Critical drivers towards generative process health and safety culture

James Xolani Nyawera
Department of Refinery Division,
Engen Petroleum Ltd., Durban, South Africa, and
Theodore Conrad Haupt
Department of Engineering, Mangosuthu University of Technology,
Scottburgh, South Africa

Received 6 May 2020
Revised 14 July 2020
Accepted 16 July 2020

Abstract

Purpose – This paper aims to report on the development of a model to improve process health and safety within the context of a petrochemical environment to achieve a generative health and safety culture within that sector.

Design/methodology/approach – A quantitative research methodology and deductive research approach were used in the study. A survey was conducted in a major petrochemical enterprise in the KwaZulu-Natal province of South Africa with 259 returned and duly completed questionnaires. The data was statistically analysed using statistical packages for social science version 25.

Findings – This study found that the key process health and safety critical drivers needed to grow a generative process health and safety culture were leadership commitment, chemical exposure management, health and safety risk assessment, process hazard analysis and permit to work.

Research limitations/implications – This study was conducted in the KwaZulu-Natal Province of South Africa within the petrochemical industry. Because of self-reported methods of data collection, there is a probability of bias existing in the results of the study.

Practical implications – The contribution of this research is to understand, based on theoretical assumptions, how health and safety improvement could be institutionalised in an organisation. The developed model can be used as a practical tool.

Social implications – This paper is part of the larger discussion of increasing importance in health and safety policy-making. This study aims at contributing to the literature in the field of health and safety by incorporating the drivers towards a generative process health and safety culture.

Originality/value – This study provides a model to assist senior management to reduce exposure to process health and safety hazards in the petrochemical industry and improve overall performance.

Keywords Process, Health, Safety critical drivers

Paper type Research paper

The corresponding author would like to thank the Almighty GOD for granting him the power, courage and wisdom to finish this study. The author would also like to express his deep sense of gratitude to Professor Theodore Conrad Haupt, for providing his treasurable advice, recommendations and guidance to complete this journal paper.

THANK YOU to all the participants in this research, may GOD bless you and your families. The author is grateful to his wife, Dr Bongiwe Pepu, for her support, understanding and allowing him to work extra hours. In addition, the author is thankful to his sons Mfundo Nyawera and Nkazimulo Nyawera, his daughters Sandiswa Nyawera and Khwezilokusa Nyawera for providing him invaluable pleasure and amusement. You are AWESOME and HE LOVE YOU.

Journal of Engineering, Design and Technology
Vol. 19 No. 2, 2021
pp. 385-411

1726-0531
DOI 10.1108/JEDT-05-2020-0165

1. Introduction

Worldwide, oil and gas resources provide some of the richest and most valuable energy sources available (Kim, 2016). According to Eyayo (2014), the importance of occupational health and safety is often neglected and people tend to equate occupational illness with industrialisation and huge factories in urban areas. Occupational health and safety play a significant role in the industry as it protects all workers from health and safety-related issues in their working environment (Hughes and Ferret, 2007). The workers in the oil and gas industry are exposed to a substantial amount of hazards, namely, 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 exposure to health and safety hazards (Hughes and Ferret, 2007). According to Eyayo (2014), globally, there are 2.9 billion workers who are exposed to hazardous risks at their workplace. 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 are without a doubt, the most crucial investment that an organisation should make and the question is not what it costs, but what it saves (Hughes and Ferret, 2007).

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 towards 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 that may be toxic, reactive, flammable or explosive or may exhibit a combination of these properties (OSHAcademy, 2017).

Against this background, this paper reports on a study that sought:

- To evaluate the effectiveness of the existing process health and safety management systems in the petrochemical industry.
- To identify critical drivers to achieve a generative health and safety culture within that industrial sector.

2. Literature review

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). 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 to a six-year fatal occupational injury 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. The petrochemical industry releases 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).

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). According to Ezejiofor (2014), for many occupational toxicologists, industrial hygienists and others with a stake in the field of occupational health and safety, the safety of the workplace has always been a major concern.

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). 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. 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 daily.

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). 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. According to Albert, Hallowell, and Kleiner (2014), occupational safety has gained considerable attention following the Occupational Safety and Health Act, which shifted substantial health and safety responsibility to employers. Employers must develop and implement written operating procedures that provide clear instructions for safely conducting operations and maintenance (Hardy, 2013).

A critical part of any safety and health programme 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 are categorised into a 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). It is impossible to eliminate all hazards, so the goal is to eliminate and/or control the hazards with high potential and to reduce the rest of the hazards to the lowest reasonable risk level to protect workers from harm (Dunbar, 2014).

2.1 Leadership commitment

It is imperative that leadership ensures that each employee is trained in an overview of the process and 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 the work plan is in place before the work is started on site (Spillane and Oyedele, 2015).

2.2 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). According to Elssayed *et al.* (2012), to commit top safety management and 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. 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).

2.3 Chemical exposure management

Chemicals can be classified on the bases 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). 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).

2.4 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 to prevent and control them is very imperative to the health and well-being of the workers (Eyayo, 2014). Hazard identification and risk assessment are carried for the identification of undesirable events that can lead to a hazard (Purohit *et al.*, 2018). According to Dabup (2012), risk assessment is a critical step in risk management and if done correctly, it determines the minimum level of preparedness to respond effectively by applying qualitative or quantitative techniques.

2.5 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. Commonly used study methodologies are hazard identification (HAZID), hazard and operability (HAZOP), What-If analysis, safety integrity level, failure mode and effects analysis and a layer of protection analysis. 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 because of energy sources, working conditions or activities performed (Purohit *et al.*, 2018).

2.6 Process health and safety information

According to Tzou *et al.* (2004), managing health and safety-related information inadequately has been cited as a significant factor in industrial accidents. Knowledge is more than information, as it involves an awareness or understanding gained through experience, familiarity or learning (Chen, 2016).

2.7 Operating procedure

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).

2.8 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.

