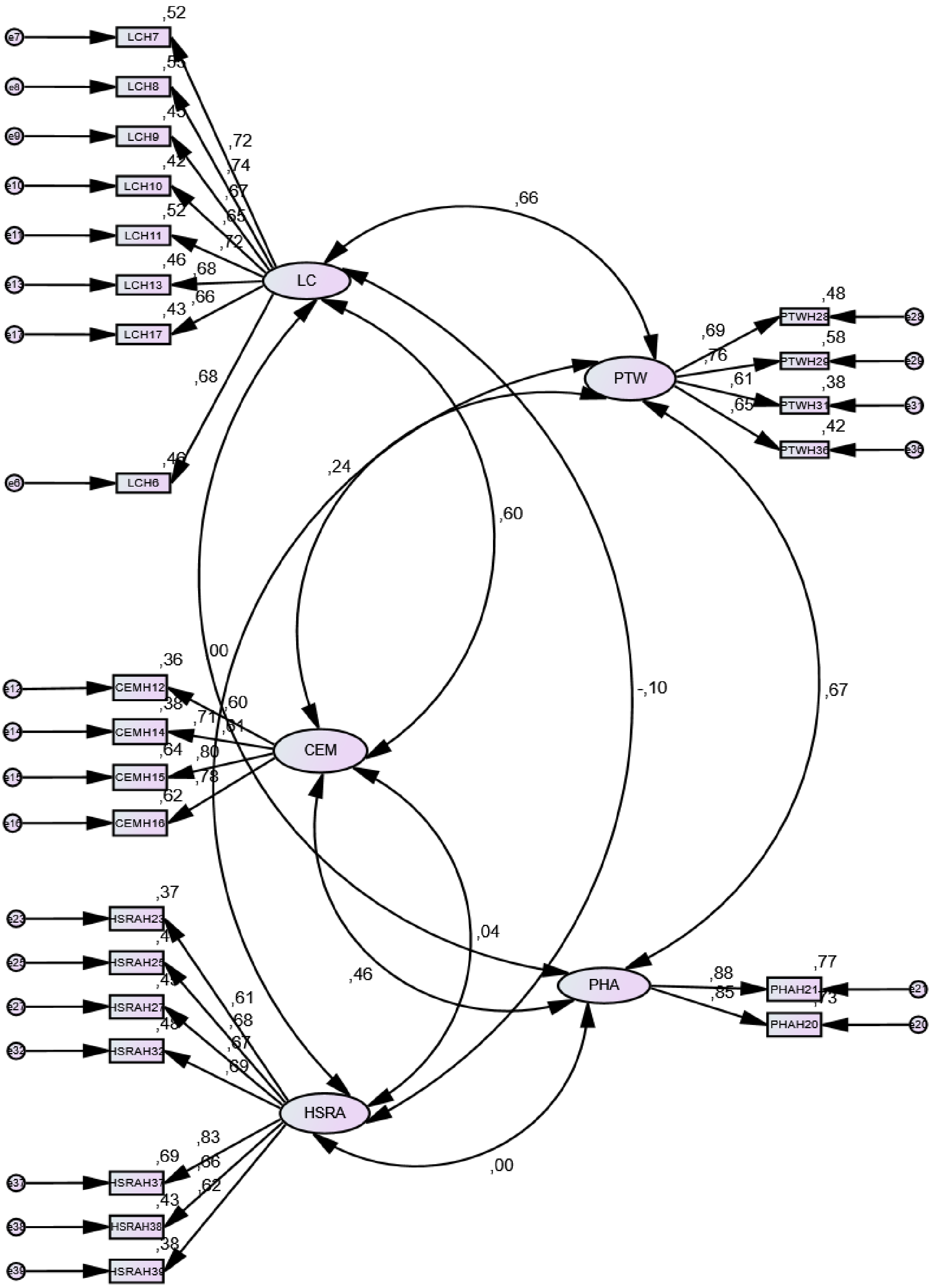

Figure 5.2 Refined Measurement Model

5.5 Chapter Summary

This chapter discussed model development. The descriptive statistics, reliability analysis and confirmatory analysis were used. Descriptive statistics used was the cumulative percentage, mean and standard deviation using SPSS (version 25). Cronbach's alpha was used for reliability analysis and principal component analysis was used to provide the goodness of fit. In this research, there were three observed variables that were eliminated since the loading was less than 0.5 and they were five latent constructs that were identified as drivers towards generative process health and safety culture. This chapter discussed model fit to empirical data set for all five latent constructs and final refined measurement model. This chapter is responding to the following research question, namely, what are the critical drivers to achieve generative health and safety culture? The next chapter seven discusses the model validation.

CHAPTER SIX

Model Validation

6.1 Introduction

In this chapter, the final research model was evaluated further and validated. Internal reliability and validity tests were carried out through model fitness tests and hypotheses testing involving a statistical test of significance. The internal reliability and validity test results were used in this research. The normal distribution and multicollinearity of the data were checked, and the validity of the model was assessed via tests of the research hypotheses.

Whatever modelling paradigm or solution method is being used, the performance measures extracted from a model will only have some bearing on the real system represented if the model is a good illustration of the system. What constitutes a good model is subjective, but from a performance modelling point of view the criteria judging the goodness of models is based on how accurately measures extracted from the model correspond to the measures which would be obtained from the represented system.

Structural equation modelling was chosen for the model development and internal model validation because the technique offers the most robust reliability and validity checks on the developed model (Hair *et al.,* 2010; Zhao, 2017). Structural equation modelling (SEM) is multivariate data analysis approach used to assess complex relationships among constructs. It graphically models hypothesised relationships among constructs with structural equations (Byrne, 2006; Zhao, 2017). SEM institutes how well the theoretical model is supported by empirical data using goodness-of-fit indices (Hu and Bentler, 1990). The assessment of model fitness against empirical data and the estimation of the regression parameters is the primary goal of SEM (Byrne, 2006; Hu and Bentler, 1999). In this research, the assessment of model fitness is achieved using numerous model fit indices. The fit indices are clustered into three distinct groups namely, absolute fit indices, incremental fit indices and parsimonious fit indices.

The model fitness test subroutine of the analysis of moment of structures (AMOS) provides an advanced test process for this purpose (Hafeez *et al.,* 2006; Zhao, 2017). The model fitness test studied the degrees of fit between the final model and the empirical dataset. The following subsections discuss the AMOS-based battery of model fitness tests; these include goodness of fit (GOF), normality, multi-collinearity and model adequacy.

6.2 Normality Assessment

One critical important assumption in an SEM approach, especially in AMOS, is that the data are of multivariate normality (Arbuckle, 2015). As skewness severely affects the means and kurtosis tends to impact variances and covariance, it is necessary to appraise this criterion for the final model (DeCarlo, 1997; Zhao, 2017). Histograms can provide insights on skewness, behaviour in the tails, presence of multi-modal behaviour, and data outliers. Histograms can be compared to the fundamental shapes associated with standard analytic distributions. SEM is a method that is based on the analysis of covariance structures, hence, the multivariate kurtosis is exceptionally important in SEM analysis. Prerequisite to the test of multivariate normality is the need for assessment of univariate normality (DeCarlo, 1997; Zhao, 2017).

If an observed variable fails a normality test, it is vital to look at the histogram and the normal probability plot to see if an outlier or small subset of outliers has caused the non-normality. If there are no outliers, it is recommended to try a transformation (such as, the log or square root) to make the data normal (DeCarlo, 1997; Zhao, 2017). If a transformation is not a feasible alternative, nonparametric methods that do not require normality. The Kurtosis values and corresponding critical values of the measurement indicators in the model can be computed by AMOS version 25 in the section of assessment of normality. According to Hoyle (1995; Zhao, 2017), a kurtosis value greater than seven or equal to seven is an indication of a violation of normality. Using this rule of thumb as a guide, an assessment of the generating kurtosis value in Table 6.1 revealed two observed variables Permit to Work (PTWH28 and PTWH29) are greater than seven and that reveals violation of normality.

Table 6.1 Assessment of Normality

Assessment of Normality				
Observed Variables	**Skewness**	**Std Error**	**Kurtosis**	**Std Error**
Leadership Commitment (LCH6)	1.170	0.152	2.295	0.303
Leadership Commitment (LCH7)	1.735	0.152	3.793	0.302
Leadership Commitment (LCH8)	1.200	0.152	1.547	0.302
Leadership Commitment (LCH9)	0.945	0.151	0.809	0.302
Leadership Commitment (LCH10)	1.540	0.151	3.016	0.302
Leadership Commitment (LCH11)	1.061	0.151	0.722	0.302
Leadership Commitment (LCH13)	1.058	0.151	1.201	0.302
Leadership Commitment (LCH17)	0.803	0.152	0.058	0.302
Leadership Commitment (LCH40)	1.712	0.151	3.324	0.302
Chemical Exposure Management (CEMH12)	0.953	0.151	0.668	0.302
Chemical Exposure Management (CEMH14)	0.778	0.152	0.098	0.302
Chemical Exposure Management (CEMH15)	0.209	0.153	-0.470	0.304
Chemical Exposure Management (CEMH16)	0.090	0.152	-0.399	0.302
Chemical Exposure Management (CEMH30)	1.979	0.151	4.430	0.302

Health and Safety Risk Assessment (HSRAH23)	-0.401	0.152	-0.195	0.303
Health and Safety Risk Assessment (HSRAH25)	-0.219	0.152	-0.418	0.303
Health and Safety Risk Assessment (HSRAH27)	-0.033	0.152	-0.761	0.302
Health and Safety Risk Assessment (HSRAH32)	0.024	0.151	-0.912	0.302
Health and Safety Risk Assessment (HSRAH33)	0.473	0.152	-0.365	0.302
Health and Safety Risk Assessment (HSRAH35)	0.454	0.152	-0.026	0.302
Health and Safety Risk Assessment (HSRAH37)	-0.194	0.152	-0.727	0.302
Health and Safety Risk Assessment (HSRAH38)	-0.021	0.152	-0.744	0.302
Health and Safety Risk Assessment (HSRAH39)	0.157	0.152	-0.969	0.302
Process Hazard Analysis (PHAH20)	1.112	0.151	1.368	0.302
Process Hazard Analysis (PHAH21)	1.007	0.151	1.476	0.302
Process Hazard Analysis (PHAH22)	1.244	0.151	1.877	0.302
Process Hazard Analysis (PHAH24)	1.564	0.152	3.449	0.303
Process Hazard Analysis (PHAH26)	1.478	0.151	2.653	0.302
Permit to Work (PTWH28)	2.571	0.152	8.903	0.303
Permit to Work (PTWH29)	3.297	0.151	16.586	0.302
Permit to Work (PTWH31)	1.874	0.152	3.394	0.303
Permit to Work (PTWH36)	1.847	0.152	3.984	0.303

6.3 Multicollinearity

Multicollinearity is defined as two or more predicators being highly correlated with each other (Lauridsen and Mur, 2006; Zhao, 2017). Multicollinearity arises from two different sources – one is the high correlation among underlying constructs and the other case is where two or more measurement variables are highly correlated as they both essentially represent the same latent construct (Temme *et al.*, 2006; Zhao, 2017). Multicollinearity influences the parameter estimates and standard errors so that they are far the real estimates and large standard errors. Moreover, it also affects significant values of hypotheses testing and then it is likely to poses difficulties for theory testing (Hwang, 2009; Zhao, 2017).

The multicollinearity difficult is well understood in traditional analysis methods for non-latent variables. However, the detection and consequence of the multicollinearity in SEM are not sufficiently addressed (Kelava *et al.,* 2008; Zhao, 2017). This problem cannot vanish by using more progressive analysis techniques like SEM. Moreover, it can render the aftermath uninterpretable and generate erroneous conclusions (Kelava *et al.,* 2008; Zhao, 2017). Specifically, this problem imposes aggregate influences on non-linear latent variables rather than manifest variables (Kelava *et al.,* 2008; Zhao, 2017). In defending the final research model, the study should provide adequate checking on the multicollinearity in order to avoid unsuitable understanding and spurious conclusions.

According to Zhao (2017) a vital evaluation of the output of the AMOS analysis explores that no enormously large correlations (r >1) exist between the variables, with all latent constructs and measurement indicators. Moreover, the signs of the standard errors also signal no multicollinearity problem in the variables as they are extremely small.

Correlations indicate both the strength and the direction of the relationship between a pair of variables and ranges between -1 to +1 (Bryman and Cramer, 2005). The direction of the relationships is indicated by the positive and negative signs while the strength of the relationship is indicated by the magnitude of the value (Bryman and Cramer, 2005). Correlation does not necessarily indicate causation (Leedy and Ormrod, 2010). According to Pallant (2010) correlation coefficients should be greater than 0.30. Correlations should be checked to provide a more rigorous assessment of the convergent validity. If the correlations exceed the value of 0.30, convergent is achieved (Robinson *et al.*, 1991). According to Kline (2011) correlations values less than 0.90 is indicative of discriminant validity.

Table 6.2 Correlation Matrix of Leadership Commitment Latent Variable

Leadership Commitment Correlation Matrix								
Leadership Commitment	**LCH6**	**LCH7**	**LCH8**	**LCH9**	**LC10**	**LCH11**	**LCH13**	**LCH17**
LCH6	1.000							
LCH7	0.510	1.000						
LCH8	0.538	0.586	1.000					
LCH9	0.564	0.439	0.513	1.000				
LC10	0.434	0.452	0.502	0.400	1.000			
LCH11	0.412	0.545	0.579	0.421	0.565	1.000		
LCH13	0.485	0.448	0.466	0.457	0.472	0.512	1.000	
LCH17	0.401	0.515	0.489	0.424	0.407	0.507	0.429	1.000

The correlation values between eight observed variables for leadership commitment were greater than 0.30. The results displayed in Table 6.2 suggest the attainment of convergent validity. The correlation values ranged from 0.400 to 0.586 for the observed variables LCH6, LCH7, LCH8, LCH9, LCH10, LCH11, LCH13 and LCH17 (above the cut off), therefore this scale meets the requirement for discriminant validity as the correlations were less than 0.9. The Cronbach's alpha value was above the minimum value of 0.7 with value of 0.881 and the convergent validity characterised by high correlation values were found to be satisfactory. This latent construct (leadership commitment) satisfied the internal reliability criteria and construct validity.

