An optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa

by

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Declaration

I declare that the PhD thesis, *An optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa,* is my own work. It has not been submitted previously for any degree or examination at any other university. All the sources I have used or quoted have been indicated and acknowledged as complete references. I furthermore cede copyright of the thesis in favour of the University of the Free State.

Alfonso Niemand

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Abstract

The society we live in is becoming more complex by the day as a result of a multitude of factors, such as economic development, wars, terrorist attacks, technological innovation and societal demands for wealth creation. Human populations are rapidly growing to extremes, where the sustainable utilisation of natural and man-made resources is stretched to the limit. The regulation of major hazard installations near densely populated areas in South Africa and worldwide has consequently become critical.

South African legislation on the health and safety of people in and around hazardous facilities does not cover an exogenous, outward-focused approach by which communities around the hazardous installation are assessed to determine their vulnerability to a major disastrous incident. This legislation is largely based on legislation developed in the United Kingdom under the guidance of their Health and Safety Executive (HSE), and is fragmented and spread across several government departments.

An optimised model was developed in this study for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa. The model is based on a systems approach, with three open and interactive domains or spheres where the hazardous facility has an influence: environment, community and the hazardous facility itself. The model further contains the concept of disaster vulnerability, not only as regards the employees at the hazardous facility and the communities around the facility, but also the organisation that houses the hazardous facility. The concepts of the social and economic sustainability of communities at and around the hazardous facility are also introduced in the model, as well as the sustainability of the organisation and business continuity, as critical parts of the regulatory management process.

The model has been verified against 21 critical success factors for effective legislation in health and safety, three relevant case studies from South Africa, India and England, the South African disaster regulatory framework as well as 14 local Acts and Regulations relevant to the governance of the health and safety of people.

Key concepts

Business continuity.

Community coping capacity.

Community resilience.

Community vulnerability.

Critical success factors.

Disaster management.

Hazardous facilities.

Major hazard installations.

Natural technological disasters.

Regulations and control.

Sustainable development.

Systems.

Technological disasters.

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Abbreviations and acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute emergency guideline limit
AIA	Approved inspection authority
AIChE	American Institute of Chemical Engineers
ALARP	As low as reasonably practicable
ASECU	Association of Economic Universities of South and Eastern Europe and the Black Sea Region
BCM	Business continuity management
BMIIB	Buncefield Major Incident Investigation Board
CCPS	Centre for Chemical Process Safety
CCTV	Closed circuit television
CEC	Council of the European Communities
COGTA	Cooperative Governance and Traditional Affairs
COMAH	Control over major accident hazards
CSF	Critical success factor
DEA	Department of Environmental Affairs
DOL	Department of Labour
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ER	Emergency response
EU	European Union
HOSL	Hertfordshire Oil Storage Limited
HSE	Health and Safety Executive, UK
IAEA	International Atomic Energy Agency
IBCM	Institute of Business Continuity Management
ICAO	International Civil Aviation Organisation
IEA	International Energy Agency
IoDSA	Institute of Directors Southern Africa
ISDR	International Strategy for Disaster Reduction
ISO	International Organisation for Standardisation
JRC	Joint Research Centre

kg	Kilogram
kJ	Kilojoule
MHI	Major hazard installation
MOVE	Methods for the Improvement of Vulnerability Assessment in Europe
MSDS	Material safety data sheet
Natech	Natural-technological
NEA	Nuclear Energy Agency
NEDIES	Natural and Environmental Disaster Information Exchange System
NEDLAC	National Economic Development and Labour Council
NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
NNR	National Nuclear Regulator
NOAA	National Oceanographic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
OHS	Occupational health and safety
PADHI	Planning advice for developments near hazardous installations
PLRS	Persistent lower respiratory symptoms
ppm	Parts per million
Psi	Pounds per square inch
PWSRCAC	Prince William Sound Regional Citizens’ Advisory Council
SANAS	South African National Accreditation System
STEL	Short-term exposure limit
TLV	Threshold limit values
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
UNISDR	United Nations International Strategy for Disaster Reduction
USA	United States of America
WHO	World Health Organisation

Definitions

Acceptable risk	The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions (UNISDR 2009)
Adaptation	The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNISDR 2009)
Business continuity management	A holistic management process that identifies potential threats to an organisation and the impacts to business operations that those threats, if realized, might cause, and which provides a framework for building organisational resilience with the capability for an effective business continuity response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities (ISO-22301 2012)
Capacity	The combination of all the strengths, attributes and resources available within a community, society or organisation that can be used to achieve agreed goals (UNISDR 2009)
Capacity development	The process by which people, organisations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions (UNISDR, 2009)
Community	The people or social receptor group who may be near or inside a hazardous facility and whose health and safety may be affected by the facility. Also see receptor (Author)
Competent authority	The relevant government department at national, provincial or local level that is responsible for the administration of an Act (Author)

Coping capacity	The ability of people, organisations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters (UNISDR 2009)
Corrective disaster risk management	Management activities that address and seek to correct or reduce disaster risks which are already present (UNISDR 2009)
Critical facilities	The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency (UNISDR 2009)
Critical success factors	A limited number of characteristics, conditions or variables that have a direct and serious impact on the effectiveness, efficiency and viability of an organisation, programme or project (BusinessDictionary.com, 2016). Applied in this research as a measure of how successfully health and safety functions are regulated at hazardous facilities in order to protect the health and safety of people
Disaster	A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UNISDR, 2009)
Disaster risk	The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period (UNISDR 2009)
Disaster risk management	The systematic process of using administrative directives, organisations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster (UNISDR 2009)

Domain	Sphere of influence (Oxford Dictionary of English, 2016)
Early warning system	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss (UNISDR 2009)
Emergency management	The organisation and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps (UNISDR 2009)
Emergency services	The set of specialised agencies that have specific responsibilities and objectives in serving and protecting people and property in emergency situations (UNISDR 2009)
Environment	A living, functioning and highly complex unit composed of a large number of elements and organisms which are all functionally interdependent (Hugo, Viljoen & Meeuwis 2000)
Exposure	People, property, systems or other elements present in hazard zones that are thereby subject to potential losses (UNISDR 2009)
Extensive risk	The widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts (UNISDR 2009)
Hazard	A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR 2009)

Hazardous facility	A dangerous facility, installation or factory where a substance is manufactured, handled or stored that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (Expanded from the MHI Regulations 2001)
Human-induced risk	Anthropogenic risk or risk that arises directly and exclusively as a result of human activity, either in the form of a direct trigger to a disaster, or through the construction or operation of a hazardous installation or facility (Author)
Individual risk	The risk to a single person exposed to a hazard (AIChE-CCPS, 2009)
Intensive risk	The risk associated with the exposure of large concentrations of people and economic activities to intense hazard events that can lead to potentially catastrophic disaster impacts involving high mortality and asset loss (UNISDR 2009)
Land-use planning	The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long-term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses (UNISDR 2009)
Major hazard installation	An installation where any substance is produced, processed, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (MHI Regulations 2001)
Major incident	An occurrence of catastrophic proportions, resulting from the use of plant or machinery, or from activities at a workplace
Mission statement	A description of the aims of a business, charity, government department or public organisation (Cambridge Dictionaries Online 2016)

Mitigation	The lessening or limitation of the adverse impacts of hazards and related disasters (UNISDR 2009)
Natural hazard	Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR 2009)
Preparedness	The knowledge and capacities developed by governments, professional response and recovery organisations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current hazard events or conditions (UNISDR 2009)
Prevention	The outright avoidance of adverse impacts of hazards and related disasters (UNISDR 2009)
Prospective disaster risk management	Management activities that address and seek to avoid the development of new or increased disaster risks (UNISDR 2009)
Public awareness	The extent of common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards (UNISDR 2009)
Receptor	A social system or part of it that is exposed to a hazard (Author)
Recovery	The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors (UNISDR 2009)
Regime	The complex system of institutional geography, rules, practice and animating ideas that are associated with the regulation of a particular risk or hazard (Hood, Rothstein & Baldwin 2001)