2.9 Control of confined space entry

The other high-risk operational activity in the petrochemical industry is the confined space entry and it is defined as an enclosed or partially enclosed area that is big enough for a worker to enter (Stojković, 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.

2.10 Permit to work

A permit to work is a document that specifies the task to be performed, associated foreseeable hazards and the safety measures (Reddy and Reddy, 2015). According to Navadiya (2017), the design of permit to work is very significant but the most key thing is the definition of roles and responsibilities of involved employees in the procedure part and preparing checklist, which is to be covered in a synchronised way. Effective implementation of a comprehensive permitting programme certainly helps to prevent 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 the procedure of permit to work help actual work to be smooth and without miss understanding that may further lead to an accident (Navadiya, 2017).

3. Research design and methodology

The deductive approach is concerned with developing a hypothesis (or hypotheses) based on existing theory, and 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.

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.

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 several participants to a limited set of questions, thereby facilitating comparison and statistical aggregation of the data (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. Qualitative research is often said to use inductive thinking or induction reasoning, as it moves from specific observations about individual occurrences to broader generalisations and theories (Creswell, 2005). Quantitative research and deductive research approach were used in this research.

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 generalisation of the results with the help of statistical methods (Williams, 2011). Interpretive researchers start with the assumption that access to reality is only through social constructions such as language, consciousness and shared meanings (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).

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).

The study was conducted by manually distributing close-ended questionnaires to 400 randomly sampled potential participants in a large petrochemical organisation that employed more than 800 employees and could, therefore, be considered to be a convenient sample. The employees to whom questionnaires were handed during health and safety talks and production meetings were then requested to remain behind for an explanation. 259 questionnaires were returned duly completed and used. The response rate was, therefore, computed to be 64.75%.

Statistical packages for social science (SPSS) version (25) was used to analyse the data collected. The research applied the structural equation modelling (SEM) technique and used SPSS AMOS version (25) tools to test the hypotheses among the variables in the model. SEM is a statistical technique that allows the researcher to examine multiple interrelated dependence relationships in a single model. SEM 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, mean and standard deviation.

According to Hair *et al.* (2010), 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).

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 GOF of the proposed model to the empirical data set. Without this GOF 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.

$$n \geq 50r^2 - 450r + 1100 \tag{1}$$

where:

n= number of samplesr is the ratio of indicators to latent constructs.

Using equation (1), the minimum number of samples for this research was calculated as 138 with 35 being the number of observed variables and 10 latent constructs as shown in observed variables statements.

3.1 Latent variables and observed variables

(1) *Leadership Commitment* (LCH7) – Senior Management prioritises health and safety in my organisation.
- LCH8 – Senior Management has an open-door policy on health and safety issues.
- LCH10 – Senior Management communicates Health and Safety policy to all employees.
- LCH11 – Senior Management allocates enough time to address Health and Safety concerns.
- LCH17 – Senior Management prioritises mechanical/asset integrity of our process plant
- LCH38 – Poor housekeeping in my organisation is the cause of many health and safety incidents.
- LCH40 – Audit compliance is an excellent practice to prevent most health and safety incidents in the petrochemical industry.

(2) *Chemical Exposure Management* (CEMH6) – My organisation has excellent chemical exposure management systems.
- CEMH12 – Most employees are aware of hazardous chemicals in their work environment.
- CEMH14 – Most permanent employees know how to handle hazardous chemicals in the workplace.
- CEMH15 – The contractor's onboarding appreciates all hazardous chemicals in my organisation.
- CEMH16 – Most contractors know how to handle hazardous chemicals in my organisation.
- CEMH30 – All employees are aware that when you handling hazardous chemicals you need to use prescribed personal protective equipment.

(3) *Health and Safety Risk Assessment* (HSRAH9) – There are effective noise exposure management systems in my organisation.
- HSRAH32 – Most of health and safety incidents in the petrochemical industry are due to not verifying energy isolation before you start working on equipment.
- HSRAH33 – My organisation diligently manages fatigue in both permanent employees and contractors.
- HSRAH34 – My organisation has all management systems in place to manage substance misuse.
- HSRAH39 – Poor health and safety risk assessments are responsible for most of health and safety incidents in the petrochemical industry.

(4) *Process Hazard Analysis* (PHAH20) – In my organisation all engineering changes undergo comprehensive management of change.

- PHAH21 – The organisation does a comprehensive process hazard analysis before engineering changes are made.
- PHAH23 – Most of the health and safety incidents are due to poor engineering design integrity.
- PHAH24 – In my organisation we have a comprehensive pre-activity start-up review and pre-activity shutdown review.

(5) *Permit to Work* (PTWH25) – Most of the health and safety incidents in the petrochemical industry are due to poor controls when working at heights.

- PTWH28 – All the work activities in my organisation are done after a valid permit to work has been approved by the authorities.
- PTWH29 – In my organisation before you start excavation or entering a trench you need to obtain authorisation.
- PTWH31 – In my organisation all safety-critical equipment is disabled with permission from the authorities.

(6) *Training and Competency* (TCH13) – Employees undergo comprehensive training on health and safety in my organisation.

- TCH19 – The organisation closes all corrective action items effectively after the root cause analysis for all incidents happening onsite.
- TCH35 – Most of the health and safety incidents are due to human error in my organisation.

(7) *Process Health and Safety Information* (PHSIH18) – The organisation communicates effectively all lessons learned after the occupational health and safety incidents.

- PHSIH22 – The organisation has all process health and safety information available to all employees.

(8) *Control of Confined Space Entry* (CCSEH36) – My organisation has effective management systems to manage working in confined space.

- CCSEH37 – Most of the health and safety incidents are due to poor controls in place when working with suspended loads.

(9) *Operating Procedure* (OPH26) – In my organisation, all work activities have a detailed operating procedure or work instruction.

(10) *Control of Ignition Source* (CISH27) – Most of the health and safety incidents in the petrochemical industry are due to poor controls of the source of ignition.