Table 6.3 Correlation Matrix of Chemical Exposure Management Latent Variable

Chemical Exposure Management Correlation Matrix				
Chemical Exposure Management	**CEMH12**	**CEMH14**	**CEMH15**	**CEMH16**
CEMH12	1.000			
CEMH14	0.485	1.000		
CEMH15	0.443	0.469	1.000	
CEMH16	0.454	0.469	0.666	1.000

The correlation values between four observed variables for chemical exposure management were greater than 0.30 all the observed variables. The results displayed in Table 6.3 suggest the attainment of convergent validity. The correlation values ranged from 0.443 to 0.666 for the observed variables CEMH12, CEMH14, CEMH15 and CEMH16 (above the cut off), therefore this scale meets the requirement for discriminant validity as the correlations were less than 0.9. The Cronbach's alpha value was above the minimum value of 0.7 with the value of 0.798 and the convergent validity characterised by high correlation values were found to be satisfactory. This latent construct (Chemical Exposure Management) satisfied the internal reliability criteria and construct validity.

Table 6.4 Correlation Matrix of the Health and Safety Risk Assessment Latent Variable

Health and Safety Risk Assessment Correlation Matrix							
Health and Safety Risk Assessment	**HSRAH23**	**HSRAH25**	**HSRAH27**	**HSRAH32**	**HSRAH37**	**HSRAH38**	**HSRAH39**
HSRAH23	1.000						
HSRAH25	0.463	1.000					
HSRAH27	0.398	0.511	1.000				
HSRAH32	0.427	0.520	0.523	1.000			
HSRAH37	0.498	0.602	0.598	0.609	1.000		
HSRAH38	0.448	0.445	0.398	0.440	0.529	1.000	
HSRAH39	0.340	0.378	0.409	0.415	0.497	0.606	1.000

The correlation values between seven observed variables for health and safety risk assessment were greater than 0.30 for all the observed variables. The results displayed in Table 6.4 suggest the attainment of convergent validity. The correlation values ranged from 0.340 to 0.606 for the observed variables HSRAH23, HSRAH25, HSRAH27, HSRAH32, HSRAH37, HSRAH38 and HSRAH39 (above the cut off), therefore this scale meets the requirement for discriminant validity as the correlations were less than 0.9. The Cronbach's alpha value was above the minimum value of 0.7 with the value of 0.865 and the convergent validity characterised by high correlation values were found to be satisfactory. This latent construct (Health and Safety Risk Assessment) satisfied the internal reliability criteria and construct validity.

Table 6.5 Correlation Matrix of the Process Hazard Analysis Latent Variable

Process Hazard Analysis Correlation Matrix		
Process Hazard Analysis	**PHAH20**	**PHAH21**
PHAH20	1.000	
PHAH21	0.751	1.000

The correlation values in Table 6.5 indicates that both observed variables of the process hazard analysis were related to each other. The correlation value was 0.751. Discriminant validity was achieved as the correlations were less than 0.9 and the Cronbach's alpha value was above the minimum value of 0.7 with the value of 0.858. The convergent validity characterised by high correlation values were found to be satisfactory. This construct therefore satisfied the internal reliability criteria and the construct validity.

Table 6.6 Correlation Matrix of the Permit to Work Latent Variable

Permit to Work Correlation Matrix				
Permit to Work	**PTWH28**	**PTWH29**	**PTWH31**	**PTWH36**
PTWH28	1.000			
PTWH29	0.597	1.000		
PTWH31	0.417	0.473	1.000	
PTWH36	0.399	0.438	0.402	1.000

The correlation values in Table 6.6 indicates that all four observed variables of the permit to work were related to each other. The correlation values ranged between 0.399 to 0.597. Discriminant validity was achieved as the correlations were less than 0.9 and the Cronbach's alpha value was above the minimum value of 0.7 with the value of 0.769. The convergent validity characterised by high correlation values were found to be satisfactory. This construct therefore satisfied the internal reliability criteria and the construct validity.

Table 6.7 Correlation Matrix of Latent Variables

Correlation Matrix of Latent Variables					
Latent Variables	**LC**	**CEM**	**HSRA**	**PHA**	**PTW**
LC	1				
CEM	0.604	1			
HSRA	-0.099	0.040	1		
PHA	0.707	0.463	-0.002	1	
PTW	0.658	0.241	0.004	0.668	1

The correlation values in Table 6.7 indicates that all five latent variables of the generative health and safety culture were related to each other. The correlation values ranged between -0.002 to 0.707.

Discriminant validity was attained as the correlations were less than 0.9. The convergent validity characterised by high correlation values were found to be acceptable. These latent constructs therefore fulfilled the construct validity. The results of the correlations of the latent variables are revealed in Table 6.7. From the results, the final research model is free from multicollinearity problem.

6.4 Reliability and Validity

The validity of the research model should be evaluated satisfactorily from the results of SEM. Given the above validation, the reliability and validity were further assessed. Composite reliability and discriminant validity of the final research model were further evaluated.

6.4.1 Composite Reliability

$$CR = \sum \varphi_i^2 / (\sum \varphi_i^2 + \sum \delta_i^2) \quad \textbf{(6.1)}$$

Where
φi is the regression factor loading for corresponding measurement indicator
δi is the measurement error of the corresponding measurement indicator
$\delta = (1-\varphi)$

Table 6.8 Composite Reliability Index

Composite Reliability Index	
Influencing Factors	**CR**
Leadership Commitment (LC)	0.840
Chemical Exposure Management (CEM)	0.835
Health and Safety Risk Assessment (HSRA)	0.814
Process Hazard Analysis (PHA)	0.977
Permit to Work (PTW)	0.816

Composite reliability is usually used to measure how well all the measurement indicators consistently represent the corresponding latent construct (Hair *et al.*, 2010). Moreover, the evidence of composite reliability is established if the value of CR is more than 0.7 (Linn, 1989). The composite reliability can be calculated by equation 6.1. The results shown in Table 6.8 suggest that the CR values of all the constructs exceed the rule of thumb value of 0.70, demonstrating the achievement of composite reliability on the model of acceptability and appropriateness.

6.4.2 Discriminant Validity

According to Zait and Bertea (2011) it is imperative to make the distinction between internal validity and construct validity. Internal validity refers to assuring a methodology that enables the research to rule out alternative explanations for the dependent variables, while construct validity is more concerned with the choice of the instrument and its capability to capture the latent variable (Zait and Bertea, 2011). Construct validity has three components, namely, convergent, discriminant and nomological validity (Zait and Bertea, 2011).

Discriminant validity assumes that items should correlate with other items from other constructs that are hypothetically supposed not to correlate (Zait and Bertea, 2011). Testing for discriminant validity can be done using one of the following methods, namely, O-sorting, Chi-square difference test and the average variance extracted analysis (Zait and Bertea, 2011). It is recommended that Q-sorting procedure be used in the phase of exploratory research when developing a scale for measuring latent variables, while the AVE analysis and Chi-square difference test must be used in the confirmatory stage.

This research discriminant validity was used to examine the shared variance between the constructs by computing the average variance extracted. Discriminant validity is achieved when the AVE is greater than the cut-off criterion 0.5. The equation 6.2 was used to calculate AVE.

$$AVE = \sum \varphi_i^2 / n \qquad \textbf{(6.2)}$$

Where
φi is the regression factor loading for corresponding measurement indicator
n is the number of measurement indicators of the corresponding construct

Table 6.9 Average Variance Extracted Value

Average Variance Extracted Value	
Influencing Factors	**AVE**
Leadership Commitment (LC)	0.650
Chemical Exposure Management (CEM)	0.499
Health and Safety Risk Assessment (HSRA)	0.467
Process Hazard Analysis (PHA)	0.751
Permit to Work (PTW)	0.466

It is evident from Table 6.9 that the constructs in the final research model are unique and show good discriminant validity, as their values are mostly greater than the acceptable value of 0.5. The results recommend that they possess acceptable discriminant validity. The resulting scores for AVE ranged

0.466 and 0.751 and can be seen in Table 6.9. Based on the extensively acceptable minimum threshold of 0.50 by Fornel and Larcker (1981), three constructs fell below the thresholds. The affected constructs are chemical exposure management (CEM), health and safety risk assessment (HSRA) and permit to work (PTW) which had values of 0.499, 0.467 and 0.466 respectively. While 0.50 is the widely accepted threshold for AVE, 0.40 is also consider marginally acceptable especially when other measures of validity are adequately met (Chin, 1998). Based on this threshold of 0.40, all latent constructs met the acceptable minimum threshold.

Table 6.10 Reliability and Validity

Latent Constructs	Observed Variable	Factor Loading	CR	AVE	Cronbach's Alpha
Leadership Commitment (LC)	LCH6	0.682	0.840	0.650	0.881
	LCH7	0.719			
	LCH8	0.742			
	LCH9	0.669			
	LCH10	0.647			
	LCH11	0.721			
	LCH13	0.680			
	LCH17	0.719			
Chemical Exposure Management (CEM)	CEMH12	0.602	0.835	0.499	0.798
	CEMH14	0.615			
	CEMH15	0.799			
	CEMH16	0.785			
Health and Safety Risk Assessment (HSRA)	HSRAH23	0.608	0.814	0.467	0.865
	HSRAH25	0.684			
	HSRAH27	0.670			
	HSRAH32	0.693			
	HSRAH37	0.828			
	HSRAH38	0.659			
	HSRAH39	0.620			
Process Hazard Analysis (PHA)	PHAH20	0.854	0.997	0.751	0.858
	PHAH21	0.879			
Permit to Work (PTW)	PTWH28	0.764	0.816	0.466	0.769
	PTWH29	0.694			
	PTWH31	0.615			
	PTWH36	0.648			

It is evident in Table 6.10 that factor loading CFA ranged from 0.602 to 0.879 confirming that all factor loading was above the threshold limit of 0.50 recommended by Anderson and Gerbing (1988). Composite reliability index ranged from 0.814 to 0.997 for the five latent constructs signifying the attainment of composite reliability on the model of adequacy and appropriateness. Average variance extracted value ranged from 0.466 to 0.751, AVE measures the level of variance captured by a construct versus the level due to measurement error. Internal reliability is achieved when Cronbach's alpha value is above 0.7 and the range of 0.769 to 0.881 was realised from the five latent constructs.

6.5 Model Parameter and Hypothesis Testing

Structural equation modelling has been used to test the hypotheses in this study. The path diagram describes the hypothesised relationships among the latent constructs. The goodness-of-fit indices indicate the research model is reliable and can be used to test the hypothesised relationship set in this study. The analysis results shown in figure 6.1 are based on the questionnaire data collected from the major petrochemical industry in South Africa, KwaZulu-Natal Province.

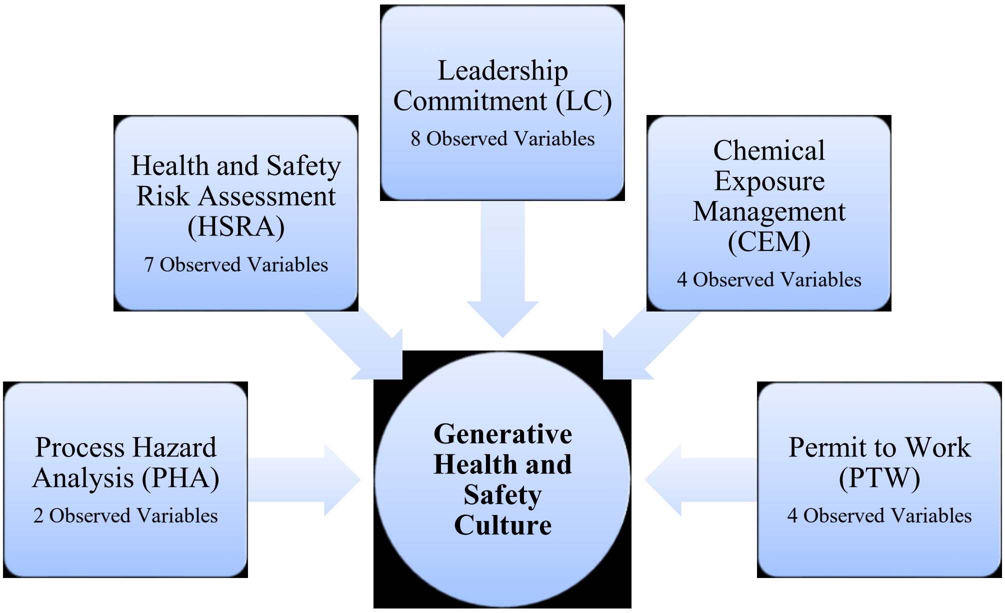

Figure 6.1 Hypothesis Testing Model

In this research factor loading was used to consider model parameters. The direction of association between the observed variable and the latent construct as well as the size of the statement can be determined by using unstandardized and standardised factor loadings. Unstandardised factor loadings indicate the relationships between the manifest variables and latent variables (Diamantopoulos and Siguaw, 2000). Unstandardized factor loadings should always be used in conjunction with standardised factor loadings. According to Schumacker and Lomax (2004) the standardised factor loadings are used in determining the importance one variable to other variables and is easier to interpret. In this research only standardised factor loadings greater than 0.50 were considered suitable. Variables greater than 0.50 indicate reasonably good convergent and construct validity of the model (Hair *et al.*, 2010).

The standardised regression weights indicated in the path diagram were used to accept or reject the hypotheses. According to Hair *et al*. (2005); Hung and Lu (2008); Lattin *et al.* (2009) cited in Zhao (2017) the hypotheses corresponding to a standardised regression weight less than 0.1 were rejected. The five hypotheses were supported at the five percent level of significance.

Figure 6.1 presents the final structural research model for generative health and safety culture with standardised regression weights on structural paths of the proposed hypothesised relationships. The proposed hypothesised relationships were established by using standard regression weights, standard errors, critical ratios and their level of statistical significance to examine whether the hypothesised relationships are supported by the collected data.

Table 6.11 Hypothesised Relationships Testing in the Research Model

Latent Constructs	Estimate	S.E.	C.R.	P - Value	Conclusion
Leadership Commitment (LC)	0.257	0.040	6.415	***	Supported
Chemical Exposure Management (CEM)	0.221	0.045	4.897	***	Supported
Health and Safety Risk Assessment (HSRA)	0.397	0.078	5.065	***	Supported
Process Hazard Analysis (PHA)	0.412	0.050	8.159	***	Supported
Permit to Work (PTW)	0.201	0.035	5.776	***	Supported

Note: *** Sig (p) value is infinitesimally small (close to 0) hence cannot be reported.