Regulation of risk	Governmental interference with market or social processes to control potential adverse consequences to health. It means attempts to control risk, mainly by setting and enforcing behavioural standards (Hood et al. 2001)
Residual risk	The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained (UNISDR 2009)
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR 2009)
Response	The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (UNISDR 2009)
Risk	The combination of the probability of an event and its negative consequences (UNISDR 2009)
Risk assessment	A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend (UNISDR 2009)
Risk management	The systematic approach and practice of managing uncertainty to minimise potential harm and loss (UNISDR 2009)

Risk transfer	The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party (UNISDR 2009)
Societal risk	The cumulative risk to groups of people who are exposed to a hazard or might be affected by a major incident (disaster). (AIChE-CCPS, 2009)
Socio-natural hazard	The phenomenon of increased occurrence of certain geophysical and hydro meteorological hazard events, such as landslides, flooding, land subsidence and drought that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources (UNISDR 2009)
Structural and non-structural measures	Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems (UNISDR 2009) Non-structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education (UNISDR 2009)
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UNISDR 2009)
Technological accident	An accident that is caused by a technological installation (Krausmann, Cozzani, Salzano & Renni 2011)

Technological hazard	A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR 2009)
Technological installation	An installation where certain chemical and engineering technology is applied for the production, processing, use, handling or storage of any substance in such a form and quantity that it has the potential to cause a major incident (MHI Regulations 2001, expanded by Author)
Trigger	An event that initiates, causes or starts a major incident to create a disaster. The event can be of natural origin (uncontrolled by humans) or can be induced by human action (independent of nature) (Author)
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR 2009). In this research, vulnerability means health and safety vulnerability.

Chapter 1

Introduction to the study

1.1 Introduction

This chapter presents an introduction to the study by explaining the need for the proper regulatory management of hazardous facilities with a view to protecting the health and safety of people in all countries of the world.

The society we live in is becoming more complex by the day owing to a multitude of factors such as economic development, wars, terrorist attacks, technological innovation, societal demands for wealth creation and an increased awareness of the health and safety impact of human activities on people (Perrow 1999). Human populations are rapidly growing to extremes where the sustainable utilisation of natural and manmade resources is stretched to the limit. Clarke (2006) summarises it as follows:

"People are worried, now, about terror and catastrophe in ways that a short time ago would have seemed merely fantastic. Not to say that horror and fear suffuse the culture, but they are in the ascendant. And for good reason. There are possibilities for accident and attack, disease and disaster that would make September 11 seem like a mosquito bite".

In view of these concerns and the occurrence of human-induced technological disasters, the regulation of major hazard installations near densely populated areas in South Africa and worldwide has become critical in order to limit the human-induced safety risks to which communities are exposed.

During the past two decades, environmental conservation awareness has grown substantially around the world, also in South Africa as a developing economy. However, it would appear that, as far as the human-induced impacts of major hazardous industrial installations are concerned, the safety of human communities has not enjoyed the same prominence as environmental issues in South Africa. This could be the result of international pressure, because developing countries consider environmental degradation, especially global warming (climate change), as a serious threat to human, animal and plant life here on earth (McGuire et al. 2002; Gupta 2001).

In its State of the Environment Report, the South African Department of Environmental Affairs and Tourism (2006) confirmed that the focus was on the condition of the environment and natural resources (the ecological system) in South Africa. The safety impacts that major hazard installations could have on people was not addressed at all in the publication. One reason for this is that environmental matters in South Africa are governed by the National Environmental Management Act (NEMA) (Act 107 of 1998) and the Environmental Impact Assessment Regulations of August 2010 under the national and provincial Departments of Environmental Affairs, while the Major Hazard Installation Regulations are governed by the Occupational Health and Safety Act, under the Department of Labour. The prime focus of the latter legislation in South Africa is the safety and health of employees in organisations (the labour force) and to a lesser extent that of the general public.

1.2 An overview of some human-induced technological accidents in the world

A brief overview is given of a number of disastrous technological incidents worldwide that were caused by human activity. The incidents cover fires, explosions and the release of toxic gas, which led to numerous fatalities and disruptions in communities and countries.

1.2.1 The nuclear explosion in Chernobyl (CubeStat Disasterium 2015)

On 26 April 1986 the Chernobyl nuclear plant in the Ukrainian Soviet Socialist Republic experienced a major meltdown. It resulted in the release of atmospheric radioactive material with four hundred times higher radioactivity than the Hiroshima atom bomb. The effect of the incident was long-term. Countless children with birth defects, an increase of cancer cases and many other health issues were the result of this incident. It is estimated that the disaster could result in about 100 000 fatal cancers and that the area would not be safe for up to 200 years for any activity including farming.

Figure 1.1 The Chernobyl nuclear reactor plant after the disaster

1.2.2 The Kuwait oil fires (CubeStat Disasterium 2015)

In 1991, during the Gulf War and following the invasion of Kuwait, Sadam Hussein sent men to blow up the Kuwait oil wells. It created the largest oil spill in history, making it one of the 10 worst manmade disasters of all time (Young, 2013). About 600 wells were set ablaze and these burned for more than seven months. The oil spill that resulted from the fires caused considerable damage to the environment.

Figure 1.2 Burning oil wells in Kuwait

1.2.3 The dioxin pollution in Meda (CubeStat Disasterium 2015)

On 10 July 1976, a reactor in the ICMESA chemical company in Meda, Italy, exploded. It created a toxic cloud of dioxin that was released into the atmosphere. Dioxin is one of the most toxic chemicals known to man. No person died as a direct result of the explosion, but many children were affected by the serious skin disease chloracne that resulted from the accident.

Figure 1.3 Disaster response after dioxin pollution in Meda, Italy

1.2.4 The Three Mile Island nuclear explosion (CubeStat Disasterium 2015)

On 28 March 1979 the Three Mile Island nuclear reactor in Harrisburg, Pennsylvania, experienced a partial core meltdown. Little radiation was released from the reactor due to an effective containment system, but the accident created fear about the nuclear power industry. Livestock deaths, premature deaths and birth defects have been attributed to the nuclear meltdown. The incident confirmed that human activity going wrong can have a devastating effect on the environment for decades afterwards. These disasters are generally related to poor industrial management in developing countries. However, even with regulation a catastrophe can strike.

Figure 1.4 Nuclear power plant at Three Mile Island, Pennsylvania

1.2.5 The Fukushima reactor meltdown (CubeStat Disasterium 2015)

On 11 March 2011 an earthquake registering 9.0 on the Richter scale created a tsunami that caused damage to three nuclear reactors at the Fukushima Daiichi nuclear power plant in Japan. It led to the only other Level 7 nuclear meltdown besides Chernobyl. More than 100 000 people were evacuated from the surrounding areas with 600 people dying during the evacuation. This only exacerbated the problems caused by the earthquake and tsunami. Three hundred clean-up employees received excessive exposure to radioactive waste. The long-term health effects of the nuclear disaster are still unknown, but the number of persons affected could be more than 1 000, including people as far away from the meltdown as North America. It will probably take decades to know all the complications resulting from the meltdown. Some people are already arguing that this incident was worse than Chernobyl.