The value of r in equation (1) is 35/10 = 3.5; then equation (1) evaluates $n = [(50 * 3.5^2) - (450 * 3.5) + 1{,}100] = 138$; this is less than the 259 samples used in this research (i.e. $259 > 138$). Therefore, qualifying the use of covariance-based structural equation modelling (CB-SEM) in place of partial least squares SEM (Westland, 2010; Zhao, 2017). The satisfaction of the 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.

4. Results

4.1 Demographic profile of participants

From Table 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 one year and a maximum of 46 years. The participants could, therefore, be 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 2 indicates that 80.6% of the participants were men, 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 suggest that in the case of the sample organisation the petrochemical industry is still male-dominated. Operations and maintenance generally have more employees that are exposed to health and safety risks in the petrochemical industry.

4.2 Quantitative data analysis

The observed variables were measured using a five-point Likert scale of responses to statements that were presented to the participants where 1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree and 5 = Strongly Disagree.

Table 3 shows the responses to statements and leadership commitment have LCH10 with a mean of 1.40 ranked highest out of the seven statements presented to the participants. Further, LCH 7 with a mean of 1.48 ranked second highest. Chemical exposure management has CEMH30 with a mean of 1.35 ranked highest out of the six statements presented to the participants. Further, CEMH6 with a mean of 1.62 ranked second highest. Health and safety risk assessment has HSRAH9 with a mean of 1.70 and a standard deviation of 0.737 ranked highest out of the five statements presented to the participants. Further, HSRAH34 with a mean of 1.70 and a standard deviation of 0.784 ranked second highest. Process hazard analysis has PHAH24 with a mean of 1.49 ranked highest out of the four statements presented to the participants. Further, PHAH21 with a mean of 1.70 ranked second-highest.

Age and years of service	Minimum	Maximum	Median
Age	22	66	38
Years of service	1	46	11

Table 1. Age and years of service ($N = 259$)

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 2. Gender, marital status and department ($N = 259$)

Table 3.
Observed variables
(N = 259)

Observed variables	Str agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Str disagree (%)	Mean	SD	Rank
Leadership commitment (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	8.53	25.2	31.0	26.4	8.9	3.02	1.103	7
Chemical exposure management (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
Health and safety risk assessment (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
Process hazard analysis (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
Permit to work (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
Training and competency (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

(*continued*)

Observed variables	Str agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Str disagree (%)	Mean	SD	Rank
Process health and safety information (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
Control of confined space entry (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
Operating procedure (OPH26)	55.2	36.3	5.8	2.3	0.4	1.56	0.741	1
Control of ignition source (CISH27)	10.5	23.6	31.4	25.2	9.3	2.99	1.133	1

Table 3.

Permit to work has PTWH29 with a mean of 1.20 ranked highest out of the four statements presented to the participants. Further, PTWH28 with a mean of 1.34 ranked second highest. Training and competence have TCH13 with a mean of 1.78 ranked highest out of the three statements presented to the participants. Further, TCH19 with a mean of 1.86 ranked second highest. Process health and safety information has PHSIH22 with a mean of 1.61 ranked highest out of the two statements presented to the participants. Further, PHSIH18 with a mean of 1.64 ranked second highest. Control of confined space entry has CCSEH36 with a mean of 1.46 ranked highest out of the seven statements presented to the participants. Further, CCSEH37 with a mean of 3.16 ranked second highest.

4.3 Categorisation of observed variables

Categorisation was considered in this study where a sum of both strongly agree and agree greater than 80% was classified as High, between 80% and 40% was classified as Medium and less than 40% was classified as Low.

It is evident in Table 4 in this study that 23 observed variables were categorised as High, 6 observed variables were categorised as Medium and 6 observed variables were categorised as Low. PTWH29 (obtaining authorisation before excavation or entering a trench) was the highest at 98.5% and PHAH23 (incident are due to poor design integrity) was the lowest at 20.6%.

4.4 Model fit

A range of established fit indices should be introduced to decide upon the GOF between the research model and empirical data. Broadly, fit indices can be classified into three categories, namely, overall model fit, GOF 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 statistical significance exists between the observed and estimated variance-covariance matrix (Bagozzi, 2010; Zhao, 2017). However, it must be noted that chi-square statistics are sensitive and artificially inflated by sample size (Iacobucci, 2010; Zhao, 2017) (Table 5).

In this study 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 to assess the model fit for the dependent variables.

4.4.1 Leadership commitment goodness-of-fit. It is evident in Table 6 that root mean square error of approximation (RMSEA) = 0.067, relative normed chi-square value (CMIN)/df = 2.151 indicates that the theoretical model of leadership commitment fitted the empirically data satisfactory. The comparative fit index (CFI) (0.971), incremental fit index (IFI) (0.972), normed fit index (NFI) (0.949) and Tucker-Lewis index (TLI) (0.948) were 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 parsimony adjusted normed fit index (PNFI) and parsimony adjusted comparative fit index (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 authors decided to eliminate LCH40 to improve CMIN/df from 2.394 to 2.151, which was then marginally accepted.