It is evident in Table 6.11 that the standardised regression weights were all above the threshold limit of 0.1 with the highest value of PHA (0.412) process hazard analysis. The standardised regression weights ranged between 0.201 and 0.412. The standard errors do not present with any extremely large or small values and all the hypothesised relationships are supported at the statistical significance level $p < 0.05$ except for health and safety risk assessment (HSRA) with 0.078 standard error. The hypothesised relationship between process hazard analysis and generative health and safety culture with a CR value of 8.159 and regression coefficient 0.412 strongly support this hypothesis. The hypotheses leadership commitment (LC) had CR value of 6.415, permit to work (PTW) had CR value of 5.776, health and safety risk assessment (HSRA) had CR value of 5.065 and chemical exposure management (CEM) had CR value of 4.897 and were all supported by the analysis results.

The analysis results indicates that the participants consider the five latent constructs as vital for generative health and safety culture. As reported in the preceding chapter six, ten observed variables were eliminated during the model refinement/modification for the final model to achieve the best fit, namely, TCH18, PTW19, TCH34, LCH40, CEMH30, HSRAH33, HSRAH35, PHAH22, PHAH24 and PHAH26.

6.6 Model Acceptance

The model evaluation should mainly centre on the adequacy of the parameter estimates and the whole research model (Byrne, 2010; Zhao, 2017). Looking at the adequacy of the parameters estimated by the model, the feasibility of the parameters and the appropriateness of standard errors were checked. To test the feasibility of the parameters, the parameters should have correct sign and size to represent the underlying theory (Motawa and Oladokun, 2015; Zhao, 2017). Any deviations from these recommend that the model is unable to sufficiently explain and capture the subject under examination. An example of these is the negative variances.

Table 6.12 Variances Estimated by the Model

Variances Estimated by the Model					
Latent Constructs	**Error**	**Estimate**	**Standard Errors**	**Critical Ratio**	**p-Value**
Leadership Commitment (LC)	e6	0.255	0.025	10.215	***
	e7	0.241	0.024	9.977	***
	e8	0.261	0.027	9.777	***
	e9	0.299	0.029	10.329	***
	e10	0.202	0.019	10.443	***
	e11	0.268	0.027	9.976	***
	e13	0.347	0.034	10.264	***
	e17	0.526	0.051	10.362	***
Chemical Exposure Management (CEM)	e12	0.390	0.039	10.053	***
	e14	0.363	0.037	9.943	***
	e15	0.265	0.037	7.125	***
	e16	0.375	0.05	7.508	***
Health and Safety Risk Assessment (HSRA)	e23	0.676	0.065	10.323	***
	e25	0.547	0.056	9.818	***
	e27	0.704	0.071	9.946	***
	e32	0.702	0.072	9.771	***
	e37	0.398	0.052	7.609	***
	e38	0.687	0.068	10.032	***
	e39	0.838	0.082	10.279	***
Process Hazard Analysis (PHA)	e20	0.167	0.028	6.037	***
	e21	0.121	0.024	5.078	***
Permit to Work (PTW)	e28	0.217	0.024	8.98	***
	e29	0.095	0.012	7.791	***
	e31	0.366	0.037	9.799	***
	e36	0.303	0.032	9.506	***

Note: *** Sig (p) value is infinitesimally small (close to 0) hence cannot be reported.

Critically reviewing all the variances estimated by the model, Table 6.12, proposes that the model is acceptable in this respect. Moreover, to ensure the adequacy of the final research model the appropriateness of the standard error should be assessed due to the fact that it supports the accuracy of the parameter estimates. Extremely large value of standard error indicates a poor model fit. In addition, the statistical significance of the parameter estimates should be checked as all the estimates should be significant in the model.

Table 6.13 Parameter Estimated and Standard Errors

Parameter Estimates and Standard Errors				
Observed Variable	**Estimate**	**Standard Errors**	**Critical Ratio**	**P-Value**
LCH6 ← LC	0.928	0.089	10.37	***
LCH7 ← LC	1			
LCH8 ← LC	1.114	0.099	11.297	***
LCH9 ← LC	0.969	0.095	10.197	***
LCH10 ← LC	0.752	0.076	9.866	***
LCH11 ← LC	1.062	0.097	10.996	***
LCH13 ← LC	1.076	0.104	10.368	***
LCH17 ← LC	1.252	0.125	10.039	***
CEMH12 ← CEM	1			
CEMH14 ← CEM	0.998	0.129	7.752	***
CEMH15 ← CEM	1.454	0.16	9.112	***
CEMH16 ← CEM	1.649	0.182	9.055	***
HSRAH23 ← HSRA	1			
HSRAH25 ← HSRA	1.102	0.126	8.71	***
HSRAH27 ← HSRA	1.204	0.14	8.594	***
HSRAH32 ← HSRA	1.281	0.145	8.81	***
HSRAH37 ← HSRA	1.481	0.15	9.856	***
HSRAH38 ← HSRA	1.152	0.136	8.483	***
HSRAH39 ← HSRA	1.147	0.142	8.104	***
PHAH20 ← PHA	1.046	0.073	14.355	***
PHAH21 ← PHA	1			
PTWH28 ← PTW	1			
PTWH29 ← PTW	0.813	0.081	10.025	***
PTWH31 ← PTW	1.053	0.125	8.444	***
PTWH36 ← PTW	1.044	0.118	8.831	***

Note: *** Sig (p) value is infinitesimally small (close to 0) hence cannot be reported.

6.7 Expert Validation

The aim of this section was to further ascertain external validation by experts using literature review.

6.7.1 Leadership Commitment

Having senior managers who take a proactive interest in establishing a health and safety culture has been considered to be a key influence on organisational health and safety performance (Hardy, 2013). According to Okoye *et al.* (2016) a vital element in health and safety management system is visible health and safety commitment from leadership and managers. Perceptions of the commitment of leadership towards health and safety rather than just the intentions have a strong bearing on the actual behaviours and performance of the people in the organisation (Holstvoogd *et al.,* 2006).

Management commitment provides the motivation force and resources for health and safety activities within the organisation and creating an environment of continuous improvement belongs to all levels of management (Okoye *et al.*, 2016). According to Hardy (2013) it is recognised that leadership is important in the creation of a culture that supports and promotes a strong health and safety performance of an organisation.

According to Elssayed *et al.* (2012) management actions related to health and safety should be adequate and be prioritised to improve health and safety quality efficiently. Health and safety issues cannot be tackled effectively without interference of employers with a particular pattern of behaviour as important criteria needed to change employee's behaviours (Zin, 2012).

6.7.2 Chemical Exposure Management

According to Vitharana *et al.* (2015) health hazards are properties of a chemical that have the potential to cause adverse health effects and exposure usually occurs through inhalation, skin contact or ingestion. The major consequences of chemical disasters include impact on livestock, flora/fauna, the environment (air, soil, and water) and losses to industry (Reddy and Yarrakula, 2016). Chemical process hazards at a chemical plant can give rise to accidents that affect both workers inside the plant and members of the public who reside nearby (Chen, 2016).

According to International Labour Organisation (2017) some of the duties of the employer are to identify risk of physical or chemical reaction of hazardous chemical and ensuring the stability of hazardous chemicals, ensure that exposure standards are not exceeded. Process health and safety management is critical in the chemical process industry and improving organisation knowledge and knowledge management capabilities is an important means to prevent chemical accidents and improve organisations' health and safety level (Chen, 2016).

6.7.3 Health and Safety Risk Assessment

According to Eyayo (2014) globally, there are 2.9 billion workers who are exposed to hazardous risks at their work place and annually there are two million deaths that are attributable to occupational diseases and injuries while 4% of gross domestic product is lost due to occupational diseases and injuries. According to Dabup (2012) the risk assessment provides a systematic approach for the identification, management and reduction of the risk to an acceptable level.

Health and safety risk assessment is the evaluation of hazards to determine their potential to cause an accident and identifying health and safety hazards in order to prevent and control them is very imperative to the health and well-being of the workers (Eyayo, 2014). According to Albert, Hallowell and Kleiner (2014) a critical component in health and safety risk management is to adequately identify hazards and mitigate its associated risk using safety program elements.

The management of health and safety at work require employers to make a suitable and sufficient assessment of the health and safety risks to employees and non-employees, arising from their work activities (Kumar *et al.*, 2017). Health and safety risk analysis remains an important tool in safety management for prioritizing actions and plans, in order to commit top health and safety management systems (Elssayed *et al.*, 2012).

6.7.4 Process Hazard Analysis

The process hazard analysis is vital to the health and safety efforts as it provides information to assist management and operations team to improve health and safety by reducing risk (Hardy, 2013). The hazards may not be obvious and it is imperative that the assessments must be done by a qualified person familiar with the work to be done (Karthika, 2013). A process hazard analysis must be conducted by a team with expertise in engineering and process operations, including at least one employee who has experience and knowledge on the system (Department of Transport [USA], 2000). The employers should ensure the safe use, handling and storage of hazardous substances (Vitharana *et al.*, 2015).

6.7.5 Permit to Work

Hazards are identified, the risk to health and safety assessed, an appropriate prevention or control strategy gets done, but many times people still get killed in the petrochemical industry because of misunderstandings like entering confined space without permission (Karthika, 2013). Effective implementation of a comprehensive permitting program certainly helps preventing several undesirable incidents. However, deficiencies in implementing a permit to work system have been a contributing factor in several catastrophic incidents (Reddy and Reddy, 2015). According to Karthika (2013) normally all maintenance, repair, construction work shall be carried out with a proper work permit.

6.8 Chapter Summary

This chapter evaluated the research model further and validated it. Internal reliability and validity tests were carried out through model fitness tests and hypotheses testing involving a statistical test of significance. The internal reliability and validity test results were used in this chapter. The normal distribution and multicollinearity of the data was checked, and the validity of the model was assessed via tests of the research hypotheses. The next chapter discusses the results of the model fit and the hypotheses in relation to existing literature.

CHAPTER SEVEN

Discussion

7.1 Introduction

This chapter discusses the findings of the study in relation to the research objectives. The main objectives were, to identify the main process health and safety management deficiencies that require senior management's attention, to identify the main drivers that could be used to improve health and safety to reach generative process health and safety culture level five and to develop a model of effectively managing hazardous chemical substance exposure in the petrochemical industry. The discussion and results emphasis is on model fit in relation to existing literature. The chapter also highlights the observed variables that were eliminated from the research and the latent variables that were eliminated from the research.

7.2 Discussion of Findings

The study has investigated the process health and safety management systems, the ten latent variables were assessed with observed variables. The ten latent variables were reduced to five latent variables after principal component analysis and then structural equation modelling was employed. This advanced method was employed to test the statistical adequacy of the proposed research model in order to confirm whether or not the hypothesised relationships between the latent variables towards generative health and safety culture were true. The analysis result statistically proved that the five latent variables, namely, leadership commitment, chemical exposure management, health and safety risk assessments, process hazard analysis and permit to work collectively influenced a generative health and safety culture.

Path models and cognitive mapping were used to describe and explain the observed and latent variables that significantly influenced generative health and safety culture. The reliability and validity of the five latent constructs in this study are adequate. The goodness-of-fit indices of the structural research model are satisfactory. The hypothesised relationship in the structural research model was tested by AMOS version 25. The strength of the relationship between the latent constructs was represented by the statistical significance of the path coefficient. Maximum likelihood method was used to estimate path coefficients.

In testing the conceptual model, after identifying the underlying structure based on the existing literature, the five latent constructs, namely, leadership commitment, chemical exposure management, health and safety risk assessments, process hazard analysis and permit to work were retained in the final model. The other five latent constructs, namely, Training and Competency, Process Health and Safety Information, Control of Confined Space Entry, Operating Procedure and Control of Ignition Source in the original conceptual model were eliminated from the final research model.

There were three observed variables that were eliminated since their loadings were less than 0.5 and they are namely, observed variable 18 - The organisation communicates effectively all lessons learned after the occupational health and safety incidents. Observed variable 19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite). Observed variable 34 - My organisation has all management systems in place to manage substance misuse. Other Observed variables were allocated to different latent variables after principal component analysis.

Leadership commitment is the latent construct that had nine observed variables and only LCH40 was eliminated, LCH40 - Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry. Under chemical exposure management there were originally five observed variables and only CEMH30 was eliminated, CEMH - All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.

Health and safety risk assessment is the latent construct that had nine observed variables and two HSRAH33 and HSRAH35 were eliminated, HSRAH33- My organization diligently manages fatigue in both permanent employees and contractors, and HSRAH35 - Most of the health and safety incidents are due to human error in my organization.

Process hazard analysis is the latent construct that had five observed variables, namely, PHAH20 – In my organization all engineering changes undergo a comprehensive management of change. PHAH21 – The organization does comprehensive process hazard analysis before engineering changes are made. PHAH22 – The organization has all process health and safety information available to all employees. PHAH24 – In my organization we have a comprehensive pre-activity start up review and pre-activity shutdown review. PHAH26 – In my organization all work activities have a detailed operating procedure or work instruction. The final model eliminated PHAH22, PHAH24 and PHAH26 and remained with only PHAH20 and PHAH21.

Ten observed variables were eliminated during the model refinement/modification for the final model to achieve the best fit, namely, TCH18, PTW19, TCH34, LCH40, CEMH30, HSRAH33, HSRAH35, PHAH22, PHAH24 and PHAH26.

7.2.1 Findings related to Leadership Commitment

Table 7.1 Leadership Commitment Hypotheses Ranking

Leadership Commitment	Mean	Std. Deviation	Ranking
Senior Management communicates Health and Safety policy to all employees (LCH10).	1.40	0.591	1
Senior Management prioritises Health and Safety as in my organisation (LCH7).	1.48	0.707	2
My organization has excellent chemical exposure management systems (LCH6).	1.62	0.692	3
Senior Management allocates enough time to address Health and Safety concerns (LCH11).	1.63	0.748	4
Senior Management has an open door policy on Health and Safety issues (LCH8).	1.64	0.763	5
There are effective noise exposure management systems in my organization (LCH9).	1.70	0.737	6
Employees undergo comprehensive training on health and safety in my organization (LCH13).	1.78	0.805	7
Senior management prioritizes mechanical/asset integrity of our processing plant (LCH17).	1.98	0.966	8

Table 7.1 shows the responses to statements about leadership commitment. It is evident that LCH10 (Senior Management communicates Health and Safety policy to all employees) with a mean of 1.40 ranked highest out of the eight statements presented to the participants. Further, LCH 7 (Senior Management prioritises health and safety in my organisation) with a mean of 1.48 ranked second highest.

LCH6 (My organization has excellent chemical exposure management systems), LCH11 (Senior Management allocates enough time to address Health and Safety concerns), LCH8 (Senior Management has an open door policy on health and safety issues), LCH9 (There are effective noise exposure management systems in my organization), LCH13 Employees undergo comprehensive training on health and safety in my organization, and LCH17 (Senior Management prioritises mechanical/asset integrity of our process plant), ranked 3rd to 8th within the leadership commitment latent variable.