Figure 1.5 Daiichi nuclear reactor meltdown in Fukushima

1.2.6 The North Korea oil pipe explosion (Time Magazine 2007)

On 9 June 2007 oil started to leak from an aging oil pipeline in the North Pyongyang province of North Korea. Local residents in the fuel-starved country rushed in to scavenge what they could and then the oil caught fire, followed by a vapour cloud explosion. At least 110 people died in this incident.

1.2.7 The Siberia mine explosion (Time Magazine 2007)

The Russian Ulyanovskaya coal mine, located in the Kemerovo region of Siberia about 3 200 kilometres east of Moscow, was less than five years old and had modern safety features. None of that, however, was enough to prevent a massive methane explosion from ripping through the mine on 19 March 2007. Tunnels collapsed as the blast wave spread from an epicentre nearly 43 metres below surface. Working their way through smoke and flooded shafts, rescuers got more than 90 miners safely out. The death toll reached 107.

Figure 1.6 Recovering bodies from the Ulyanovskaya coal mine in Kemerovo

1.2.8 The Mozambique munitions explosion (Lemonick, Time Magazine 2007)

On 22 March 2007 a stockpile of old ammunition stored at a Mozambican army facility in the outskirts of the city of Maputo, blew up, killing 117 people. According to the Mozambique Red Cross, heavy traffic in the area hampered the organisation's rescue attempts.

Figure 1.7 Demolished buildings in Maputo

1.2.9 The Piper Alpha oil rig explosion (The Guardian 2013)

On 6 July 1988 the Piper Alpha oil rig disaster occurred in the North Sea off the coast of Aberdeen, killing 167 employees. It was considered to be the deadliest ever oil rig accident in the world. An investigation report on the disaster indicated that the operator, Occidental Petroleum, had used inadequate maintenance and safety procedures. The report made more than 100 recommendations about how safety should be improved on oil platforms in the North Sea.

Figure 1.8 Burning Piper Alpha oil rig

1.2.10 The Seveso disaster (Time Magazine 2010; Homberger et al. 1979)

On 10 July 1976 an explosion at a northern Italian chemical plant released a thick, white cloud of dioxin that quickly settled on the town of Seveso, north of Milan. First, animals began to die. As *Time* wrote about a month after the incident, *"One farmer saw his cat keel over, and when he went to pick up the body, the tail fell off. When authorities dug the cat up for examination two days later, said the farmer, all that was left was its skull."* It was four days before people began to feel ill effects, including *"nausea, blurred vision and, especially among children, the disfiguring sores of a skin disease known as chloracne"* and weeks before the town itself was evacuated. Residents eventually returned to the town, and today a large park sits above two giant tanks that hold the remains of hundreds of slaughtered animals, the destroyed factory and the soil that received the largest doses of dioxin. This accident had a profound impact on regulatory requirements for hazardous installations and resulted in the well-known Seveso Directives adopted by the UK and the EU (CEC, 1996).

Figure 1.9 The Seveso disaster scene in Italy

1.2.11 The Bhopal disaster (Union Carbide Corporation 1984)

On the night of 2 December 1984 the Union Carbide pesticide plant in Bhopal, India, began to leak methyl isocyanate gas into the atmosphere. More than 500 000 people were exposed to the chemical and there were almost 15 000 deaths. In addition, more than 20 000 people have died since the accident from gas-related diseases. Union Carbide India Limited (UCIL) was established in 1934, when Union Carbide Corporation (UCC) became one of the first US companies to invest in India. UCIL was a diversified manufacturing company, employing approximately 9 000 people and operating 14 plants in five divisions. The Bhopal plant in India was built in the late 1970s. The plant produced pesticides for use in India to help the country's agricultural sector increase its productivity and meet the food needs of one of the world's most heavily populated regions. Shortly after midnight on 3 December 1984 toxic methyl isocyanate gas leaked from a tank at the UCIL Bhopal plant. Word of the disaster was received at Union Carbide headquarters in Connecticut. Chairman and chief executive officer Warren Anderson, together with a technical team, departed to India to assist the government in dealing with the incident. Upon arrival, Anderson was placed under house arrest and urged by the Indian government to leave the country within 24 hours.

Figure 1.10 Victims of the Bhopal disaster

1.2.12 The Flixborough disaster (Bennett 1999)

On 1 June 1974 a massive explosion occurred at the site of the Nypro chemical plant at the town of Flixborough in England. The explosion killed 28 employees, injured 36 and led to the destruction of the entire facility. In addition 53 off-site injuries were reported, along with damage to private property. The Flixborough plant had been in operation since 1967. It was operated by Nypro, a joint venture between Dutch State Mines and the British National Coal Board. It produced caprolactam, which was then used to manufacture nylon. The process used six large pressurized reactors containing cyclohexane.

In March 1974 a vertical crack had appeared in Reactor 5. It was decided to remove this reactor and install a bypass between Reactor 4 and 6. The bypass had been designed by engineers who were not experienced in high-pressure pipe work. No plans or calculations had been produced, the pipe was not pressure-tested and it was mounted on temporary scaffolding poles that allowed the pipe to twist under pressure. Moreover, the bypass pipe was a smaller diameter (508 mm) than the reactor flanges (610 mm). In order to align the flanges, short sections of steel bellows were added at each end of the bypass. Following start-up of the modified system the 508-mm bypass failed, probably due to lateral stresses in the pipe caused by a pressure surge. It is thought that the dog-leg shape of the bellows connecting the 508-mm to the 610-mm lines squirmed and failed once the system was under pressure. The rupture resulted in the release of a large quantity (about 40 tons) of cyclohexane into the atmosphere. The cyclohexane-air mixture found a source of ignition, which led to a massive vapour cloud explosion. Not only was the plant destroyed, but the windows of the control room were shattered and the roof collapsed. All eighteen persons in the control room died.

Figure 1.11 Destruction at the Nypro plant in Flixborough

1.2.13 The Buncefield depot fire (UK Health and Safety Executive 2008)

The Buncefield oil storage depot is a large, strategically important fuel storage site (known as a tank farm) operated by a number of companies. The depot receives petrol, aviation fuel, diesel and other fuels by pipeline. It stores and then distributes these fuels by pipeline and road tanker to London and southeast England, including to Heathrow

Airport. On 11 December 2005, a number of fuel vapour cloud explosions occurred at Buncefield oil storage depot, Hemel Hempstead.

Figure 1.12 Burning fuel tanks at Buncefield

At least one of the initial explosions at Buncefield was of massive proportions. A fire engulfed over 20 large fuel storage tanks over a large proportion of the site. There were 43 people injured in the incident, none seriously. There were no fatalities. Significant damage occurred to both commercial and residential properties in the vicinity and a large area around the site was evacuated on emergency service advice. About 2 000 people were evacuated. Sections of the M1 motorway were closed. The fire burned for several days, destroying most of the site and emitting large clouds of black smoke into the atmosphere, dispersing over southern England and beyond. Large quantities of foam and water were used to control the fire, with risks of contaminating watercourses and groundwater.

1.3 Human-induced technological accidents

The accidents described in this section had several common factors that serve as the foundation of this study. These factors are:

- The accidents occurred at manmade hazardous installations.

- All accidents had a prominent anthropogenic cause due to human error in the operation of the hazardous facility, a technological deficiency in the facility or a design deficiency in the facility.

- Fatalities among members of the community, severe injuries or long-term negative health implications were general phenomena in all these accidents. In the case of nuclear disasters, even subsequent generations were affected in the form of birth defects.

- In all cases there was serious damage to assets, leading to financial and infrastructural losses, which eventually had a negative effect on the local and regional economies.

- The close and critical interaction between individuals (employees) and communities (society) on the one hand and technological hazardous facilities on the other, is emphasised. These system interactions will be explored in detail in the study.