4.4.2 Chemical exposure management goodness-of-fit. It is evident in Table 7 that RMSEA = 0.156 and CMIN/df = 7.244 was indicative of poor model fit for the theoretical

Observed variables	Strongly agree (%)	Agree (%)	Sum (%)	Category
Leadership commitment (LCH10)	64.5	32.4	96.9	High
LCH7	61.2	32.2	93.4	High
LCH40	57.1	30.1	87.3	High
LCH11	51.0	37.5	88.4	High
LCH8	50.8	37.6	88.4	High
LCH17	37.6	36.0	73.6	Medium
LCH38	8.53	25.2	33.7	Low
Chemical exposure management (CEMH30)	71.0	24.7	95.8	High
CEMH6	47.9	44.4	92.2	High
CEMH14	42.6	42.2	84.9	High
CEMH12	42.1	44.4	86.5	High
CEMH15	22.0	40.4	62.4	Medium
CEMH16	15.5	28.3	43.8	Medium
Health and safety risk assessment (HSRAH9)	43.6	45.2	88.8	High
HSRAH34	45.7	42.2	88.0	High
HSRAH33	22.9	32.6	55.4	Medium
HSRAH39	14.0	32.2	46.1	Medium
HSRAH32	15.1	25.5	40.5	Medium
Process hazard analysis (PHAH24)	58.8	35.0	93.8	High
PHAH21	43.2	45.6	88.8	High
PHAH20	44.4	42.9	87.3	High
PHAH23	8.2	12.5	20.6	Low
Permit to work (PTWH29)	82.6	15.8	98.5	High
PTWH28	72.8	23.0	95.7	High
PTWH31	68.1	22.2	90.3	High
PTWH25	6.2	18.7	24.9	Low
Training and competency (TCH13)	40.9	45.2	86.1	High
TCH19	38.2	42.5	80.7	High
TCH35	15.5	39.5	55.0	Medium
Process health and safety information (PHSIH22)	51.7	38.2	90.0	High
PHSIH18	55.2	32.8	88.0	High
Control of confined space entry (CCSEH36)	63.8	29.2	93.0	High
CCSEH37	8.5	20.2	28.7	Low
Operating procedure (OPH26)	55.2	36.3	91.5	High
Control of ignition source (CISH27)	10.5	23.6	34.1	Low

Table 4. Categorisation of observed variables ($N = 259$)

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 authors decided to eliminate CEMH30 to improve incremental fit indices CFI, IFI and NFI to an acceptable threshold. Due to a lack of construct validity, any interpretations based on the chemical exposure management latent variable needs to be inferred carefully.

4.4.3 Health and safety risk assessment goodness-of-fit. In Table 8, RMSEA = 0.082 and CMIN/df = 2.729 were indicative of a marginally acceptable theoretical model fit for health

Table 5.
Threshold limits for model fit indices

Model fit index	Acceptable threshold	Interpretation	References
Absolute fit indices			
Relative normed Chi- value	<2	Good fit	Tabachnick and Fidell (2013);
Root mean square error of approximation	Value <0.05 Value is 0.06–0.08	Good fit Acceptable fit	Hooper *et al.* (2008), Hu and Bentler (1999); Schreiber *et al.* (2006), Schumacker and Lomax (2004).
Incremental fit indices			
Bentler comparative fit index (CFI)	Value ≥0.95 Value is 0.90–0.95	Good fit Acceptable fit	Hooper *et al.* (2008); Hsu *et al.* (2012), Hu and Bentler (1999), Schreiber *et al.* (2006); Schumacker and Lomax (2004).
Incremental fit index (IFI)	Value ≥0.95 Value is 0.90–0.95	Good fit Acceptable fit	Hooper *et al.* (2008), Hu and Bentler (1999); Schreiber *et al.* (2006), Schumacker and Lomax (2004).
Normed fit index (NFI)	Value ≥0.95 Value is 0.90–0.95	Good fit Acceptable fit	Hooper *et al.* (2008), Hu and Bentler (1999); Schreiber *et al.* (2006), Schumacker and Lomax (2004).
Tucker-Lewis index (TLI)	Value ≥0.95 Value is 0.90–0.95	Good fit Acceptable fit	Hooper *et al.* (2008), Hu and Bentler (1999); Schreiber *et al.* (2006), Schumacker and Lomax (2004).
Parsimonious fit indices			
Parsimony adjusted normed fit index (PNFI)	Value >0.90 Value >0.50	Good fit Acceptable fit	Hooper *et al.* (2008)
Parsimony adjusted comparative fit index (PCFI)	Value >0.90 Value >0.50	Good fit Acceptable fit	Hooper *et al.* (2008)

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 a marginally 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 authors 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 marginally acceptable fit. The elimination of HSRAH33 and HSRAH35 improved the overall model. Parsimony assessment was marginally acceptable PNFI (0.463) and PCFI (0.472).

4.4.4 Process hazard analysis goodness-of-fit. It is evident in Table 9 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 authors decided to eliminate three observed variables, namely, PHAH22,

Model fit index	Leadership commitment construct 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

Table 6. Leadership commitment construct GOF

Model fit index	Chemical exposure management construct 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

Table 7. Chemical exposure management construct GOF

PHAH24 and PHAH26 to improve the final model. The process hazard analysis construct had only 2 observed variables in the final model, namely, PHAH20 and PHAH21.

4.4.5 Permit to work goodness-of-fit. It is evident in Table 10 that RMSEA = 0.05, CMIN/df = 1.651 indicates that the theoretical model of permit to work construct fitted the

Table 8. Health and safety risk assessment construct GOF

Model fit index	Threshold	First SEM	Acceptability	Final SEM	Acceptability
	Health and safety risk assessment construct				
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

Table 9. Process hazard analysis construct GOF

Model fit index	Threshold	Final SEM	Acceptability
	Process hazard analysis construct		
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

empirically data satisfactory. The CFI (0.995), IFI (0.995), NFI (0.988) and TLI (0.975) were 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.

Model fit index	Permit to work construct 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	Good fit	0.050	Accepted
	Value is 0.06–0.08	Acceptable fit		
Incremental fit indices				
Bentler comparative fit index (CFI)	Value ≥0.95	Good fit	0.995	Accepted
	Value is 0.90 –0.95	Acceptable fit		
Incremental fit index (IFI)	Value ≥0.95	Good fit	0.995	Accepted
	Value is 0.90–0.95	Acceptable fit		
Normed fit index (NFI)	Value ≥0.95	Good fit	0.988	Accepted
	Value is 0.90–0.95	Acceptable fit		
Tucker-Lewis index (TLI)	Value ≥0.95	Good fit	0.975	Accepted
	Value is 0.90–0.95	Acceptable fit		
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

Table 10.
Permit to work construct GOF

4.4.6 Generative process health and safety culture model goodness-of-fit. It is evident in Table 11 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, 1988). It ranges between 0 and 1 with the value smaller than the limit value of 0.08 perceived as an acceptable fit (Kline, 2011).