This research indicates that senior management must effectively communicate health and safety policy to all employees. It is revealed in this study the senior management must prioritise health and safety in the organisation at all levels and demonstrate that by felt leadership.

According to South African Bitumen Association (2010) leadership and commitment create and sustain an organisational culture that supports effective HSE management through appropriate personal behaviour of leaders at all levels.

- Management demonstrates strong commitment, accountability and visible leadership to HSE through measurable actions.
- Management ensures HSE management system expectations are communicated, understood and implemented at the appropriate levels.
- Management insists on compliance with applicable laws and regulations and the requirements of HSE management system, and takes appropriate action to correct deficiencies.

7.2.2 Findings related to Chemical Exposure Management

Table 7.2 Chemical Exposure Management Hypotheses Ranking

Chemical Exposure Management	Mean	Std. Deviation	Ranking
Most employees know how to handle hazardous chemicals in the work place (CEMH14).	1.75	0.766	1
Most employees are aware of hazardous chemicals in their work environment (CEMH12).	1.75	0.783	2
Contractor's on boarding appreciates all hazardous chemicals in my organization (CEMH15).	2.22	0.858	3
Most contractors know how to handle hazardous chemicals in my organization (CEMH16).	2.59	0.991	4

Table 7.2 shows the responses to statements about chemical exposure management. It is evident that CEMH14 (Most permanent employees know how to handle hazardous chemicals in the work place.), with a mean of 1.35 ranked highest out of the four statements presented to the participants. Further, CEMH12 (Most employees are aware of hazardous chemicals in their work environment.), with a mean of 1.75 ranked second highest. CEMH15 (Contractor's on boarding appreciates all hazardous chemicals in my organisation.), and CEMH16 (Most contractors know how to handle hazardous chemicals in my organisation.) ranked 3rd to 4th within the chemical exposure management latent variable.

This research revealed that all employees are aware that when handling hazardous chemicals one need to use prescribed personal protective equipment. It has been highly indicated in this research that employees should know how to handle hazardous chemicals to prevent process health and safety incidents and improve the culture towards generative health and safety culture. In this research there was only one observed variable that became a management deficiency, and that had to do with contractors knowing how to handle hazardous chemicals.

7.2.3 Findings related to Health and Safety Risk Assessment

Table 7.3 Health and Safety Risk Assessment Hypotheses Ranking

Health and Safety Risk Assessment	Mean	Std. Deviation	Ranking
Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry (HSRAH39).	2.79	1.169	1
Most of the health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment (HSRAH32).	2.83	1.166	2
Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition (HSRAH27).	2.99	1.133	3
Poor housekeeping in my organization is the cause for many health and safety incidents (HSRAH38).	3.02	1.103	4
Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights (HSRAH25).	3.15	1.018	5
Most of the health and safety incidents are due to poor controls in place when working with suspended loads (HSRAH37).	3.16	1.129	6
Most of the health and safety incidents are due to poor engineering design integrity (HSRAH23).	3.21	1.038	7

Table 7.3 shows the responses to statements about health and safety risk assessment. It is evident that HSRAH39 (Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.), with a mean of 2.79 and standard deviation of 1.169 ranked highest out of the nine statements presented to the participants. Further, HSRAH32 (Most of health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.) with a mean of 2.89 and standard deviation of 1.166 ranked second highest.

HSRAH27 (Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition), HSRAH38 (Poor housekeeping in my organization is the cause for many health and safety incidents), HSRAH25 (Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights), HSRAH37 (Most of the health and safety incidents are due to poor controls in place when working with suspended loads), HSRAH23 (Most of the health and safety incidents are due to poor engineering design integrity) ranked 3rd to 7th within the health and safety risk assessment latent variable.

According to Dabup (2012) the risk assessment provides a systematic approach for the identification, management and reduction of the risk to an acceptable level. Risk assessment is a critical step in risk management. If done correctly, it determines the minimum level of preparedness in order to respond effectively. It involves applying qualitative or quantitative techniques to potential risks. It reduces the uncertainties in measuring risk and it usually involves frequency and severity.

This research revealed that 90% of the management deficiencies are in health and safety risk assessment. The composition of the team members that do health and safety risk assessments should have highly skilled and competent employees. It is imperative that the health and safety risk assessments should not be just a paper exercise but must be treated with high respect from senior management. According to Albert, Hallowell and Kleiner (2014) a critical component in health and safety risk management is to adequately identify hazards and mitigate its associated risk using safety program elements.

7.2.4 Findings related to Process Hazard Analysis

Table 7.4 Process Hazard Analysis Hypotheses Ranking

Process Hazard Analysis	Mean	Std. Deviation	Ranking
The organization does comprehensive process hazard analysis before engineering changes are made (PHAH21).	1.70	0.732	1
In my organization all engineering changes undergo a comprehensive management of change (PHAH20).	1.72	0.787	2

Table 7.4 shows the responses to statements about process hazard analysis. It is evident that PHAH21 (The organisation does comprehensive process hazard analysis before engineering changes are made.) with a mean of 1.49 ranked highest out of the five statements presented to the participants. Further, PHAH20 (In my organisation all engineering changes undergo a comprehensive management of change.) with a mean of 1.56 ranked second highest.

In this research comprehensive pre-activity start up review and pre-activity shutdown review was identified as top priority under process hazard analysis latent construct. It was also revealed that detailed operating procedure or work instructions are critical to reduce health and safety incidents and improve culture towards generative health and safety culture in organisations. It is imperative that employees comply with all operating procedure or work instructions and intervene immediately when they identify non-compliance.

According to Hardy (2013) operating procedures describe the tasks that must be performed, data to be recorded, and operating conditions to be maintained. The procedures also identify the health and safety precautions, operating procedures must be clear, concise, accurate and consistent with process safety information derived from the process hazard analysis. The procedures should be formally reviewed and updated as necessary to assure that they are consistent with existing processes.

7.2.5 Findings related to Permit to Work

Table 7.5 Permit to Work Hypotheses Ranking

Permit to Work	Mean	Std. Deviation	Ranking
In my organization before you start excavation or entering a trench you need to obtain authorization (PTWH29).	1.20	0.478	1
All the work activities in my organization are done after a valid permit to work has been signed by the authorities (PTWH28).	1.34	0.648	2
In my organization all safety critical equipment is disabled with permission from the authorities (PTWH31).	1.45	0.770	3
My organization has effective management systems to manage working in confined space (PTWH36).	1.46	0.723	4

Table 7.5 shows the responses to statements about permit to work. It is evident that PTWH29 (In my organisation before you start excavation or entering a trench you need to obtain authorisation.) with a mean of 1.20 ranked highest out of the four statements presented to the participants. Further, PTWH28 (All the work activities in my organisation are done after a valid permit to work has been approved by the authorities.) with a mean of 1.34 ranked second highest.

PTWH31 (In my organisation all safety critical equipment is disabled with permission from the authorities.), PTWH36 (My organization has effective management systems to manage working in confined space) ranked 3rd to 4th within the permit to work latent variable.

This research revealed that it is imperative that excavation or entering a trench must be done after obtaining permission from the correct authorities. It is recommended that before a worker enters any excavation over 1.2m (4 ft) in depth shoring must be in place and before a worker approaches closer to the side or bank, the excavation must be sloped, benched, shored or supported. Excavating or trenching work can be highly dangerous and may lead to death or severe injuries if not carried out safely. The hazards presented by this work include burial, falls from height or being struck by objects falling into the excavation, drowning, as well as asphyxiation or poisoning caused by fumes entering the excavation.

It was revealed in this research that a valid permit to work is critical and plays a vital role in reducing health and safety incidents in the work place. According to Reddy and Reddy (2015) a permit to work is a document which specifies the task to be performed, associated foreseeable hazards and the safety measures. The permit to work system has been widely used to ensure safety during maintenance and/or construction activities in almost every major hazard industry worldwide.

7.3 Research Questions

The research questions that responses were sought for were:

- What deficiencies exist in process health and safety management systems when dealing with hazardous chemicals?
- How should the major deficiencies be prioritised by top management to prevent process health and safety incidents when handling hazardous chemicals?
- What are the critical drivers to achieve generative health and safety culture?

These questions were aimed at illustrating the significance of health and safety to organisations.

7.3.1 Deficiencies relative to Hazardous Chemical Exposure

There were 32 statements from the original 35 statements in the questionnaire that had to be rated in order to identify the deficiencies relative to hazardous chemical exposure. The three statements that were eliminated had a loading that was less than 0.5 after principal component analysis. The key process health and safety management deficiencies for an effective process health and safety management system therefore are, namely;

- Poor engineering design integrity.
- Poor controls when working with suspended loads.
- Poor controls when working at heights.
- Poor housekeeping.
- Poor controls of source of ignition.
- Verifying energy isolation before start working on equipment.
- Poor health and safety risk assessments.
- Effective handling of hazardous chemicals.
- Human error.
- Fatigue management for both permanent employees and contractors.

Training of employees should be emphasised and done all the time to minimize human error that could result in process health and safety incident. All the employees should be competent in the tasks they do. The human element of the system has one of the biggest potentials for either causing or preventing an accident. Safe job performance by operating, maintenance personnel and contractors has a tremendous positive impact on health and safety (Karthika, 2013). Human error is the starting point of an investigation, not the end point. To do something about error, one must look at the system in which people work and focus must extend past "what occurred" to why do it occur (Bridger, 2015). Applying the hierarchy of controls – eliminate the risk and reduce the chance of human error.

This study has highlighted that organisations should manage fatigue for both permanent and contractors diligently to prevent health and safety incidents. Fatigue is an experience of physical or mental weariness that results in reduced alertness. For most people, the major cause of fatigue is not having obtained adequate rest or recovery from previous activities. In simple terms, fatigue largely results from inadequate quantity or quality of sleep. Both the quality (how good) and the quantity (how long) of sleep are important for recovery from fatigue and maintaining normal alertness and performance (Canada Aviation Industry, 2007).

7.3.2 Priority Deficiencies

Table 7.6 Means and Standard Deviations of Deficiencies

Observed Variables	Mean	Std. Deviation	Ranking
Most of the health and safety incidents are due to poor engineering design integrity.	3.21	1.038	1
Most of the health and safety incidents are due to poor controls in place when working with suspended loads.	3.16	1.129	2
Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.	3.15	1.018	3
Poor housekeeping in my organization is the cause for many health and safety incidents.	3.02	1.103	4
Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.	2.99	1.133	5
Most of the health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.	2.83	1.166	6
Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.	2.79	1.169	7
Most contractors know how to handle hazardous chemicals in my organization.	2.59	0.991	8
Most of the health and safety incidents are due to human error in my organization.	2.45	0.970	9
My organization diligently manages fatigue in both permanent employees and contractors.	2.41	1.092	10

Table 7.6 shows the list of 10 process health and safety deficiencies that require senior management's attention. It is evident that most of the health and safety incidents are due to poor engineering design integrity with a mean of 3.21 and standard deviation of 1.038 ranked highest out of the ten statements identified as process health and safety deficiencies. Further, it is revealed that most of the health and safety incidents are due to poor controls in place when working with suspended loads with a mean of 3.16 and standard deviation of 1.129 ranked second highest.

Poor controls when working at heights, Poor housekeeping, Poor controls of source of ignition, Verifying energy isolation before start working on equipment, Poor health and safety risk assessments, Effective handling of hazardous chemicals, Human error and Fatigue management for both permanent employees and contractors were ranked 3rd to 10th within the key process health and safety management deficiencies.

7.3.3 Critical Drivers towards Generative Health and Safety Culture

The key process health and safety drivers to be prioritized for generative process health and safety culture are, namely;

- Leadership Commitment with nine enablers.
- Chemical Exposure Management with five enablers.
- Health and Safety Risk Assessment with nine enablers.
- Process Hazard Analysis with two enablers.
- Permit to Work with only four enablers.

7.3.4 Leadership Commitment Enablers

According to Fernandez (2011) cited in Elssayed *et al.* (2012) employers and employees with good safety behaviour are particularly playing a significant role in achievement of safety compliance to occupational, safety and health improvement in industry. Safety behaviour depends directly on the communication that exists in the firm and indirectly on management's commitment

Maintaining a sense of vulnerability – complacency built on past success is the enemy. Leadership has to ensure continuous improvement in environment, equipment, strategy and management systems. Senior management must address culture and leadership through objective assessment and improvement plans where required. Organisations must providing courageous leadership in leading change and holding individuals accountable for safety and fatality free production. Increasing the focus on high potential near miss events reporting and investigating them at high level is critical. High potential incidents are any incident that, under different circumstances, would have caused more severe consequences leading to a major incident like fatality or lost time injury.

This research revealed that senior management should communicate health and safety policy to all employees effectively. It is imperative to prioritise health and safety over production in every organisation. To improve health and safety organisations should have excellent chemical exposure management systems. This research also revealed that senior management should allocate enough time to address all health and safety concerns raised by employees and contractors. It is encouraged that senior management should have open door policy on health and safety issues. The organisations are motivated to have effective noise exposure management systems. All employees should undergo a comprehensive training on health and safety and may be refresher training be done after every three years. Under leadership commitment it is vital that senior management priorities mechanical/asset integrity for all equipment.

7.3.5 Chemical Exposure Management Enablers

Chemicals can be classified on the base of hazards. The Globally Harmonised System divides hazardous chemicals in the workplace into different categories; physical hazards, health hazards and environmental hazards (Naafs, 2018).

This study encourages that all employees should know how to handle hazardous chemicals to prevent unnecessary incidents and also employees should be aware of hazardous chemicals in their work environment. The hazardous effect of chemicals comes through three ways, namely: fire, explosion and toxicity. The first essential step towards greater plant safety is being aware of the potentially dangerous properties of the substances, i.e. whether they are flammable, explosive or toxic (Almanssoor, 2008).

This research emphasised the importance of contractor's on boarding to appreciate all hazardous chemicals contractors will be exposed to during the project and that contractors should know how to handle hazardous chemicals.

7.3.6 Health and Safety Risk Assessment Enablers

It is critical to maintain alertness to increase and unexpected risks during abnormal operating conditions. According to Kumar *et al.* (2017) health and safety risk assessment is a management tool that allows the workplace to comply with her occupational policy,

- Helps the workers do their jobs without damage to their health,
- Enables the workplace to meet her legal responsibilities,
- Enables the workplace show due diligence in the protection and promotion of health and safety of the workers,
- Provides an auditable platform and involves the work force in protecting the health and safety of the workers.