1.4 The problem statement

At the outset it is necessary to explain what is meant by a hazardous facility. Besides the definition used in this study, the question arises: Which facilities can be classified as hazardous facilities that pose human-induced risks to society? Below is a list of typical examples of hazardous facilities, based on the definition of a *"major hazard installation"* provided in the OHS Act (Act 85 of 1993) and as applied in the MHI Regulations (2001):

- Chemical plant and processing equipment that use hazardous raw materials and/or produce hazardous products.
- Places where hazardous materials are stored or handled in some way or other.
- Underground and open cast mines where ore is produced and processed.
- Transportation equipment or facilities such as aircraft, trains, ships and road vehicles.
- Infrastructure such as buildings, bridges, electricity supply, gas supply and water supply.

The acid test for a facility to be classified as hazardous as implied in this study is as follows:

- The facility must pose a human-induced health and safety risk to society.
- The risks must originate from a human design and construction/creation of the facility or the human operation of the facility.

South African legislation (Major Hazard Installation Regulations 2001) that governs the health and safety risks associated with major hazard installations follows an endogenous, inward-focused approach, which means that the risk assessment methodology centres on the hazardous installation itself: the probability of a major incident at the installation and the consequence or severity of such an incident. From this information judgement has to be made about how other facilities in the vicinity of the hazardous installation would be affected by the anticipated major incident on a *"yes*" or *"no"* basis as calculated from the safety distances around the hazardous installation. The surrounding facilities may include infrastructure, houses, community structures, similar hazardous installations, production facilities and places where human beings may gather or be present. The legislation does not cover an exogenous, outward-focused approach through which communities around the hazardous installation are also assessed to determine their vulnerability to the analysed consequences of a major incident at the installation. Such a vulnerability assessment should include the coping capacity and resilience of the affected communities, as proposed by WHO (2002), Turner II et al. (2003a) and Birkmann (2005). The reason why community vulnerability assessment is not included in current legislation is that South African legislation is largely based on legislation developed in the UK under the guidance of their Health and Safety Executive (HSE). Their legislation is also endogenous and lacks community vulnerability assessment. In fact, this is a shortcoming throughout the EU.

The second factor that complicates South African legislation and takes away the focus from community health and safety vulnerability as well as the facility owner is that the legislation is fragmented and spread across several government departments. One of the inevitable results of this fragmentation is that government departments avoid the responsibility in the hope that another department will address the issue. Eventually, nobody does it and the vulnerability of communities is left unattended to. This aspect was discussed at length during a workshop in Bloemfontein in 2015 with government officials on national, provincial and local level, industry leaders and academic experts in the field of disaster management as part of the qualitative research.

Thirdly, under the current Major Hazard Installation Regulations the onus rests entirely on local government to make a decision on whether a new hazardous installation should be allowed near other existing facilities, or whether new land development may take place near an existing hazardous installation (MHI Regulations 2001). These are burning questions for all local authorities in South Africa when communities are at risk, especially since they have no land-use guidelines, which are of course intricately linked to community health and safety vulnerability. This aspect was discussed in the MHI task team meetings of City of Tshwane, eThekwini Metropolitan Municipality and Ekurhuleni Metropolitan Municipality during the period 2012 to 2016.

1.5 The research questions

The problem statement above gives rise to the following research questions:

- How can the health and safety vulnerability, coping capacity and resilience of communities be integrated into legislation that governs the management of hazardous installations?
- How can current health and safety legislation be defragmented or re-organised to ensure that hazardous installations are managed in the most effective manner, taking the health and safety vulnerability of communities into consideration?
- How can guidelines for land-use, which are currently lacking in the existing hazardous installation legislation, be incorporated into current legislation to ensure that the health and safety vulnerability of communities are minimised?

1.6 Three hypotheses

From the problem statement above, three hypotheses were formulated, as follows:

Hypothesis 1

Existing South African legislation for the management of hazardous installations does not deal with the health and safety vulnerability, coping capacity and resilience of communities near or around such installations with regard to fires, explosions and the release of toxic gases.

Hypothesis 2

Health and safety legislation in South Africa is fragmented and scattered among various independent state departments, which results in inefficient enforcing of the legislation for the management of hazardous installations.

Hypothesis 3

The effective planning of land-use is a critical component of the overall management of hazardous installations, but does not receive the required attention under existing South African legislation.

1.7 The objectives of the study

The main objective of the study is to develop an optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa. The model should be firmly based on the following eight theories:

- Systems theory.
- Regulation and control theory.
- Sustainability theory.
- Vulnerability theory.
- Disaster theory.
- Business continuity theory.
- Critical success factor theory.
- Theory on natural-technological disasters.

The study aims to provide a regulatory solution for the absence of community vulnerability assessment, the fragmentation of health and safety legislation and the lack of guidelines for land-use near or around hazardous installations.

The specific objectives of the study are as follows:

- To expand the existing health and safety legislation with an exogenous assessment of the vulnerability, coping capacity and resilience of communities that could be affected by a major incident at a hazardous installation.

- To seek singular responsibility for the enforcement and administration of the legislation, to avoid confusion and to enhance effective governance.
- To remove uncertainty in the existing legislation regarding land-use near or around hazardous installations and provide for clear directives on community protection.
- To incorporate the impact of natural disasters on hazardous installations.
- To test the proposed model against one international and one local historical human-induced disaster.

1.8 Research methodology

The technological disasters highlighted in this chapter illustrate the immense impact that human populations are exposed to in case of a major incident at a hazardous facility. Clarke (2006) expresses it well by saying that horror and fear caused by potential disasters are increasing due to possibilities for accidents and disasters. All these cases illustrate the role of human actions as precursor of technological disasters, through either design errors or operational deficiencies.

Environmental conservation awareness has grown substantially around the world, also in South Africa. However, it would appear that the safety of human communities, as far as the human-induced impacts of major hazardous industrial installations are concerned, has not enjoyed the same prominence as environmental issues in South Africa (South African Department of Environmental Affairs and Tourism 2006). This could be the result of international pressure, because developing countries consider environmental degradation, especially global warming (climate change) as a threat to biological life (McGuire et al. 2002; Gupta 2001).

This research is about technological, human-induced disasters and the formulation of a regulatory management process to prevent and manage such disasters. An optimised model has to be developed for this purpose.

In addition to a study of the available literature and qualitative research, quantifiable research results were obtained from respondents who owned or operated 373 hazardous facilities in South Africa. This sample represents 65% of all the registered major hazard installations in the country. The research took a multifunctional approach by covering the following steps:

- Knowledge increase through attendance of a block course on disaster vulnerability
- Study of the literature
- Quantitative data collection
- Qualitative data collection
- Action research
- Feedback received from reviews of one local publication
- Feedback received from three international conference presentations
- A structured workshop

The outcome of the study is a regulatory model that should firstly be applicable to South African conditions, but also likely in other parts of the world.

The structure of the research is represented in Figure 1.13.