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 the 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. 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 an 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 generally acceptable index limit of 0.90, which is widely accepted for all other indices might be more appropriate. Due to the complexity of the model assessed, it was expected that these indices would be lower than the widely accepted limits of 0.90, and therefore, the model presented is not parsimonious.

Table 11. Generative process health and safety culture model GOF

Model fit index	Acceptable threshold	Interpretation	First SEM	Acceptability	Final SEM	Acceptability
	Generative health and safety culture final model					
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

4.5 Model refinement

The model was refined by eliminating awkward constructs and observed variables as recommended by Hooper *et al.* (2008). In this study, 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) and Control of Ignition Source (CIS). These latent constructs were eliminated due to no observed variable allocated to it or because the loading was less than 0.50. Three observed variables were eliminated, as their loadings were less than 0.5 and they were, namely, PHSIH18, TCH19 and HSRAH34. Other observed variables were allocated to different latent variables after principal component analysis.

Leadership commitment was 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 were originally five observed variables and only CEMH30 was eliminated to improve incremental fit indices CFI, IFI and NFI to an acceptable threshold. Health and safety risk assessment was 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 model.

Process Hazard Analysis was the latent construct that had five observed variables, namely, PHAH20 –PHAH21, PHAH22, PHAH24 and PHAH26. The final model eliminated PHAH22, PHAH24 and PHAH26 and retained only PHAH20 and PHAH21 (Figures 1 and 2).

4.6 Reliability and validity

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

4.6.1 Composite reliability.

$$CR = \sum \varphi_{\mathrm{i}}^{2} / \left(\sum \varphi_{\mathrm{i}}^{2} + \sum \delta_{\mathrm{i}}^{2} \right) \qquad (2)$$

where

φ_i = regression factor loading for corresponding measurement indicator; and

δ_i = measurement error of the corresponding measurement indicator.

$$\delta = (1 - \varphi)$$

4.6.2 Discriminant validity. This research discriminant validity was used to examine the shared variance between the constructs by computing the average variance extracted (AVE). Discriminant validity is achieved when the AVE is greater than the cut-off criterion 0.5. The equation (3) was used to calculate AVE.

$$AVE = \sum \varphi_{\mathrm{i}}^{2} / n \qquad (3)$$

where

φ_i = regression factor loading for corresponding measurement indicator; and

n = number of measurement indicators of the corresponding construct.