According to South African Bitumen Association (2010), company must provide structured support for a systematic approach to manage HSE risks. High-risk work must be assessed and approved by the high-risk working committee including client's senior management and contractor's senior management team. It is also recommended that contractor's senior management team do regular health and safety talks while the task is being executed. Health and safety risk assessments should be done by competent employees, it should not be just a paper exercise but these assessments should be respected.

It is highlighted in this study that verifying energy isolation before one can start working on equipment is vital to prevent health and safety incidents. Isolation is a safety critical activity and is an integral part of effective control of work. All stored energy sources must be identified, isolated and proven safe prior to any work commencing. All isolations must be carried out by approved and competent personnel.

Poor controls of ignition source was identified as one of the items that should be treated with respect by senior management and all employees. According to Puttick (2008) fire and explosion hazard assessment flammable and potentially flammable atmospheres must be identified and compared with the potential ignition sources present. Avoidance of ignition sources can be a useful and reliable basis of safety in certain circumstances provided that it is restricted to the inside of chemical plants, and certain well defined charging and discharging areas.

After every job is completed, housekeeping should be done diligently to remove all tripping hazardous and unnecessary scrap that could be hazard in the work place. It is very important to keep the work area tidy from debris and from the materials and substances that are part of the everyday work process. One of the most common findings in workplaces is poor housekeeping i.e. untidiness, disorder, poor storage of materials and stock (Ness, 2015).

This study highlights that there should be excellent controls when working at heights, fall arresters, safety harness, three point contact must be respected at the time. The inspection of fall arrester, safety harness should be done all the time before the safety equipment is used. Work at heights means work in any place where, if there were no precautions in place, a person could fall a distance liable to cause personal injury. Employers and those in control of any work at height activity must make sure work is properly planned, supervised and carried out by competent employees.

The most obvious danger is that what goes up usually comes down and not always in the fashion we plan it. If a load falls, it can quickly break and split, becoming a series of injurious and deadly projectiles. It is discouraged in this study that employees can position themselves under suspended loads. This is considered as one of the root causes for serious health and safety incidents.

Engineers and all technical employees should improve design integrity in all new projects in the work place. Design integrity is assurance and verification function that ensure a product, process, or system meets its appropriate and intended requirements under stated operating conditions (Hardy, 2013).

7.3.7 Process Hazard Analysis Enablers

According to Hardy (2013) process hazard analysis is defined as a systematic approach for identifying, evaluating and controlling the hazards of processes involving highly hazardous chemicals. This study also encourages organisations to have comprehensive process hazard analysis before engineering changes are made to the existing facility and that these changes should go through a comprehensive management of change.

7.3.8 Permit to Work Enablers

According to Karthika (2013) normally all maintenance, repair, construction work shall be carried out with a proper work permit. Jobs where work permit is required include but not limited to following, namely, major and minor maintenance work, inspection, construction, alteration, any hot work (including use of normal battery driven equipment in operating areas), entry into confined space, excavation, vehicle entry into process areas, work at height, handling of materials using mechanised means in operating areas, erecting and dismantling of scaffolding and radiography.

This research reveals that before excavation or entering a trench one should obtain authorisation and that all work activities should not proceed if there is no valid permit to work required for the job signed by the correct authority. It is emphasised in this research that all safety critical equipment should be disabled or put on override with permission from the authorities. It is vital that all organisations should have effective management system to manage working in confined space and that permission should be given by the correct authorities.

7.4 Summary

This chapter discussed the results of the model fit and the hypotheses in relation to existing literature. The next chapter summaries the conclusion on the key findings of the research study in relation to the research objectives. The next chapter will also highlight the key contributions to knowledge and the implications for research and petrochemical industry practices. The limitations of the research study will be outline in the next chapter. It will also share the recommendations to guide the senior management team of petrochemical industries as to which factors should be prioritised to improve health and safety towards a generative culture.

CHAPTER EIGHT

Recommendations and Conclusion

8.1 Introduction

This study adopted a positivism paradigm in order to achieve the research objective by carrying out an extensive literature review and questionnaires were distributed, collected and analysed via SPSS version 25 and AMOS using path modelling. The chapter concludes the research effort by analysing how each chapter has contributed towards addressing the research questions. This chapter summarises the key findings of the study, extrapolates from the research findings, draws conclusions and makes recommendations for future research. The limitations of the study were outlined and recommendations were put forward to guide petrochemical industry senior management.

8.2 Key Research Findings and Conclusions

The findings and conclusions for each research questions are as follows:

1. What deficiencies exist in process health and safety management systems when dealing with hazardous chemicals?

This study has explored the process health and safety management systems to identify the deficiencies that require senior management's attention. The key findings in relation to the research questions are as follows. The key process health and safety management deficiencies to be prioritized for an effective process health and safety management system are, namely;

- Poor engineering design integrity.
- Poor controls when working with suspended loads.
- Poor controls when working at heights.
- Poor housekeeping.
- Poor controls of source of ignition.
- Verifying energy isolation before start working on equipment.
- Poor health and safety risk assessments.
- Effective handling of hazardous chemicals.
- Human error.
- Fatigue management for both permanent employees and contractors.

The objectives addressed in this section are to identify health and safety hazards and describe the awareness of occupational health and safety hazards to the employees in the petrochemical industry, to test the effectiveness of the existing process health and safety management systems in petrochemical industry and to review the process health and safety management systems within industries where hazardous chemical substances are being used and identify the deficiencies.

2. How should the major deficiencies be prioritised by top management to prevent process health and safety incidents when handling hazardous chemicals?

It is evident in Table 8.1 that engineering design integrity ranked highest out of the ten statements identified as process health and safety deficiencies. Further, it is revealed that working with suspended loads ranked second highest. working at heights, housekeeping, controls of source of ignition, energy isolation before start working on equipment, health and safety risk assessments, contractors knowing how to handle of hazardous chemicals, human error and fatigue management were ranked 3rd to 10th within the key process health and safety management deficiencies.

Table 8.1 Deficiencies Ranking

Process Health and Safety Deficiencies	Ranking
Engineering design integrity	1
Working with suspended loads	2
Controls when working at heights	3
Housekeeping	4
Controls of source of ignition	5
Energy isolation before you start working on equipment	6
Health and safety risk assessments	7
Contractors knowing how to handle hazardous chemicals	8
Human error	9
Fatigue Management	10

The objective addressed in this section is the one to assess the existing process health and safety management systems deficiencies and prioritise the major deficiencies that need urgent senior management's attention.

3. What are the critical drivers to achieve generative health and safety culture?

This study has explored the process health and safety management systems to identify the drivers towards generative process health and safety culture. The key process health and safety drivers to be prioritized for generative process health and safety culture are, namely;

- Leadership Commitment
- Chemical Exposure Management
- Health and Safety Risk Assessment
- Process Hazard Analysis
- Permit to Work

The objective addressed is to identify critical drivers to achieve generative process health and safety culture;

Table 8.2 Generative Process Health and Safety Culture Toolkit (JX Nyawera Toolkit)

Generative Process Health and Safety Culture Toolkit		
Latent Variable	**Observed Variable**	**%**
Leadership Commitment (Each Score > 70% and Average Score > 80%)	Do we have excellent chemical exposure management systems? Is senior management prioritising health and safety? Do we have open door policy on health and safety issues? Do we have effective noise exposure management systems? Is senior management communicating health and safety policy to all employees? Is senior management allocating enough time to address health and safety concerns? Are employees undergoing a comprehensive health and safety training? Is senior management prioritising asset integrity of the plant?	
Chemical Exposure Management (Each Score > 80% and Average Score > 90%)	Are employees aware of all hazardous chemicals in their work environment? Do all employees know how to handle hazardous chemicals in their work environment? Do we have effective contractors on boarding management system that appreciates all hazardous chemicals? Do all contractors know how to handle hazardous chemicals in their work environment?	
Health and Safety Risk Assessment (Each Score > 85% and Average Score > 95%)	Do we do effective health and safety risk assessments at engineering design stage? Do we do effective health and safety risk assessments when employees are going to work at heights? Do we have effective controls to manage source of ignition? Do we have effective lock out tag out management systems? Do we have effective management systems for lifting objects? Do we have effective housekeeping management system? Do we have effective health and safety risk assessments done by competent people?	
Process Hazard Analysis (Each Score > 80% and Average Score > 90%)	Do we do comprehensive management of change (organisation and engineering changes)? Do we do comprehensive process hazard analysis before engineering changes are made?	
Permit to Work (Each Score > 85% and Average Score > 95%)	Do we have an effective permit to work management system? Do we have an effective excavation management system? Do we have an effective safety critical protective device management system? Do we have an effective confined space entry management system?	
Total Average Score	Total Average Score is recommended > 90% for the organisation to be considered to have a Generative Health and Safety Culture	

Table 8.2 proposes a management tool that could be used as a 'thermometer' for organisations to assess the state of their health and safety management systems with an intention to gauge themselves in terms of how close they are to a generative health and safety culture. The percentages are merely suggestive of what could be used to give an indication of just where the organization might be at a given point in time and the particular areas that were deficient and needed attention to improve the prevailing health and safety culture within the organization. The generative process health and safety culture toolkit is recommended to be used by experienced employees with more than 15 years in the industry that would appreciate what was being examined within the organization and its processes. The same tool would be used to evaluate the effectiveness of interventions introduced as a result of a previous assessment. In this way the tool would be part of an iterative and evaluative process of continuous improvement.

8.3 Proposed Generative Process Health and Safety Culture Model

The proposed process health and safety model to improve organizational culture towards a generative process health and safety culture is shown in Figure 8.1.

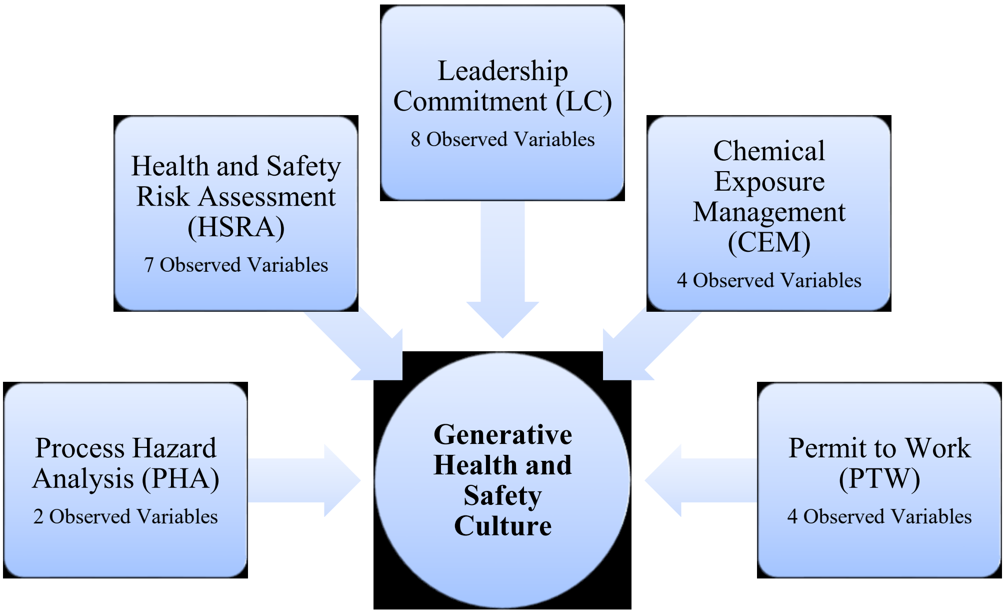

Figure 8.1 Generative Process Health and Safety Culture Model (JX Nyawera Model)

Leadership commitment had eight enablers, namely;

- Communication of Health and Safety policy to all employees;
- Senior Management to prioritise Health and Safety;
- Excellent chemical exposure management systems;
- Senior management to allocate enough time to address Health and Safety concerns;

- Senior Management has an open door policy on Health and Safety issues;
- Effective noise exposure management systems;
- Comprehensive training on health and safety; and
- Senior management to prioritize mechanical/asset integrity.

Chemical exposure management had four enablers, namely;

- Employee's knowledge of how to handle hazardous chemicals;
- Awareness of hazardous chemicals;
- Contractor's on boarding to appreciate all hazardous chemicals; and
- Contractor's knowledge of how to handle hazardous chemicals.

Health and safety risk assessment had seven enablers, namely;

- Engineering design integrity;
- Controls when working with suspended loads;
- Controls when working at heights;
- Housekeeping;
- Controls of source of ignition;
- Verifying energy isolation before start working on equipment; and
- Health and safety risk assessments.

Process hazard analysis had two enablers, namely;

- Comprehensive process hazard analysis before engineering changes are made; and
- All engineering changes undergo a comprehensive management of change.

Permit to work latent construct had four enablers, namely;

- Obtain authorization before you start excavation or entering a trench;
- A valid permit to work has been signed by the authorities;
- All safety critical equipment is disabled with permission from the authorities; and
- Effective management systems to manage working in confined space.

8.4 Contribution of the Research

This section focuses on the contributions of this thesis. The section is divided into three subsections that address its contribution to theory, methodology and practice.

8.4.1 Theoretical Contribution

The study offers an innovative analytical and methodological approach to assessment of process health and safety culture. The thesis is part of the larger discussion of increasing importance in health and safety policymaking. This study aims at contributing to the literature in the field of health and safety by incorporating management deficiencies that require senior management's attention and the drivers towards a generative process health and safety culture. It offers an innovative methodology in assessing petrochemical industry performance in health and safety.

8.4.2 Methodological Contribution

Methodological contribution lies in the experience gained through the application of a positivist approach and techniques applied for data collection. The other methodological contribution relates to the appropriateness of applying theoretical concepts and theories developed in other contexts. The successful use of these theories in this study contributes towards providing examples of the positivism research approach. The study contributes methodologically the five drivers and ten main deficiencies that require senior management's undivided attention. The research employed reliability measures and validity to ensure that the research instruments were consistent and valid.

8.4.3 Practical Contribution

One of the practical contributions of this research is the comprehensive awareness provided by the review of the literature as part of this study. The literature review revealed that senior management needed to acquire new skills in improving the health and safety culture in the petrochemical industry. The contribution of this research is to understand, based on theoretical assumptions, how the health and safety improvement could be institutionalised in an organisation and how it might contribute to 'happy' employees. The developed model can be used as a practical tool.

The research proposed a path model to improve health and safety culture towards generative health and safety where the whole organisation appreciates that health and safety systems is the way that business is and should be done in the organization. The path model in this research supported five latent constructs that were found to be drivers towards a generative process health and safety culture. There were ten deficiencies in the existing management system that required the undivided attention of senior management to improve health and safety towards the goal of a generative process health and safety culture.