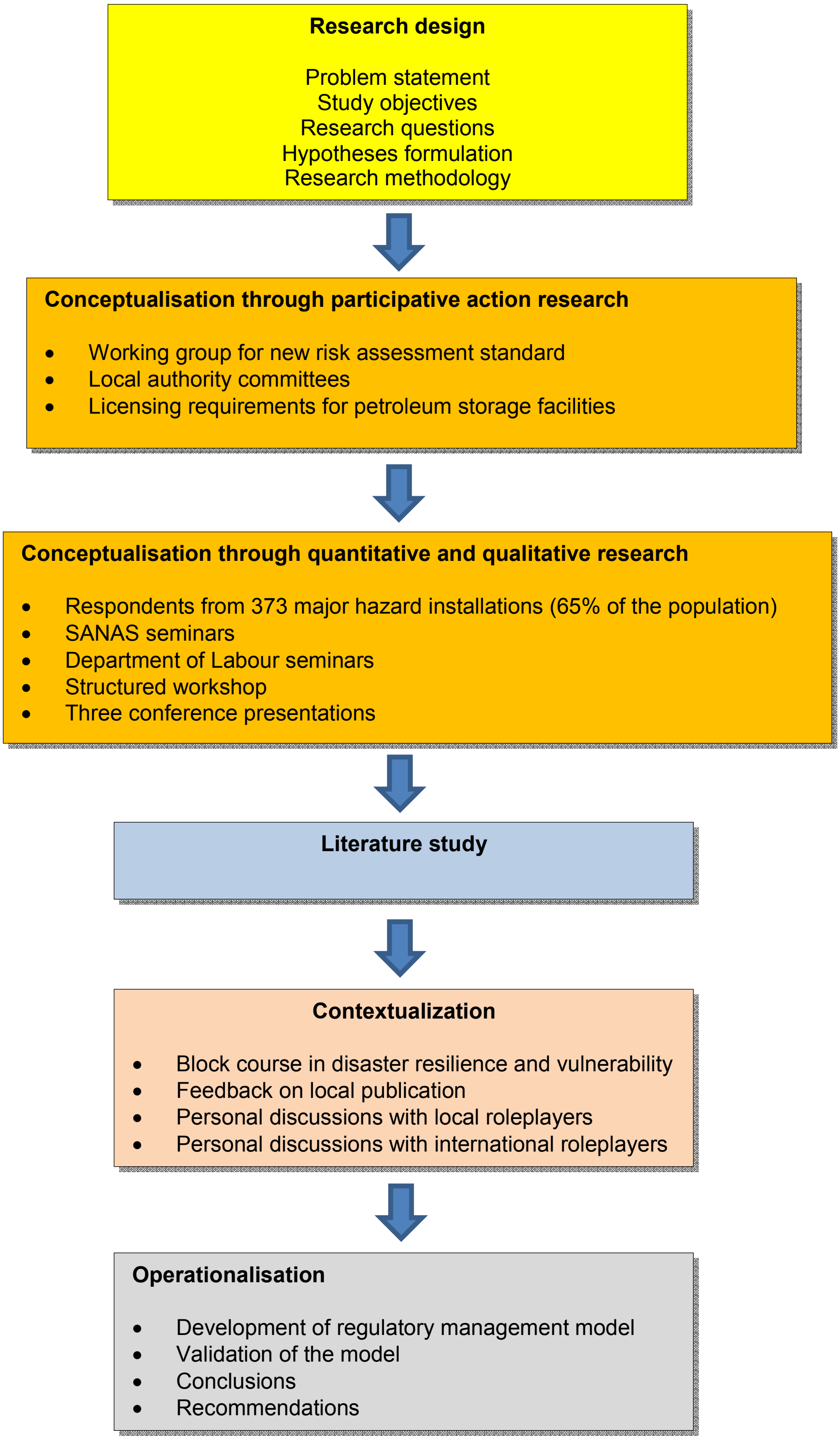

Figure 1.13 Structure of the research (Source: Author)

Chapter 2
Theoretical framework and models

2.1 Introduction

This chapter presents a theoretical foundation for the study. A literature survey was undertaken and the following theories were examined to provide a framework for the development of the proposed regulatory model:

- Systems theory
- Regulation and control theory
- Sustainability theory
- Vulnerability theory
- Disaster theory
- Business continuity theory
- Critical success factor theory

2.2 Study of theories

2.2.1 The systems theory

Systems theory is described as follows by Heylighen and Joslyn (1992):

"The transdisciplinary study of the abstract organisation of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the principles common to all complex entities, and the (usually mathematical) models which can be used to describe them."

Within the context of this research it is necessary to evaluate systems theory and its application to the proposed regulatory model.

Systems theory originated in the 1940s with the biologist Ludwig von Bertalanffy and was furthered by Ross Ashby (Heylighen & Joslyn 1992). Bertalanffy considered systems to be in interaction with their surrounding environments and in the process can acquire new qualitative properties through constant development, resulting in continual renewal and evolution. Heylighen and Joslyn (1992) maintain that, by using the principles of system analysis, the fundamental dynamics of open systems can be applied by decision-makers as a useful management instrument to identify, reconstruct, optimise and control a particular system. In this the multiple objectives that need to be achieved, potential constraints and the resources required have to be taken into account.

More recent research by Chikere and Nwoka (2015) has revealed that the complex interaction between elements of the world can be understood in an overall encompassing manner by following two different approaches: a descriptive and a prescriptive approach.

The descriptive approach uses cognitive theories, perception and reasoning to describe how humans organise and understand stimuli. The prescriptive approach makes use of two paradigms to facilitate the understanding of complex phenomena, namely reductionism and systems analysis. Reductionism claims that the best way to understand a new phenomenon is to study the functioning or properties of its individual parts. Chikere and Nwoka (2015) use the example of the human body: The best way to understand its working is to analyse its individual organs, muscles, tissues, bones and cells. Systems theory on the other hand focuses on the interrelationship between the individual parts, i.e. rather than reducing an entity such as the human body to its multiple individual elements, systems theory focuses on the arrangement of and relations between the individual elements and how they function as a whole. The way in which the elements are organised and how they function in interaction with one another determine the properties of the system.

Weihrich (2008) argues that organised enterprises do not exist in a vacuum, but depend on their surrounding, external environment. The external environment, in turn, forms part of a larger system such as the industry in which it operates, the economic system and the society. The organisation receives inputs from its environment, transforms them and exports the outputs back to the environment in a continuous process of interactive functioning. Weihrich (2008) specifically refers to organisations which comprise groups of people organised to achieve a common goal, societies, administrations and governments. This feedback trait of any system is endorsed by work done by Skyttner (2005).

Mullins (2005) emphasises the technical requirements of the organisation and its needs such as human resources, technology and financial resources. With regard to human resources human needs have to be considered, bringing into play the complex psychological and social aspects. Mullins (2005) makes out a case by arguing that the total organisation has to be considered, together with the interrelationships of structure and human behaviour. The systems approach therefore allows organisations to be viewed both as a whole and as part of the larger environment within which it functions, so that any part of an organisation affects all other parts in varying degrees of intensity.

The business organisation is an open system within a broad surrounding environment and in which multiple channels of interaction may exist. Change in one part of the organisation, whether technical or social, will inevitably affect other organisational parts and consequently, in time, the entire system.

Based on the concept of the organisation as a system, Gibson (1997) introduced the concept of feedback. Since the organisation as a subsystem interacts with a larger system, it depends on the environment not only for its inputs, but for the acceptance of its outputs. Consequently, the organisation must develop means for adjusting to environmental demands. Simply put, feedback refers to information that reflects the outcomes of an act or series of acts by an individual, group or organisation.

Skoko (2013) reports that the use of systems analysis tools is still not widely applied in environmental and health risk management. According to him risk assessment provides a systematic approach for identifying the nature and severity of the risks associated with environmental and health hazards. Risk management means the implementation of risk control measures, following the identification and characterisation of the risks. Skoko (2013) makes a very important point: All human activities and processes bring with them a degree of risk with varying severity of impact. The aim of risk assessment and management is to provide scientific, social and practical information about the risks, so that the best possible decisions can be taken as to how to mitigate them. To manage the risks, however, one first needs to measure and quantify them. Many institutions fail to do a good job of measuring the risk and therefore control environment factors that may have an impact on human health and safety. By applying a repeatable and comprehensive methodology that measures projected risk value as well as the actual risk one can significantly improve both the assessment of and control over health and safety risks in the complex environment of developing nations.