It is evident in Table 12 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

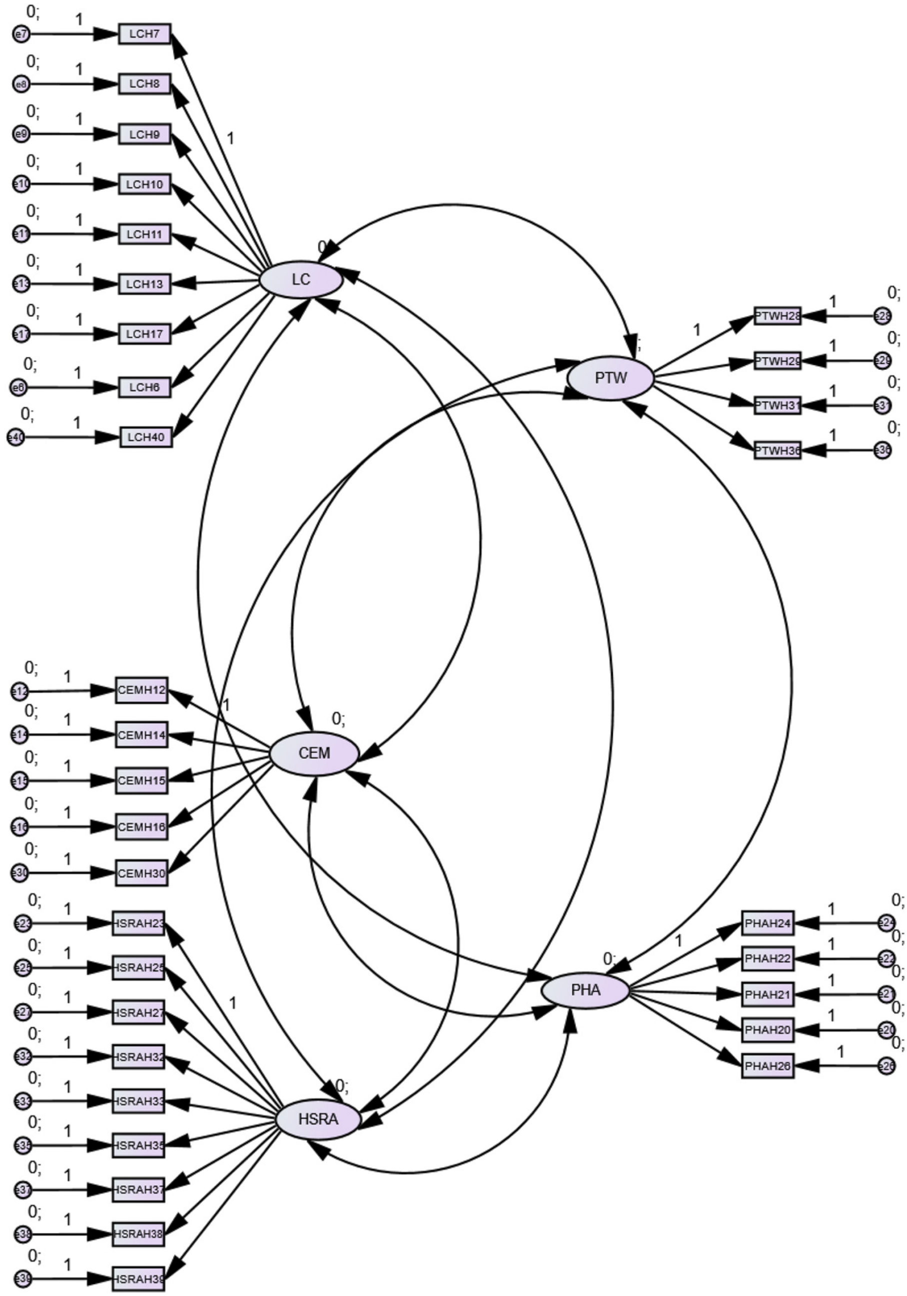

Figure 1.
Initial measurement model

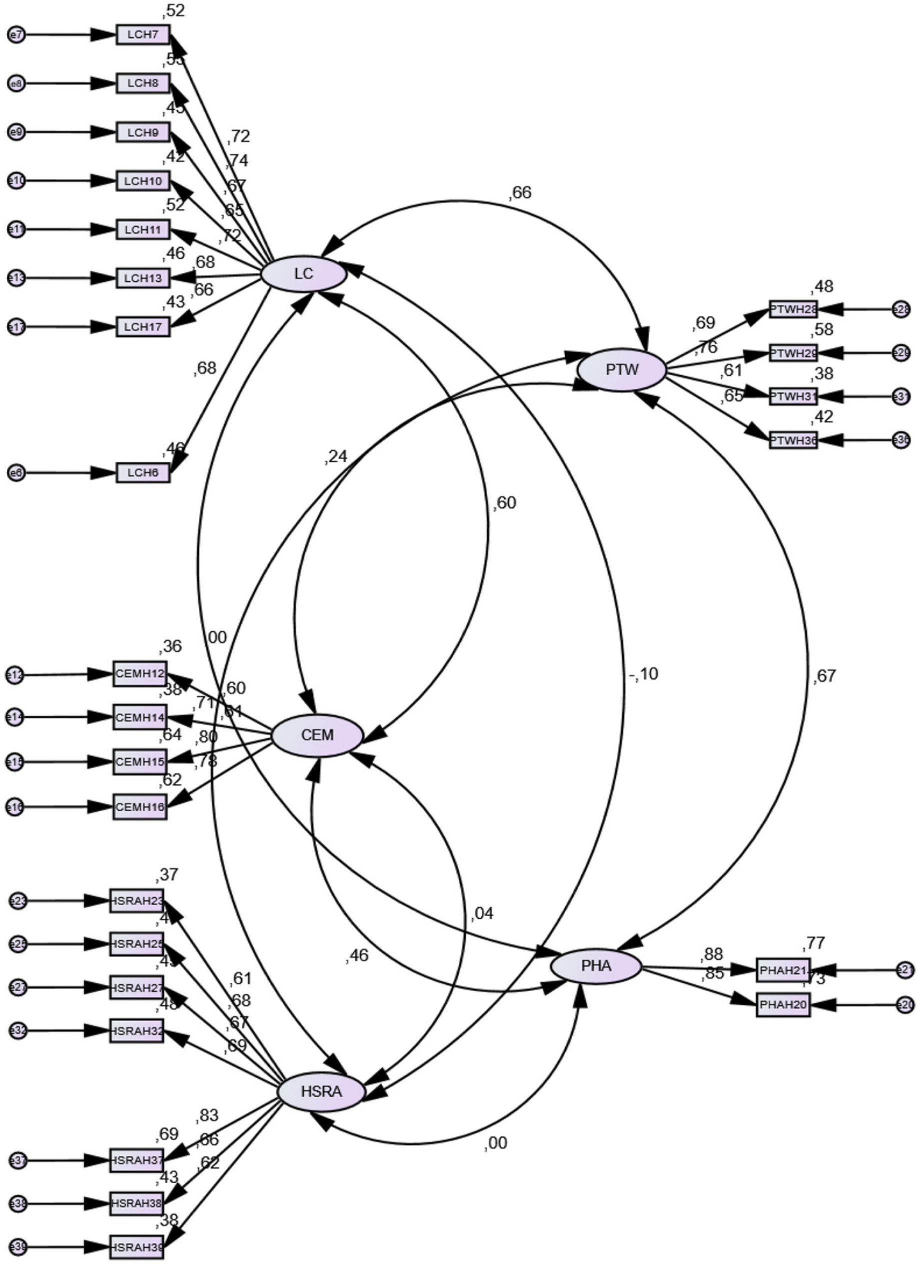

Figure 2.
Refined measurement model

Table 12.
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			

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. AVE 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.

While 0.50 is the widely accepted threshold for AVE, 0.40 is also considered 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. 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.

5. Discussion

The study investigated the process health and safety management systems and 10 latent variables were assessed with observed variables. The 10 latent variables were reduced to five latent variables after principal component analysis and then SEM was used. This advanced method was used to test the statistical adequacy of the proposed research model to confirm whether or not the hypothesised relationships between the latent variables towards generative health and safety culture were valid. The analysis result statistically demonstrated 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 (Figure 3).

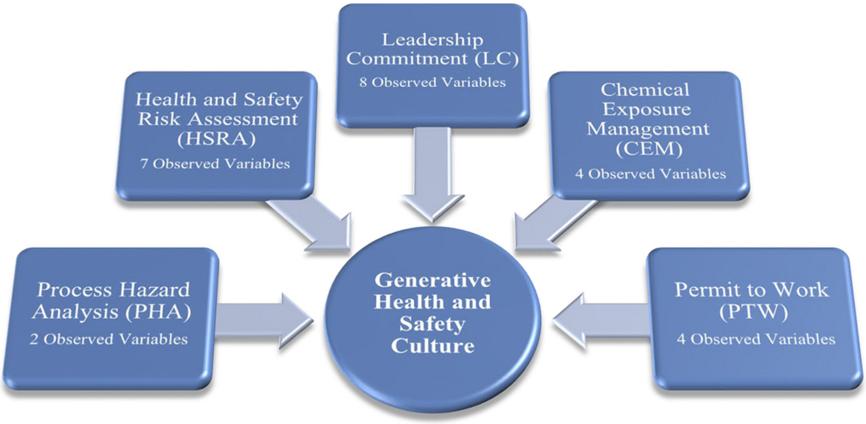

Figure 3. Generative process health and safety culture model (JX Nyawera Model)

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).