8.5 Limitations of the Research

There are limitations to this study. The proposed conceptual model has been tested and validated by gathering data and information from the key petrochemical industry stakeholders that are responsible for production, technical services, maintenance, health, safety and environment, turnarounds and engineering projects. Due to self-reported methods of data collection, there is a probability of bias existing in the results of the study. The limitations associated with self-reporting include honesty in response or social desirability, introspective ability of participants, question understanding, interpretation of the rating scale and respondent response bias. It is possible that the research sample may differ significantly from the general population of interest even though there was no evidence found to suggest so.

The sample was based on a convenient sample. The research has some limitations on external validity and so may not be entirely generalizable beyond the research sample. The research is based on survey instrument which was designed by the authors and so have not been broadly validated. The reliability and validity of the research instrument may be questioned as it was not adequately assessed for face validity through a panel of experts. Predictive and constancy were not assessed.

Common method bias might have occurred due to the data gathered from the questionnaire being self-assessed even though considerations were given to avoid bias when devising the questionnaire. Different participants might have had different interpretations about the statements assessed. In spite of this limitation, this study provides empirical support for the conceptual research model showing the relationships between observed variables, latent variables and generative health and safety culture. This builds a foundation for further studies.

The scope of information gathering for this research was limited to South Africa KwaZulu-Natal province and data collection is from the petrochemical industry. This research was limited to only petrochemical industry. However, the theoretical principles and methodologies on which the study was based are general and can be applied to other industries. The potential limitations of this study and hence the suggestions for future studies need to be addressed. The data set may be a good representation in this context only. Although the study attempts to encompass as much about process health and safety management systems, potential limitations do exist due to not assessing all health and safety management systems.

This study was based entirely on quantitative research data. A mixed methods approach would have provided a check on the validity of the findings by comparing results from a qualitative data source. The proposed generative health and safety model was not validated by testing too establish its effectiveness when used.

8.6 Suggestions for Future Research

The following suggestions are made for possible future studies.

- It is not clear from literature how the organisations are assessed for placement in the five levels in the health and safety culture ladder. Therefore, a standard check list assessment tool will be a great contribution to health and safety culture.
- Using the findings of this study as a starting point, future studies could repeat the research with broader populations, which would assist in generalisability of the findings.
- The research only considered petrochemical industry. Further study should increase the scope to other construction industries.
- This study was positivist. Future research studies could use mixed methods in order to obtain a greater perspective on the topic. A different methodology may be used to validate results from this study.
- Further research could be conducted on the hypothesized relationships that were rejected.
- This research could be used as a basis for organisations to improve the health and safety culture to generative culture.
- This research could be used where the application of the model is assessed for generative health and safety culture.

8.7 Conclusion

A generative process health and safety culture model was developed from an extensive literature review. It was theorised that five drivers, namely, Leadership Commitment, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis and Permit to Work had a positive influence towards improving process health and safety culture. It was also theorised that the main deficiencies that require senior management’s attention to improve health and safety culture towards generative culture level five are, namely, Poor engineering design integrity, Poor controls when working with suspended loads, Poor controls when working at heights, Poor housekeeping, Poor controls of source of ignition, Verifying energy isolation before start working on equipment, Poor health and safety risk assessments, Effective handling of hazardous chemicals, Human error and Fatigue management for both permanent employees and contractors.

The petrochemical industry is still considered as major hazardous installation that needs senior management team to advance health and safety culture by prioritising it at all cost. Security, affordability and sustainability remain the most fundamental trilemma for individuals, organisations, nations and the world.

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APPENDICES

Appendix 1 (Ethical Clearance Approval)

UNIVERSITY OF KWAZULU-NATAL ™
INYUVESI YAKWAZULU-NATALI

28 November 2018

Mr James Xolani Nyawera (953013647)
School of Engineering
Howard College Campus

Dear Mr Nyawera,

Protocol reference number: HSS/1094/018D
Project title: The study of process Health and Safety Management dificiencies relative to hazardous chemical exposure

Approval Notification – Expedited Application

In response to your application received on 23 July 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....
Professor Shenuka Singh (Chair)

/ms

Cc Supervisor: Professor Theo C Haupt
cc Academic Leader Research:
cc School Administrator: Ms Nombuso Dlamini

Humanities & Social Sciences Research Ethics Committee
Professor Shenuka Singh (Chair) / Dr Shamila Naidoo (Deputy Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

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Appendix 2 (Research Instrument)

University of KwaZulu-Natal

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

Dear, Sir/Madam

Researcher: James Xolani Nyawera (Cell No. 082 5577 802)
Emails: james.nyawera@engenoil.com and jxnyawera@gmail.com

Supervisor: Prof Theo C Haupt (Phone No. 0312602712)
Emails: haupt@ukzn.ac.za, pinnacle.haupt@gmail.com

My name is **James Xolani Nyawera**, a Ph.D. Candidate at the College of Agriculture, Engineering and Science in the University of KwaZulu-Natal, Howard College. My contact details and my supervisor's details are declared above. You are being invited to consider participating in a research study that is entitled **"the study of process health and safety management deficiencies relative to hazardous chemical exposure".**

The aim and purpose of this research is to review the process health and safety management systems within industries where hazardous chemical substances are being used and identify the deficiencies. The study will test the effectiveness of the existing process health and safety management systems in this industry and prioritize the major deficiencies that need urgent senior management's attention. The study is expected to enroll about 150 participants. The research will be conducted in a systematic way in Petrochemical Industry and will be limited to Durban employees in KwaZulu-Natal. Sample population will be selected randomly and will focus on the private sector fulltime employees. The study will be used to answer the research questions using this questionnaire as the research instrument. Research approach is quantitative methodology, and a model will be developed and validated. The duration of your participation if you choose to enroll and remain in the study is expected to be only to answer the research questionnaire (20 - 30 minutes). If you have any questions or concerns about completing the questionnaire or about participating in this study, you may contact me or my supervisor at the numbers listed above. We hope you will take the time to complete this survey.

There is absolutely no risk and or discomforts. There are no direct benefits to the participants/respondents, however the petrochemical industry will benefit in understanding management deficiencies better and close the gaps, employees will be far less exposed to process health and safety incidents. This research may consider interviews incase potential respondents/participants are not comfortable in answering research questionnaire.

The final thesis will not be allowed to be on loan from the library for a period of 5 years. The thesis will be store in the university for 5 years with access control. There will be no organization and individual names mentioned in the research documents. The research questionnaire answers will be shredded after 5 years of the final report approval. There will be no feedback to the research participants, unless it is requested, an electronic copy will be sent to those that ask for it, after all approvals from authorities have been granted.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (Approval Number). In the event of any problems or concerns/questions you may contact the researcher at provided contact details above or the UKZN Humanities and Social Sciences Research Ethics Committee, contact details are as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Sincerely

James Xolani Nyawera

Signature____Date_________________

CONSENT

I ____ the undersigned have read and understand the above information. I hereby consent to participate in the study outlined in this document. I understand that participation is voluntary and that I may withdraw at any stage of the process. I will not incur any penalties or loss of treatment. I will verbally notify the researcher in case I decide to withdraw and that will be enough. I will incur no incentives or reimbursements as a result of participation in the study. If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher: James Xolani Nyawera (Cell No. 082 5577 802 or jxnyawera@gmail.com). If I have any questions or concerns about my rights as a study participant or if I am concerned about an aspect of the study or the researchers then I may contact: HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION in the address provided above.

Participant's Signature____________________________________ Date________________

Questionnaire

Respondent's Particulars Questions

1. Gender.

Male	Female

2. Age.

3. Marital Status.

4. Years of service in a Petrochemical Industry.

5. Department

Health, Safety and Environment	Operations	Maintenance	Technical	Others (Specify Below)

Please indicate on scale where 1 = Strongly Agree; 2 = Agree; 3 = Neutral; 4 = Disagree and 5 = Strongly Disagree, the extent to which you agree with the following statements:

Statements	1	2	3	4	5
6. My organization has excellent chemical exposure management systems.					
7. Senior Management prioritises Health and Safety in my organisation.					
8. Senior Management has an open door policy on Health and Safety issues.					
9. There are effective noise exposure management systems in my organization.					
10. Senior Management communicates Health and Safety policy to all employees.					
11. Senior Management allocates enough time to address Health and Safety concerns.					
12. Most employees are aware of hazardous chemicals in their work environment.					
13. Employees undergo comprehensive training on health and safety in my organization.					
14. Most permanent employees know how to handle hazardous chemicals in the work place.					
15. Contractor's on boarding appreciates all hazardous chemicals in my organization.					
16. Most contractors know how to handle hazardous chemicals in my organization.					
17. Senior management prioritizes mechanical/asset integrity of our processing plant.					

Please indicate on scale where 1 = Strongly Agree; 2 = Agree; 3 = Neutral; 4 = Disagree and 5 = Strongly Disagree, the extent to which you agree with the following statements:

Statements	**1**	**2**	**3**	**4**	**5**
18. The organization communicates effectively all lessons learned after the occupational health and safety incidents.					
19. The organization closes all corrective action items effectively after the root causes analysis for all incidents happening onsite.					
20. In my organization all engineering changes undergo a comprehensive management of change.					
21. The organization does comprehensive process hazard analysis before engineering changes are made.					
22. The organization has all process health and safety information available to all employees.					
23. Most of the health and safety incidents are due to poor engineering design integrity.					
24. In my organization we have a comprehensive pre-activity start up review and pre-activity shutdown review.					
25. Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.					
26. In my organization all work activities have a detailed operating procedure or work instruction.					
27. Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.					
28. All the work activities in my organization are done after a valid permit to work has been approved by the authorities.					
29. In my organization before you start excavation or entering a trench you need to obtain authorization.					
30. All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.					
31. In my organization all safety critical equipment is disabled with permission from the authorities.					
32. Most of the health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.					
33. My organization diligently manages fatigue in both permanent employees and contractors.					
34. My organization has all management systems in place to manage substance misuse.					
35. Most of the health and safety incidents are due to human error in my organization.					
36. My organization has effective management systems to manage working in confined space.					
37. Most of the health and safety incidents are due to poor controls in place when working with suspended loads.					
38. Poor housekeeping in my organization is the cause for many health and safety incidents.					
39. Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.					
40. Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry.					

Appendix 3 (Publication 1)

ASOCSA2018 - ASOCSA 12 – 46

Process Health and Safety Management Elements: An initial review of literature

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ABSTRACT AND KEYWORDS

Purpose: There are management systems to prevent health and safety incident from taking place in the petrochemical industry but incidents still happen, people get injured, assets get damaged and environment is polluted. The aim of the study was to assess the existing process health and safety management systems and identify elements that require senior management's vigilant attention. **Design/Methodology/Approach**: This research used literature review and the methodology is qualitative. The research approach is inductive. **Findings/Observations**: The ten key process health and safety management elements from literature to be prioritized for an effective process health and safety management system are, namely Leadership Commitment, Training and Competency, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Process Health and Safety Information, Operating Procedure, Control of Ignition Source, Control of Confined Space Entry and Permit to Work. **Research Limitations:** Only petrochemical industry was considered in this literature review. The next phase in this study will be to determine the extent of the application of the key elements outlined in the literature within the petrochemical industry in KZN province. **Value of Paper:** Paper presents ten key process health and safety management elements to the petrochemical industry.

Key words: Process Health and Safety Management Elements.

1. INTRODUCTION

Process health and safety management systems are a proactive management and engineering approach to control risk of failures and errors by reducing chance of human error and protecting employees, contractor employees, environments and assets from the risks associated with hazardous chemicals, but incidents still happen, people get injured, assets get damaged and environment is polluted. According to Cooper (1998) an organisation that has a good health and safety culture consists of a strong senior management commitment, leadership and involvement in health and safety, better communications between all organisational levels, greater hazard control, good induction and follow up on health and safety training and an ongoing health and safety schemes reinforcing the importance of health and safety, including near miss reporting. Material substances, processes or circumstances which pose threat to health and well-being of workers in any occupation are termed as occupational hazards. The occupational and hazard is major issue in oil and gas extraction industry (Kulkarni, 2017). Occupational and process health and safety accidents can be reduced through effective preventative measures by investing on health and safety equipment, training and educating the employees, process design and machinery. In order to develop a good health and safety culture, attitude of the workers needs to be reoriented by applying best practices, good housekeeping, change in work culture, and work practices (Beriha *et al.,* 2012). The most important indicator of a positive health and safety culture is the extent to which employees are actively involved in health and safety on a daily basis (Cooper, 1998).

The present study was conducted by reviewing petrochemical industry health and safety literature with the aim to assess the existing process health and safety management systems and identify the top ten elements that require senior management's further vigilant attention to reduce process health and safety incidents in the petrochemical industry.

2. LITERATURE REVIEW

The petrochemical industry as the name implies is based upon the production of chemicals from petroleum such as natural gas and crude oil. The occupational health and safety plays central role in industry as it protects all workers from health and safety related issues in their working environment. It is vital to protect workers from injuries on a social level, but there is also a positive economic impact in reducing health and safety hazards. Health and safety is without doubt, the most crucial investment and the question is not what it costs, but what it saves (Hughes and Ferret, 2007).

2.1 Leadership Elements

There are five leadership process health and safety elements namely leadership and commitment, training and competency, contractor management, asset integrity and effective communication. It is recognised that leadership is important in the creation of a culture that supports and promotes a strong health and safety performance of an organisation. According to Fuller and Vassie (2005) having senior managers who take a proactive interest in establishing a health and safety culture has been considered to be a key influence on organisational health and safety performance. It is imperative that leadership ensures that each employee is trained in an overview of the process and in the operating procedures, emphasis on the specific safety and health hazards, emergency operations including shutdown, and safe work practices applicable to the employee's job tasks. The other element that requires leadership's attention is contractor management, contractors working in petrochemical industry face a great risk during maintenance work. They are exposed to a number of inevitable hazards as most workers employed by contractors are unfamiliar with hazardous materials and more work performed under high pressure (Othman *et al.,* 2014).

It is the duty of the leadership team to ensure assets are maintained effectively and are safe to be operated at all times. According to Hardy (2013) mechanical equipment must be maintained to ensure that it will continue to operate correctly and safely. Process health and safety management standards require that an organisation establish and implement written procedures for maintaining equipment such pressure vessels, storage tanks, piping systems, pressure safety valves, emergency shutdown systems, and controls (monitoring devices, sensors, alarms and interlocks). An effective quality assurance program must be implemented to assure conformance to standards and codes, identify and record deficiencies and confirm that deficiencies have been corrected (Hardy, 2013). The last element is effective communication from all levels in an organisation. It is vital that information feedback is available to the right people at the right time and that means an effective communication system needs to be in place (Cooper, 1998).