Skoko (2013) proposes the application of systems theory to understand and manage health and safety risks. Environmental and human health has to be considered as a complex system that is constantly adapting to its environment. A multikey critical success factoral, multi-stakeholder risk assessment approach is therefore required. Environmental and human health and safety are influenced by a variety of independent factors and, because the system is socially descriptive, their societal impacts are different for every community. The environmental safety and health system thus needs to be considered together with its interactions with humans, organisations and impact processes.

Skoko (2013) points out that environmental safety and human health can be affected on four different levels:

- Individual level
- Macro level
- Environmental level
- Economic level

It is proposed that the following impact levels should also be considered in the system approach and added to Skoko's list:

- Political level, to represent the influence that politicians may have on the degree to which humans may be exposed to safety and health risks
- Legal level as a description of the regulatory process that governs the safety and health risks to which communities are exposed
- Technology level, to describe the influence of manufacturing processes that may act as major hazard installations that can have a detrimental impact on the safety and health of communities

Skoko (2013) consolidated his thinking in a model (Figure 2.1) for the assessment of safety and health risks and the identification of control factors to manage these risks to which societies may be exposed. He uses this model to identify the risk factors and to explore their interrelationships, in other words the risk factors are assessed as elements of a dynamic and complex system, characterised as nonlinear, changing, self-organising and chaotic.

The model proposed by Skoko (2013) does not make provision for natural or technological health and safety risks that can lead to major disasters such as Bhopal, Buncefield or Somerset West (studied in Chapter 3). It is therefore proposed that Skoko's model be expanded as outlined in Figure 2.2.

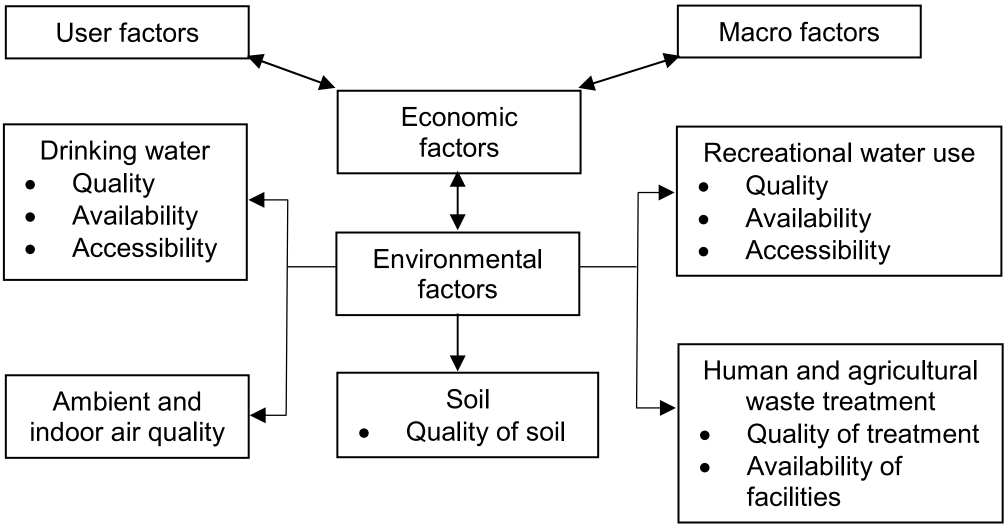

Figure 2.1 Factors and contexts of environmental and human health (Source: Skoko 2013)

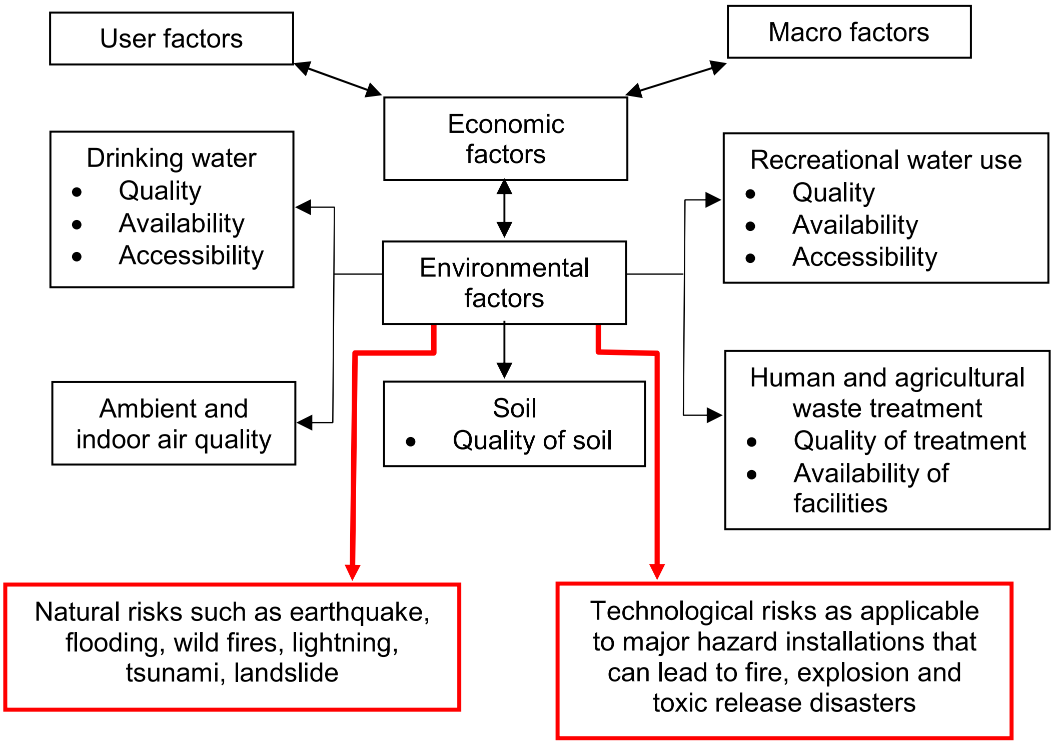

Figure 2.2 Proposed adaptation of the model of Skoko (2013) for the study of the factors and contexts of environmental and human health (Source: Adapted by author)

Holden (2005) reports that in 1963 the Massachusetts Institute of Technology studied the impact of changing only a few decimals in weather modelling data on the overall forecast result. They found that such small changes had significant effects on the overall forecast outcome, and this provided the foundation for the mathematical description of chaos. It means that small changes in the initial characteristics of an open system can have a major effect on the long-term behaviour of that system, as set out by Haigh (2002).

The characteristics of a complex system that is capable of adapting to its environment are listed by Cilliers (1998*)* as follows:

- Many different elements of the same system interact in a dynamic, interactive way with large exchanges of information among them. This concept is supported by Weihrich (2008).
- Such interactions are random, nonlinear and have a limited range due to the absence of a controlling mechanism that directs the flow of information. The nonlinearity of the interactions implies that the system behaviour cannot be predicted in any way.
- Complex systems are open systems with feedback loops, which can be both constructive and stimulating (positive) or detracting and constraining (negative). Both kinds of feedback are essential for the system to function effectively.
- Complex adaptive systems perform their functions under conditions of chaos, far from equilibrium, which means there are continual change and response to the stimuli that impact on the system. These stimuli can be regarded as the energy of the system (Cilliers 1998:4). As soon as equilibrium is attained, the system can be regarded as dead.
- Complex open systems have their own histories. No single element of the system is able to know, understand or forecast input stimuli, responses and outputs within the system.
- The complexity of a system is a direct function of the interaction patterns between the individual system elements.

Chun et al. (2008) describe the systems theory as a study that focuses on the interrelationships between the individual elements that comprise the system and the properties of a whole, rather than studying the properties of the individual elements. In this context the system is considered an entity, which maintains its function through the mutual interaction of its individual independent elements.