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 Albert *et al.* (2014), a critical component in health and safety risk management is to adequately identify hazards and mitigate its associated risk using health and safety programme elements. 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). Effective implementation of a comprehensive permitting programme certainly helps to prevent 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).

6. Conclusion

This study adopted a positivist paradigm to achieve the research objective by carrying out an extensive literature review and questionnaires were distributed, collected and analysed via SPSS AMOS version 25 and Amos using path modelling.

This study explored the process health and safety management systems to identify the critical drivers to achieve a generative process health and safety culture. The key process health and safety critical drivers to be prioritised for generative process health and safety culture in the petrochemical industry could be considered to be:

- Leadership commitment;
- Chemical exposure management;
- Health and safety risk assessment;
- Process hazard analysis; and
- Permit to work.

6.1 Contribution of the research

The study offers an innovative analytical and methodological approach to the assessment of process health and safety culture. The paper 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 the drivers towards a generative process 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 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 research used reliability measures and validity to ensure that the research instruments were consistent and valid.

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.

6.2 Limitations of the research

There are limitations to this study. 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. Because of 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, the introspective ability of participants, question understanding, interpretation of the rating scale and respondent response bias. The research sample may differ significantly from the general population of interest even though there was no evidence found to suggest so.

7. Recommendations for future study

This study was positivist. Future research studies could use mixed methods to obtain a greater perspective on the topic. A different methodology may be used to validate results from this particular study. The study only considered the petrochemical industry. Further study should increase the scope to other construction industries. 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.

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.

References

Albert, A., Hallowell, M.R. and Kleiner, B.M. (2014), “Emerging strategies for construction safety and health hazard recognition”, *Journal of Safety, Health and Environmental Research*, Vol. 10 No. 2, pp. 152-161.

Alshetewi, S., Karim, F., Goodwin, R. and de Vries, D. (2015), “A structural equation model of governing factors influencing the implementation of T-government”, *International Journal of Advanced Computer Science and Applications*, Vol. 6 No. 11, pp. 119-125.

Anderson, J.C. and Gerbing, D.W. (1988), “Structural equation modelling in practice: a review and recommended two-step approach”, *Psychological Bulletin*, Vol. 103 No. 3, pp. 411-423.

Bagozzi, R.P. (2010), "Structural equation models are modelling tools with many ambiguities: comments acknowledging the need for caution and humility in their use", *Journal of Consumer Psychology*, Vol. 20 No. 2, pp. 208 -241.

Barrett, P. (2007), "Structural equation modelling: adjudging model fit", *Personality and Individual Differences*, Vol. 42 No. 5, pp. 815-824.

Bentler, P.M. and Bonett, D.G. (1980), "Significance tests and goodness of fit in the analysis of covariance structures", *Psychological Bulletin*, Vol. 88 No. 3, pp. 588 -606.

Chen, M. (2016), "Process safety knowledge management in the chemical process industry", *American Journal of Chemical Engineering*, Vol. 4 No. 5, pp. 131-138.

Chin, W.W. (1998), "Issues and opinion on structural equation modelling", *MIS Quarterly*, Vol. 19 No. 2, pp. 7-16.

Creswell, J.W. (2005), *Educational Research, Planning, Conducting, and Evaluating Quantitative and Qualitative Research*, Pearson Merrill Prentice Hall, Upper Saddle River.

Creswell, J.W. (2009), *Research Design: Qualitative and Mixed Methods Approach*, Sage Publications, London.

Creswell, J.W. and Plano Clark, V.L. (2007), *Designing and Conducting Mixed Methods Research*, Sage Publications, Thousand Oaks, CA.

Dabup, N.L. (2012), *Health, Safety and Environmental Implications in Nigeria's Oil and Gas Industry*, Nelson Mandela Metropolitan University.

Dunbar, M. (2014), *Hazard Identification and Risk Assessment*, Publication of the Association for Iron and Steel Technology.

Elssayed, M.Y., Hassan, H.M. and Hosny, G. (2012), "Assessment of occupational level of awareness for health and safety in Sidi Kerir petrochemical company", *Egyptian Journal of Occupational Medicine*, Vol. 36 No. 2, pp. 191-203.

Eyayo, F. (2014), "Evaluation of occupational health hazards among oil industry workers: a case study of refinery workers", *Iosr Journal of Environmental Science, Toxicology and Food Technology*, Vol. 8 No. 12, pp. 22-53.

Ezejiofor, T.I.D. (2014), "Risk assessment: reappraisals for potential hazards in the operational environment and facilities of petroleum refining and distribution industry in Nigeria – research and review", *Occupational Medicine and Health Affairs*, Vol. 2 No. 4, pp. 1-19.

Green, T. (2016), "A methodological review of structural equation modelling in higher education research", *Studies in Higher Education*, Vol. 41 No. 12, pp. 2125-2155.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2010), *Multivariate Data Analysis*, 7th ed., Prentice-Hall, Upper Saddle River, NJ.

Hardy, T.L. (2013), *Elements of Process Safety Management*, Great Circle Analysis, Denver, CO, pp. 1-12.

Hooper, D., Coughlan, J. and Mullen, M.R. (2008), "Structural equation modelling: guidelines for determining model fit electronic ", *Journal of Business Research Methods*, Vol. 6 No. 1, pp. 53-60.

Hox, J.J. and Boeije, H.R. (2005), "Data collection, primary vs secondary", *Encyclopaedia of Social Measurement*, Vol. 5, pp. 593-599.