2.2 Health and Safety Elements

Process health and safety elements include chemical exposure management, health and safety risk assessment, incident investigation, emergency response and audit compliance. The management of health and safety at work requires employers to make a suitable and sufficient assessment of the health and safety risks to employees and non-employees, arising from their work activities. It must be noted though that health and safety incidents still happen in the work place and it is important to investigate those incidents and appreciate root causes so that corrective actions can be assigned to employees that will close them. The intention is to prevent the similar incidents from happening again. According to Bond (2007) the sole objective of the investigation of an accident or incident under regulations shall be the prevention of accidents and incidents. Such incidents include those that could be called a near miss and incident or problem investigation should be factored back into the hazard analysis. According to Hardy (2013) organisations must plan for an emergency and be prepared to respond. As an absolute minimum, employers must develop an emergency action plan that includes evacuation and shelter in place instructions and training in the use of personal protective equipment. Audit compliance is a proactive attempt to identify gaps to comply and intervene when non-compliance is ascertained. Compliance audits provide a means for assuring that the procedures and practices in process health and safety management systems are being followed and are adequate (Hardy, 2013). The other potential topics to be considered under process health and safety when dealing with hazardous chemicals are noise exposure management, substance misuse and fatigue management.

2.3 Technical Elements

Four technical elements are important, namely, management of change, process hazard analysis, process health and safety information and human factor. To prevent or minimize process health and safety incidents in a petrochemical industry process hazard analysis is conducted by a team with expertise in engineering and process operations, including at least one employee who has experience and knowledge on the system. These process hazard analyses require process health and safety information to be clear and understood by all team members involved. According to Tzou *et al*. (2004) managing health and safety related information inadequately has been cited as a significant factor to industrial accidents. Accidents can take place even where process health and safety management systems exist and the probability of such occurrence increase if documentation is deficient.

Health and safety issues cannot be tackled effectively without interference of employers with a particular pattern of behaviours as important criteria needed to change employee's behaviours (Zin, 2012). Employers and employees with good safety behaviour are particularly playing a significant role in achievement of safety compliance to occupational health and safety improvement in industry. According to Bond (2007) it is clear that in the vast majority of accidents or near misses employees were acting with the best intentions and did not expect a serious event to occur from their actions. It has to be accepted that to err is human but one can learn from these events and share with others the lesson learnt. Human error is not the sole cause of failure, but it is a symptom of a deeper trouble. Human error is the starting point of an investigation, not the end point. To do something about error, one must look at the system in which people work and focus must extend past "what occurred" to why do it occur (Bridger, 2015). Many accidents have resulted from small changes that did not appear to have an effect on health and safety prior to the incident (Hardy, 2013). These changes must be thoroughly evaluated to assure that health and safety in the process industry is maintained.

2.4 Operational Elements

Operational elements include pre-activity and shutdown reviews, operating procedure, control of ignition source, control of confined space entry and permit to work. Often accidents occur in the transition between operational phases, rather than when the process system is up and running in "steady state" mode. Start up and shutting down new and existing process systems can be hazardous because changes to design or operations may be made in real time to meet schedule temperatures and pressures, potentially introducing new hazards (Hardy, 2013). The other high risk operational activity in the petrochemical industry is the confined space entry. A confined space is an enclosed or partially enclosed area that is big enough for a worker to enter. It is not designed for someone to work in regularly, but workers may need to enter the confined space for tasks such as inspection, cleaning, maintenance, and repair. Confined spaces may contain hazardous atmospheres, including insufficient oxygen, toxic air, and an explosive atmosphere (Stojkovic', 2013).

In a petrochemical industry control of ignition sources is vital. Fire and explosion hazards prevention involves dealing with the elements of the fire triangle. They fall into three categories, namely absence of flammable atmospheres achieved by limited fuel quantities, control/avoidance of ignition sources and absence of flammable atmospheres by limiting the quantities of oxidant present (Puttick, 2008). A permit to work system is a formal written system used to control work that is potentially hazardous. According to Iliffe *et al.* (1998), many incidents in the petrochemical industry workplace are associated with maintenance works, which are typical controlled by permit to work. There are many other operational elements that may be considered when dealing with hazardous chemicals, such as working at heights, energy isolation, suspended loads, excavation and entering a trench, disabling safety critical equipment and use of correct personal protective equipment when handling hazardous chemicals.

The hearts and minds paper published by Shell Global Solutions International symposium in 2016, suggests that there is a health and safety culture ladder with five levels, namely pathological (level 1), reactive (level 2), calculative (level 3), proactive (level 4) and generative (level 5). Pathological culture level 1 is where nobody cares to understand why accidents happen and how they can be prevented and at generative culture level 5, health and safety is seen as a profit centre and it is how business is done. Reactive culture level 2 says safety is important, and people do a lot when there has been an accident while the proactive culture is where employees work safely because they intrinsically motivated to do the right things naturally. Level 3 is calculative where an organisation says there are management systems in place to manage all hazards.

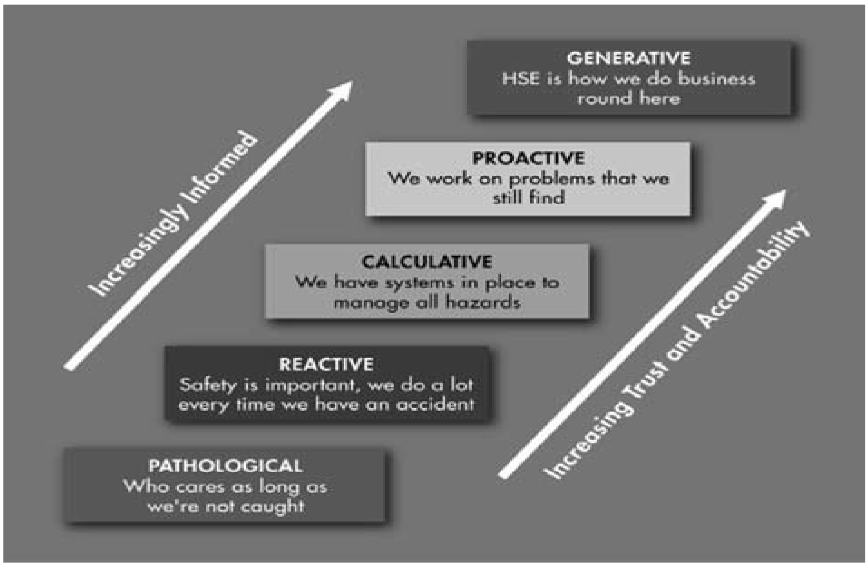

Figure 2.1 Health and Safety Culture Ladder
Adapted from Holstvoogd *et al*., 2006.

The health and safety culture ladder in Figure 2.1 shows the various levels of cultural maturity, and the change process required to achieve a lasting change in personal and organisational culture (Holstvoogd *et al*., 2006).

3. RESEARCH DESIGN AND METHODOLOGY

According to Crotty (1998) methodology is the strategy or plan of action which lies behind the choice and use of particular methods. Methodology is concerned with why, what, from where, when and how data is collected and analysed. Methodology asks the question "how can the researcher go about finding out whatever they believe can be known (Guba and Lincon, 1994)? Methods are the techniques and procedures used to collect and analyse data. The data collected will either be qualitative or quantitative. All paradigms can use both qualitative and quantitative data (Crotty, 1998). However, this paper has reviewed literature to determine the important elements to be considered in an effective process health and safety management system. The research methodology is qualitative and the research approach is inductive.

4. KEY OBSERVATIONS

The key ten process health and safety management elements from literature to be prioritized for an effective process health and safety management system are, namely Leadership Commitment, Training and Competency, Chemical Exposure Management, Health and Safety Risk Assessment, Process Hazard Analysis, Process Health and Safety Information, Operating Procedure, Control of Ignition Source, Control of Confined Space Entry and Permit to Work. It is not clear from literature how the organisations are assessed for placement in the five levels in the health and safety culture ladder hence a standard check list assessment tool will be a great contribution to health and safety culture.

5. CONCLUSION

Health and safety standards and regulations reasonably cannot cover all the possible cases for different types of works in a variety of hazards in a petrochemical industry. It is the duty of health and safety experts to share as much as they can on this subject of health and safety in the petrochemical industry that can expose employees and contractors to hazardous chemicals. The next phase in this study will be to determine the extent of the application of the key elements outlined in the literature within the petrochemical industry in KZN province.

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Appendix 4 (Publication 2)

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Process Health and Safety Management Deficiencies

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ABSTRACT AND KEYWORDS

Purpose: The study aims to investigate existing process health and safety systems to identify deficiencies that require senior management's attention to improve process health and safety to a generative culture level. **Design/Methodology/Approach**: A quantitative research methodology and deductive research approach was used, and questionnaire survey to collect the data. The targeted population was 800 employees in one major petrochemical enterprise in the KwaZulu-Natal province of South Africa. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants of which 259 were returned duly completed and used. They were statistically analysed using descriptive statistics (frequency of responses) in SPSS version 25. Ethical clearance to conduct the study was obtained from the University of KwaZulu - Natal Humanities and Social Sciences Research Ethics Committee (HSS/1094/018D). **Findings**: The results showed that the key process health and safety focus areas for an effective process health and safety management system are, namely, Effective handling of hazardous chemicals, Poor engineering design integrity, Poor controls when working at heights, Verifying energy isolation before start working on equipment, Fatigue management for both permanent employees and contractors, Poor controls when working with suspended loads, Poor housekeeping, Human error, Poor health and safety risk assessments, and Poor controls of source of ignition. **Research Limitations:** The study was conducted in South Africa (KwaZulu-Natal Province) and only the petrochemical industry was considered. **Value of Paper:** This study will assist senior management with a framework to reduce process health and safety incidents in the petrochemical industry. **Response to the Conference Theme:** Paper responds to Health and Safety.

Key words: Process Health and Safety Management Deficiencies.

1. INTRODUCTION

Many studies have been conducted on health and safety, attempting to improve health and safety in organisations. The workers in the oil and gas industry are exposed to many hazards, namely, physical hazards, chemical hazards, ergonomic hazards, psychosocial hazards and radiological hazards (Kim, 2016). The evolution of petroleum refining from simple distillation to today's sophisticated processes has created a need for health and safety management procedures and safe work practices (Kumar *et al.,* 2017). The International Labour Organisation (ILO) has estimated that 2 million workers die each year from work related injury and illness. According to Ezejiofor (2014) difficulties are encountered in obtaining information concerning occupational diseases and injuries in developing countries due to lack of comprehensive and harmonious data collecting systems. In 2002, in Sub-Saharan Africa alone, the ILO estimated more than 257,000 total work-related fatalities, including about 50,000 injuries. Previous studies have shown that the fatality rate in the petroleum industry is 2.5 times more than construction industry and 7 times more than general industry (Kulkarni, 2017).

The study aims to investigate the deficiencies in the existing process health and safety management systems that require senior management attention for the improvement of process health and safety systems in the petroleum industry. The research objective was to review the process health and safety management systems where hazardous chemical substances are being used and identify the major deficiencies.

2. COMPONENTS OF PROCESS HEALTH AND SAFETY MANAGEMENT SYSTEMS

There are several components that comprise the health and safety management systems used in the petrochemical industry. These components include leadership commitment and chemical exposure management, health and safety risk assessment and process hazard analysis, permit to work and operating procedures, training and competency, process health and safety information, control of confined space entry and ignition source. These are briefly discussed in the following sub-sections.

2.1 Leadership Commitment and Chemical Exposure Management.

According to Hardy (2013) it is recognised that leadership is important in the creation of a culture that supports and promotes a strong health and safety performance of an organisation Chemical process hazards at a chemical plant can give rise to accidents that affect both workers inside the plant and members of the public who reside nearby (Chen, 2016). The hazardous effect of chemicals comes through three ways, namely: fire, explosion and toxicity. The first essential step towards greater plant safety is being aware of the potentially dangerous properties of the substances, i.e. whether they are flammable, explosive or toxic (Almanssoor, 2008).

2.2 Health and Safety Risk Assessment and Process Hazard Analysis.

Risk assessment is the evaluation of hazards to determine their potential to cause an accident. According to Albert *et al.,* (2014) a critical component in safety risk management is to adequately identify hazards and mitigate its associated risk using safety program elements. According to Dabup (2012) the risk assessment provides a systematic approach for the identification, management and reduction of the risk to an acceptable level. According to Hardy (2013) process hazard analysis is defined as a systematic approach for identifying, evaluating and controlling the hazards of processes involving highly hazardous chemicals. A process hazard analysis must be conducted by a team with expertise in engineering and process operations, including at least one employee who has experience and knowledge on the system (Department of Labour [USA], 2016).

2.3 Permit to Work and Operating Procedures

The permit to work system has been widely used to ensure safety during maintenance and/or construction activities in almost every major hazard industry worldwide (Reddy and Reddy, 2015). According to Navadiya (2017) design of permit to work is very significant but most key thing is definition of roles and responsibilities of involved employees in procedure part and preparing checklist which is to be covered in synchronize way. The procedures should be formally reviewed and updated as necessary to assure that they are consistent with existing processes. Training must accompany these operating procedures, with an emphasis on what employees should do in case of emergency (Hardy, 2013).

2.4 Training and Competency

Improving organisational knowledge and knowledge management capabilities is an important means to prevent chemical accidents and improve organisations safety level (Chen, 2016). According to Hardy (2013), training provides employees with the knowledge and tools to fully understand the risks in working with hazardous chemicals. Health and safety knowledge encompasses awareness of occupational health and safety risks, including an evaluation of occupational health and safety programmes in an organisation (Okoye *et al.,* 2016).

2.5 Process Health and Safety Information

According to Tzou *et al.,* (2004) managing safety related information inadequately has been cited as a significant factor to industrial accidents. Awareness on possible risk factors and knowledge on how to reduce these risk factors among workers and contractors will enhance site safety (Vitharana *et al.,* 2015).

2.6 Control of Confined Space Entry and Ignition Source

Confined spaces may contain hazardous atmospheres, including insufficient oxygen, toxic air, and an explosive atmosphere (Stojkovic', 2013). According to Karthika (2013) even though accidents can never be eliminated completely, employers can prevent many of the injuries and fatalities that occur each year. According to Puttick (2008) fire and explosion hazard assessment flammable and potentially flammable atmospheres must be identified and compared with the potential ignition sources present.