The process of government regulation fits the model of a systems approach with continuous interaction between a variety of system elements such as individual state departments, business enterprises, industry, individual roleplayers, society as a whole, technology and the prevailing legal environment. This process is shown in Figure 2.3, specifically tailored for the process of health and safety regulation in a country.

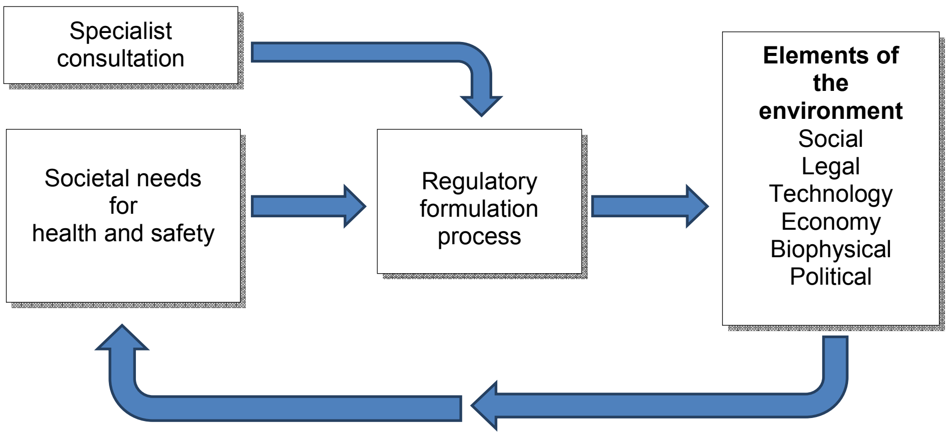

Figure 2.3 The legal regulatory process for health and safety as a system (Source: Cilliers 1998; Weihrich 2008)

Coetzee and Van Niekerk (2012) agree with a systems approach to the analysis of the evolution of a disaster management cycle. The concept of the disaster management cycle has been used for several decades to understand and manage disaster impacts. Coetzee and Van Niekerk (2012) study the origins of the disaster management cycle by applying the concepts of general systems theory, including open systems and feedback loops, similar to the work done by Cilliers (1998) and Weihrich (2008). By doing so they have been able to identify how disaster management is related to procedures such as emergency response, disaster relief, disaster recovery and post-disaster rehabilitation.

The traditional approach to disaster management was focused on response and relief actions as a consequence of disaster events, as pointed out by Twigg (2004). A preventative approach to disasters and especially a detailed analysis of the vulnerability of receptor communities were not considered at all. The high and increasing human and capital costs caused by disasters led to an awareness among nations of a more efficient way of utilising capital than merely providing rehabilitation and relief actions. Pre-disaster preventative planning appeared to be a much needed pragmatic new way of thinking about disaster management.

Renewed thinking about disaster management occurred during the early 1970s, when a sharp increase in disastrous events that caused increased deaths and greater economic losses than in previous decades was experienced (Wisner et al. 2004). The worldwide change in disaster management thinking came with a realisation that disaster risk reduction is more important than dealing with the effects in a post-disaster scenario (UNISDR 2004). The focus started to shift from effective post-disaster response to effective prevention of the devastating effects of a disaster on society.

Skyttner (2005) proposed dynamic interactive feedback models as a useful analytical tool to describe the relations and mutual influences between humans and their environment. He describes it as a process that follows three distinctive steps: Firstly, outputs from the system cross the system boundary; secondly, the outputs become modified through their interaction with the environment; and thirdly, the modified outputs re-enter the system as new impacting inputs. It allows for the analysis of exogenous factors that contribute to the initial creation of the disaster cycle. A schematic representation of the disaster cycle is given in Figure 2.4.

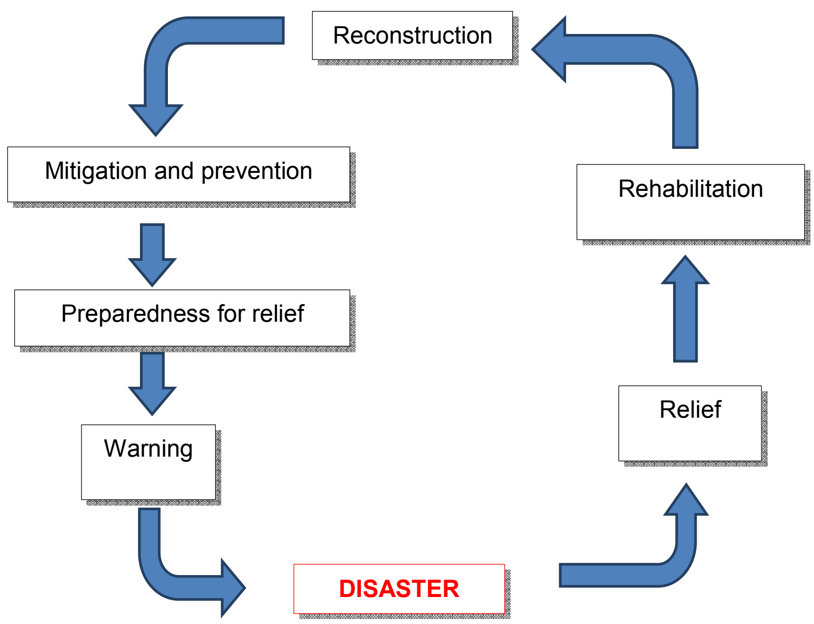

Figure 2.4 Disaster management cycle (Source: Skyttner 2005)

Authors such as Kelman (2007) and Lewis (2007) believe that the earliest research on disaster management centred on a phase approach, including phases such as emergency, relief, recovery and rehabilitation, but they are unsure when these phases started to become expressed in a cyclical format with an explicit consequential nature.

In 2010 The Swiss Federal Office for Civil Protection developed an integrated risk management model (Figure 2.5) that shows improvements on the model of Skyttner. The Swiss model includes human vulnerability assessment as an important step in the risk management cycle, but lacks any reference to Natech incidents.