Hu, L. and Bentler, P.M. (1999), "Cut-off criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives", *Structural Equation Modeling: A Multidisciplinary Journal*, Vol. 6 No. 1, pp. 1-55.

Hughes, P. and Ferret, E. (2007), *An Introduction to Health and Safety in Construction*, The Handbook for the NEBOSH (National Examination Board in Occupational Safety and Health).

Iacobucci, D. (2010), "Structural equation modelling: fit indices, sample size, and advanced topics", *Journal of Consumer Psychology*, Vol. 20 No. 1, pp. 90-98.

International Labour Organisation (2017), *Occupational Safety and Health in the Oil and Gas Industry in Selected Sub-Saharan African Countries*, 1st ed., Sectoral Policies Department. First Edition.

Karthika, S. (2013), "Accident prevention by using Hazop study and work permit system in boiler", *International Journal of Advanced Engineering Research and Studies*, Vol. 2 No. 2, pp. 125-129.

Kim, I. (2016), "Ergonomic involvement for occupational safety and health improvements in the oil and gas industry", *Journal of Ergonomics*, Vol. 6 No. 1, pp. 1-3.

Kline, R.B. (2011), *Principles and Practice of Structural Equation Modelling*, 3rd ed., Palgrave-Macmillan, New York, NY.

Kumar, R.M., Karthick, R.B., Bhuvaneswari, V. and Nandhini, N. (2017), "Study on occupational health and diseases in oil industry", *International Research Journal of Engineering and Technology*, Vol. 4 No. 12, pp. 954-958.

Malhotra, G. (2017), "Strategies in research", *International Journal of Advanced Research and Development*, Vol. 2 No. 5, pp. 172-180.

Naafs, M.A.B. (2018), "Occupational diseases in the petrochemical sector and offshore upstream petrochemical industry", *Progress in Petrochemical Science*, Vol. 2 No. 2, pp. 1-6.

Navadiya, R. (2017), "Practice of permit to work in industries and its challenges", *International Journal of Scientific Research*, Vol. 6 No. 6.

Okoye, P.U., Ezeokonkwo, J.U. and Ezeokoli, F.O. (2016), "Building construction workers' health and safety knowledge and compliance on Site", *Journal of Safety Engineering*, Vol. 5 No. 1, pp. 17-26.

OSHAcademy (2017), *Introduction to Process Safety Management. OSHAcademy Course 736 Study Guide*, Occupational Safety and Health Training.

Purohit, D.P., Siddiqui, N.A., Nandan, A. and Yadav, B.P. (2018), "Hazard identification and risk assessment in construction industry", *International Journal of Applied Engineering Research*, Vol. 13 No. 10, pp. 7639-7667.

Puttick, S. (2008), "Avoidance of ignition sources as a basis of safety-limitations and challenges", *IchemE, Symposium series no. 154*, pp. 1-9.

Reddy, V. and Reddy, I. (2015), "Study of electronic work permit system in oil and gas industry – Kuwait", *International Journal of Innovative Science, Engineering and Technology*, Vol. 2 No. 4, pp. 533-537.

Rigdon, E.E. (2016), "Choosing PLS path modelling as analytical method in European management research: a realist perspective", *European Management Journal*, Vol. 34 No. 6, pp. 598-605.

Schreiber, J.B., Stage, F.K., King, J., Nora, A. and Barlow, E.A. (2006), "Reporting structural equation modelling and confirmatory factor analysis results: a review", *The Journal of Educational Research*, Vol. 99 No. 6, pp. 323-337.

Schumacker, R.E. and Lomax, R.G. (2004), *A Beginner's Guide to Structural Equation Modelling*, Erlbaum, Hillsdale, NJ.

Sharma, A., Sharma, P., Sharma, A., Tyagi, R. and Dixit, A. (2017), "Hazardous effects of petrochemical industry: a review", *Recent Advances in Petrochemical Science*, Vol. 3 No. 2, pp. 1-3.

Spillane, J. and Oyedele, L. (2015), "Strategies for effective management of health and safety in confined site construction", *Construction Economics and Building*, Vol. 13 No. 4, pp. 50-64.

Stojković, A. (2013), "Occupational safety in hazardous confined space", *Safety Engineering*, Vol. 3 No. 3.

Tabachnick, B.G. and Fidell, L.S. (2013), *Using Multivariate Statistics*, Pearson Education.

Trochim, W.M.K. (2006), "Research methods knowledge base", available at: www.socialresearchmethods.net

Tzou, T.L., Hankinson, G., Edwards, D. and Chung, P. (2004), "Evaluating safety information management performance – a key to preventing disaster Bhopal and its effects on process", *Safety International Conference on the 20th Anniversary of the Bhopal Gas Tragedy at Indian Institute of technology*, *Kanpur*.

Vitharana, V.H.P., De Silva, G.H.M.J. and De Silva, S. (2015), "Health hazards risk and safety practices in construction sites – a review study", *Engineer: Journal of the Institution of Engineers, Sri Lanka*, Vol. 48 No. 3, pp. 35-44.

Westland, J.C. (2010), "Lower bounds on sample size in structural equation modelling", *Electronic Commerce Research and Applications*, Vol. 9, pp. 476-487.

Williams, J. (2011), "Research paradigm and philosophy".

Yilmaz, K. (2013), "Comparison of quantitative and qualitative research traditions: epistemological, theoretical, and methodological differences", *European Journal of Education*, Vol. 48 No. 2, pp. 1-16.

Zhao, L.L. (2017), *Building Development Cost Drivers in the New Zealand Construction Industry: A Multilevel Analysis of the Causal Relationships*, School of Engineering and Advanced Technology.

Zin, S.M. (2012), "Employers' behavioural safety compliance factors toward occupational safety and health improvement in the construction industry", *Procedia, Social and Behavioural Sciences*, Vol. 36, pp. 742-751.

Corresponding author
James Xolani Nyawera can be contacted at: james.nyawera@engenoil.com