3. RESEARCH DESIGN AND METHODOLOGY

A quantitative research methodology and the deductive research approach in the form of questionnaire instrument was used to collect the data. According to Trochim (2006) quantitative research often translates into the use of statistical analysis to make the connection between what is known and what can be learned through research. The major advantage of this method is that it allows one to measure the responses of number of participants to a limited set of questions, thereby facilitating comparison and statistical aggregation of the data (Yilmaz, 2013). The deductive approach is concerned with developing a hypothesis (or hypotheses) based on existing theory, and the designing a research strategy to test the hypothesis. The study was conducted by distributing 400 questionnaires manually to the randomly selected potential participants within a single petrochemical organization and therefore considered to be a convenience sample. The targeted population was 800 employees. The employees to whom questionnaires were handed during health and safety talks and production meetings were then requested to remain behind for an explanation. The duly completed questionnaires were 259, and were analysed using descriptive statistics (frequency of responses) in SPSS version 25. The response rate was computed to be 64.75%. The observed variables was measure through a Likert scale where 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree and 5=Strongly Disagree.

4. FINDINGS

4.1 Demographics of Participants

Table 4.1 Age and Years of Service

	Minimum	Maximum	Median
Age	22	66	38
Years of Service	1	46	11

From Table 4.1 it is evident that the median age of participants was 38 with a minimum age of 22 years and a maximum age of 66 years. Further, the median number of years of service was 11 years with a minimum of 1 year and a maximum of 46 years. The participants were matured with considerable years of experience in the petrochemical industry. This aspect increases the reliability of the responses received from the participants in terms of their accuracy and completeness.

Table 4.2 Gender, Marital Status and Department

Gender	
	Percent
Male	80,6
Female	19,4
Total	**100,0**
Marital Status	
Single	37,2
Married	61,6
Divorced	1,2
Total	**100,0**
Department	
Health, Safety and Environment	8,2
Operations	50,6
Maintenance	24,1
Technical	12,5
Others	4,7
Total	**100,0**

Table 4.2 indicates that 80.6% of the participants were males, 61.6% were married and most of the respondents were from the Operations Department (50.6%), followed by the Maintenance Department (24.1%).The results show that the petrochemical industry in the case of the sample organization is still male dominated. Operations and maintenance generally have more employees that are exposed to health and safety risks in petrochemical industry.

Table 4.3 Latent Variables and Observed Variables Frequency Table

Latent Variables and Observed Variables	(Str Agree + Agree)%	Neutral%	(Str Disagree + Disagree)%
Leadership Commitment (LCH7) - Senior Management prioritises health and safety in my organisation.	93.4	4.3	2.3
LCH8 - Senior Management has an open door policy on health and safety issues.	88.4	9.3	2.3
LCH10 - Senior Management communicates Health and Safety policy to all employees.	96.9	1.9	1.2
LCH11 - Senior Management allocates enough time to address Health and Safety concerns.	88.4	9.3	2.3
LCH17 - Senior Management prioritises mechanical/asset integrity of our process plant	73.6	18.6	7.8
LCH38 - Poor housekeeping in my organisation is the cause for many health and safety incidents.	33.7	31.0	35.3
LCH40 - Audit compliance is an excellent practice to prevent most of health and safety incidents in the petrochemical industry.	87.3	9.3	3.4
Chemical Exposure Management (CEMH6) - My organisation has excellent chemical exposure management systems.	92.2	6.2	1.6
CEMH12 - Most employees are aware of hazardous chemicals in their work environment.	86.5	9.6	3.9
CEMH14 - Most permanent employees know how to handle hazardous chemicals in the work place.	84.9	12.8	2.3
CEMH15 - Contractor's on boarding appreciates all hazardous chemicals in my organisation.	62.4	32.1	5.5
CEMH16 - Most contractors know how to handle hazardous chemicals in my organisation.	43.8	40.3	15.9
CEMH30 - All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.	95.8	2.7	1.5
Health and Safety Risk Assessment (HSRAH9) - There are effective noise exposure management systems in my organisation.	88.8	8.5	2.7
HSRAH32 - Most of health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.	40.5	27.8	31.7
HSRAH33 - My organisation diligently manages fatigue in both permanent employees and contractors.	55.4	29.5	15.1
HSRAH34 - My organisation has all management systems in place to manage substance misuse.	88.0	8.5	3.5
HSRAH39 - Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry	46.1	22.1	31.8

Latent Variables and Observed Variables	(Str Agree + Agree)%	Neutral%	(Str Disagree + Disagree)%
Process Hazard Analysis (PHAH20) - In my organisation all engineering changes undergo a comprehensive management of change.	87.2	3.5	9.3
PHAH21 - The organisation does comprehensive process hazard analysis before engineering changes are made.	88.8	9.3	1.9
PHAH23 - Most of the health and safety incidents are due to poor engineering design integrity.	20.6	38.5	40.9
PHAH24 - In my organisation we have a comprehensive pre-activity start up review and pre-activity shutdown review.	93.8	4.6	1.6
Permit to Work (PTWH25) - Most of the health and safety incidents in petrochemical industry are due to poor controls when working at heights.	24.9	36.6	38.5
PTWH28 - All the work activities in my organisation are done after a valid permit to work has been approved by the authorities.	95.7	2.7	1.6
PTWH29 - In my organisation before you start excavation or entering a trench you need to obtain authorisation.	98.4	1.2	0.4
PTWH31 - In my organisation all safety critical equipment is disabled with permission from the authorities.	90.3	6.6	3.1
Training and Competency (TCH13) - Employees undergo comprehensive training on health and safety in my organisation.	86.1	9.7	4.2
TCH19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite.	80.7	15.4	3.9
TCH35 - Most of the health and safety incidents are due to human error in my organisation.	55.0	32.2	12.8
Process Health and Safety Information (PHSIH18) - The organisation communicates effectively all lessons learned after the occupational health and safety incidents	88.0	6.6	5.4
PHSIH22 - The organisation has all process health and safety information available to all employees.	90.0	8.1	1.9
Control of Confined Space Entry (CCSEH36) - My organisation has effective management systems to manage working in confined space.	93.0	4.3	2.7
CCSEH37 - Most of the health and safety incidents are due to poor controls in place when working with suspended loads.	28.7	29.8	41.5
Operating Procedure (OPH26) - In my organisation all work activities have a detailed operating procedure or work instruction.	91.5	5.8	2.7
Control of Ignition Source (CISH27) - Most of the health and safety incidents in petrochemical industry are due to poor controls of source of ignition.	34.1	31.4	34.5

The frequency of responses is shown in Table 4.3. These were used to determine the major deficiencies existing in process health and safety management systems when dealing with hazardous chemicals. The following formula was used to decide on main deficiencies (Strongly Agreed + Agreed < 60% , Neutral > 20% = Main Deficiencies). The cumulative percentages of both strongly agree plus agree and disagree plus strongly disagree were used to simplify the assessment of observed variables.

The key process health and safety management focus areas from Table 4.3 that have to be prioritized to minimise health and safety incidents are, namely, CEMH16 - Effective handling of hazardous chemicals

(43.8%, 40.3), PHAH23 -Poor engineering design integrity (20.6%, 38.5%), PTWH25 - Poor controls when working at heights (24.9%, 36.6%), HSRAH32 - Verifying energy isolation before start working on equipment (40.5%, 27.8%), HSRAH33 - Fatigue management for both permanent employees and contractors (55.4%, 29.5%), CCSEH37 - Poor controls when working with suspended loads (28.7%, 29.8%),. LCH38 - Poor housekeeping (33.7%, 31.0%), TCH35 - Human error (55.0%, 32.2%), HSRAH39 - Poor health and safety risk assessments (46.1%, 22.1%), and CISH27 - Poor controls of source of ignition (34.1%, 31.4%). Participants in this study reported low levels of satisfaction with these observed variables of health and safety in the petrochemical industry.

According Zohrabi (2013) one of the main requirements of any research process is the reliability of the data and findings. The reliability and validity of the data are vital for a research study. The Cronbach's Alpha is a high-quality test widely used for reliability testing and an essential test for evaluating a questionnaire instrument. Cronbach's Alpha test is a widely-used method to test the internal consistency of measurement indicators, based on the correlations between indicators.

Table 4.4 Reliability Test for Constructs

Latent Construct	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	7 (LCH7, LCH8, LCH10, LCH11, LCH17, LCH38, LCH40)	0.819
Chemical Exposure Management (CEM)	6 (CEMH6, CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.797
Health and Safety Risk Assessment (HSRA)	5 (HSRAH9, HSRAH32, HSRAH33, HSRAH34, HSRAH39)	0.435
Process Hazard Analysis (PHA)	4 (PHAH20, PHAH21, PHAH23, PHAH24)	0.776
Permit to Work (PTW)	4 (PTWH25, PTWH28, PTWH29, PTWH31)	0.718
Training and Competency (TC)	3 (TCH13, TCH19, TCH35)	0.481
Process Health and Safety Information (PHSI)	2 (PHSIH18, PHSIH22)	0.581
Control of Confined Space Entry (CCSE)	2 (CCSEH36, CCSEH37)	0.105
Operating Procedure (OP)	1 (OPH26)	N/A
Control of Ignition Source (CIS)	1 (CISH27)	N/A

Table 4.4 outlines the ten latent constructs with observed variables. Reliability test shows four latent constructs with acceptable Cronbach's alpha > 0.7 and four latent constructs with Cronbach's alpha < 0.7 and two latent constructs that were not computed due to one observed variable.

4.2 Principal Component Analysis

Confirmatory factor analysis was carried out to test whether the measure of latent construct correspond with the study of the nature of the individual factor. At this stage, the indicator elimination and model re-specification are performed for each latent construct. A common acceptable threshold value for a good indicator is having a loading higher than 0.5 (Rahman *et al.,* 2013).

Table 4.5 Principal Component Analysis

Rotated Component Matrix[a]					
Observed Variables	**Latent Variables**				
	PTW	**PHA**	**LC**	**HSRA**	**CEM**
Permit to Work (PTWH29)	0,779				
Permit to Work (PTWH28)	0,687				
Permit to Work (PTWH31)	0,661				
Permit to Work (PTWH36)	0,649				
Process Hazard Analysis (PHAH24)		0,630			
Process Hazard Analysis (PHAH22)		0,587			
Process Hazard Analysis (PHAH20)		0,564			
Process Hazard Analysis (PHAH21)		0,504			
Process Hazard Analysis (PHAH26)		0,586			
Leadership Commitment (LCH8)			0,726		
Leadership Commitment (LC10)			0,725		
Leadership Commitment (LCH11)			0,698		
Leadership Commitment (LCH7)			0,660		
Leadership Commitment (LCH13)			0,547		
Leadership Commitment (LCH9)			0,524		
Leadership Commitment (LCH17)			0,519		
Leadership Commitment (LCH6)			0,604		
Leadership Commitment (LCH40)			0,587		
Health and Safety Risk Assessment (HSRAH37)				0,833	
Health and Safety Risk Assessment (HSRAH32)				0,788	
Health and Safety Risk Assessment (HSRAH25)				0,785	
Health and Safety Risk Assessment (HSRAH27)				0,739	
Health and Safety Risk Assessment (HSRAH23)				0,690	
Health and Safety Risk Assessment (HSRAH38)				0,598	
Health and Safety Risk Assessment (HSRAH39)				0,573	
Health and Safety Risk Assessment (HSRAH33)				0,637	
Health and Safety Risk Assessment (HSRAH35)				0,769	
Chemical Exposure Management (CEMH30)					0,735
Chemical Exposure Management (CEMH16)					0,763
Chemical Exposure Management (CEMH15)					0,731
Chemical Exposure Management (CEMH14)					0,695
Chemical Exposure Management (CEMH12)					0,654
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.[a]					
a. Rotation converged in 6 iterations.					

Structural equation modelling combines multiple regression analysis and factor analysis together to analyse the relationship between measured variables and latent constructs or factors (Raykov, 2006). It provides a quantitative method to test a hypothesised model (Byrne, 2016). Structural equation modelling can be employed to capture complex relationships between one or more dependent variables that can be sourced from qualitative or quantitative data (Hox and Kleiboer, 2007).

According to Schreiber *et al.*, (2006) Confirmatory Factor Analysis and Structural Equation Modelling are statistical techniques that one can use to reduce the number of observed variables into a smaller number of latent variables by examining the covariation among the observed variables. In this research paper, there were three observed variables (OV) that were eliminated since the loading was less than 0.5 and they are namely, PHSIH18 - The organisation communicates effectively all lessons learned after the occupational health and safety incidents. TCH19 - The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite). HSRAH34 - My organisation has all management systems in place to manage substance misuse. Other observed variables were allocated to other latent variables after principal component analysis as indicated in Table 4.5.

Table 4.6 Reliability Test after Principal Component Analysis for Constructs

Latent Construct	No of Observed Variables	Cronbach's Alpha
Leadership Commitment (LC)	9 (LCH6, LCH7, LCH8, LCH9, LCH10, LCH11, LCH13, LCH17, LCH40)	0.867
Chemical Exposure Management (CEM)	5 (CEMH12, CEMH14, CEMH15, CEMH16, CEMH30)	0.781
Health and Safety Risk Assessment (HSRA)	9 (HSRAH23, HSRAH25, HSRAH27, HSRAH32, HSRAH33, HSRAH35, HSRAH37, HSRAH38, HSRAH39)	0.829
Process Hazard Analysis (PHA)	5 (PHAH20, PHAH21, PHAH22, PHAH24, PHAH26)	0.810
Permit to Work (PTW)	4 (PTWH28, PTWH29, PTWH31, PTWH36)	0.749

The five latent constructs for process health and safety culture in this study are, namely, Leadership Commitment (0.867), Chemical Exposure Management (0.781), Health and Safety Risk Assessment (0.829), Process Hazard Analysis (0.810) and Permit to Work (0.749), they all have Cronbach's Alpha > 0.7, and that confirms reliability of the data.

5. CONCLUSION AND RECOMMENDATIONS

The study investigated existing process health and safety systems by surveying a sample of employees in a petrochemical business enterprise in KZN province to identify deficiencies that required senior management's attention to improve process health and safety to a generative culture. It can be concluded that senior management has to increase attentiveness to handling of hazardous chemicals, engineering design integrity, controls when working at heights, verification of energy isolation before start working on equipment, fatigue management, controls when working with suspended loads, housekeeping, human error, health and safety risk assessments and controls of ignition sources to improve health and safety culture. It is recommended that industry develop process health and safety elements from the focus areas and to enforce compliance and intervention timely when there is non-compliance. It is recommended that the next phase in this study be to determine the key drivers to generative health and safety culture within the petrochemical industry.

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