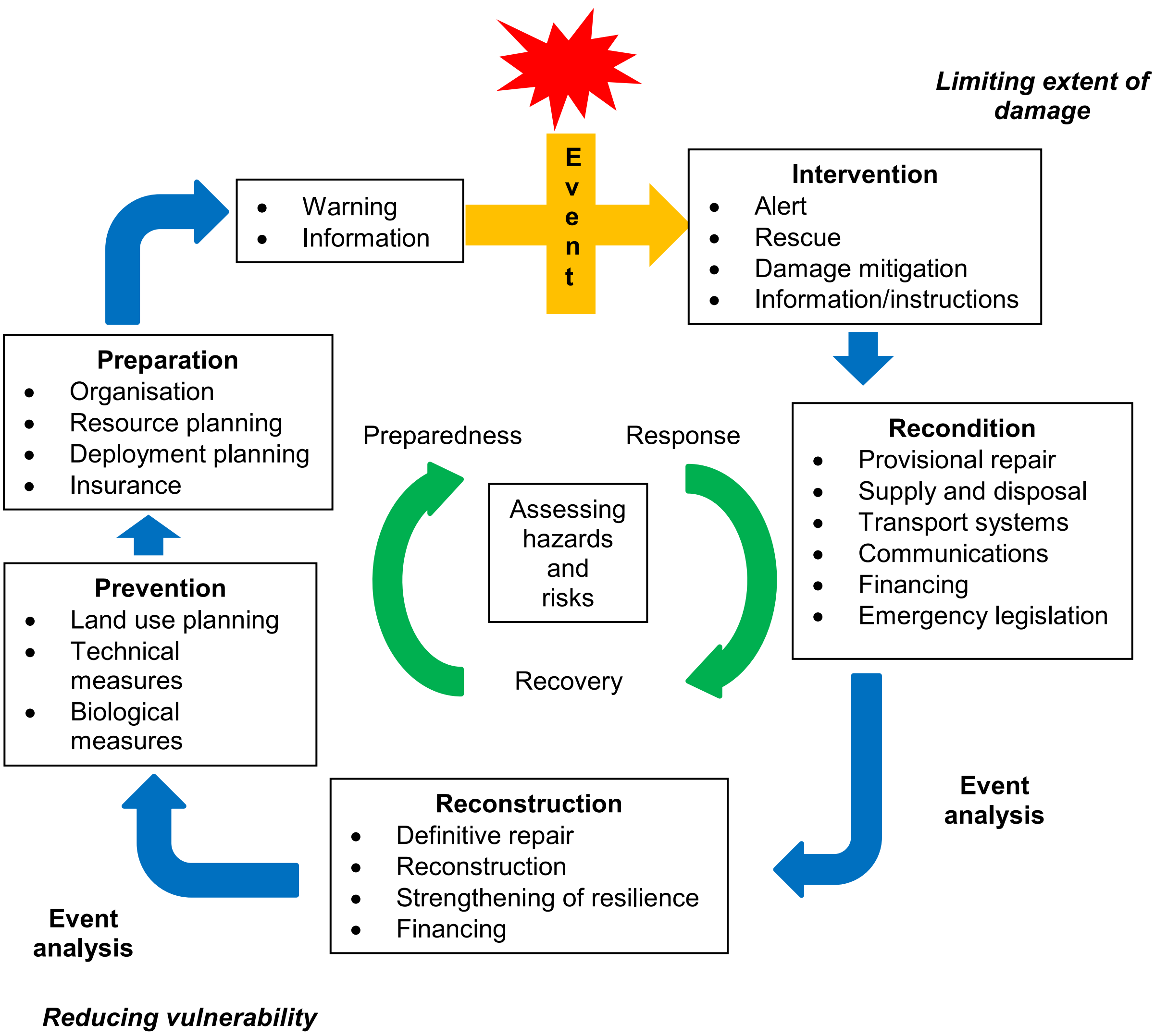

Figure 2.5 Cycle for integrated risk management (Source: Swiss Federal Office for Civil Protection 2010)

In the development of the proposed model for the regulatory management of hazardous installations in South Africa, a systems approach will be followed, focusing in particular on the following three system components:

- The environment in which the installation operates, including its exposure to natural disasters
- The society in the installation (employees) and around the installation (communities)
- The economy, which comprises a technological and a legal/political component

2.2.2 The regulation and control theory

The global society in which we live is complex. Human populations are growing to extremes where the sustainable utilisation of natural and manmade resources is stretched to the limit. It is becoming increasingly difficult to balance the allocation of capital as wealth creation instrument in societies with the available skilled human resources. Beck (1992) states that we live in a *"risk society"*. This means that *"risk"* has a different significance for everyday life from that applying in previous eras. Human activity and technology in *"advanced modernity"* produce as a side-effect risks that:

- Need specialised expertise to assess and recognise
- Are collective, global and irreversible in their impact
- Are potentially catastrophic on a scale never seen before

We also live in a *"regulatory state"* (Majone 1994). A new institutional and policy style has emerged in which the role of government as regulator advances, while its role as a direct employer or property owner may decline through privatisation and bureaucratic downsizing. In the process the state assumes a stronger regulatory function. Risk society and regulatory state can be linked: Risk and safety are often seen as the major drivers of contemporary regulatory growth, for example in the development of European Union Regulations.

Gunningham (2014) studied the role of systemic risk management and regulation as one crucial component of an effective preventative workplace health and safety strategy. In particular, the author examined the implications of the study on the coal mining industry in two coal mining states of Australia.

According to Gunningham (2014) there has been a substantial decline in the rates of fatal and other recorded injuries in Australian coal mines since the late 1990s. This decline correlates with the introduction of new coal mine workplace health and safety legislation, which structured health and safety risk management concepts and workplace health and safety management systems, aligned with international best practice. Most injuries and incidents are not simply due to technical failures, but usually involve an organisational or management failure. Gunningham (2014) believes that the best way of addressing such failure is to develop a systemic risk-based approach rather than a localised prescriptive one. The systemic approach means that the regulator looks at the industry as a whole, including all its facets of operation, their interactivity and mutual dependence. In short, a holistic system approach was followed. This regulatory design resembles the systemic risk management practices of the industry itself, which have evolved over the years.

However, according to Gunningham (2014), even the best legislation may not deliver its intended outcomes if it is resisted by stakeholders or if it is not effectively implemented and administered. Resistance has grown within various stakeholder groups like industry management, government inspectorates and the principal trade union. A further contributing factor to hampered legislation implementation is the failure of senior management in some organisations to exercise strong leadership or to entrench systemic risk management at worker level. Within a well-established set of health and safety legislation, a good safety record should not be a reason for complacency. Gunningham's research (2014) suggests that serious concerns remain within some mines that could lead to disaster. Senior management should be made aware of the nature and extent of these problems.

The research by Gunningham (2014) raises a number of learning points that are useful for the development of a new regulatory model for hazardous installations, such as:

- No regulation is perfect. The element of human behaviour, in all its complex facets, cannot be eliminated by laws. No matter how well the legislation has been researched, planned, designed and communicated to stakeholders, it is inevitable that it will encounter social resistance from the public, employees, trade unions and investors.

- Legislation has a higher chance of being successfully implemented with a high compliance rate if a systemic risk-based approach is followed instead of a localised prescriptive approach. This implies that all stakeholders must be engaged and that all the interdependent social-environmental components must be addressed successfully.

- Performance measurement is a useful instrument to gauge the success or failure of implemented legislation. Record keeping of parameters that form the focal point of the legislation (injuries and fatalities in the case of the Australian coal mining industry) is essential to perform a before and after evaluation.

- No matter how meticulously the legislation has been designed and implemented, there will always be a crucial governance role in the form of inspections. This is an important part of regulatory administration at all levels of government and must not be neglected.

The development of new risk regulation can also be interpreted to reflect broader political and cultural change (Hood et al. 2001), which is especially true in the case of South Africa's relatively new democratic state. Hood et al. (2001) focus on the origin of regulations and how initial concepts are developed into formal regulatory structures in a country.

The work of Hood et al. (2001) is of paramount importance for this study, as it lays the conceptual foundation for the formulation of a new regulatory model for health and safety regulation. It forms the fundamental point of departure for this research. The authors utilised systems theory for regulation formulation, viewed from a cybernetic perspective as their departure point, to generate a general control theory that is widely used in the sociology of law and policy studies.

There is an interesting similarity in the empirical conclusions that Gunningham (2014) reached and the theory put forward by Hood et al. (2001) with regard to the following:

- A structured approach has to be followed in the development of new legislation. A systemic risk-based plan shows high potential for success.

- Information should continuously be gathered as input to new legislation formulation, but also as indicator of the success of the legislation in terms of its goal.

- Consultation with all relevant stakeholders is important to get buy-in and prevent later resistance after the legislation has been implemented.

- The overall purpose of any legislation is to achieve social behavioural change. People must be encouraged to do things differently, especially with regard to the health and safety of others. This is a core concept that has to be taken into consideration in any new legislation formulation.

- The vital role of managers must never be underestimated. Health and safety legislation is focused on the way in which hazardous installations are designed, operated, inspected and maintained, for the safety of employees and the public at large. Systems should be in place in the workplace to ensure that employees are managed properly with the aim of avoiding major destructive incidents.

According to Hood et al. (2001) any regulation regime has two critical dimensions, shown in Figure 2.6.

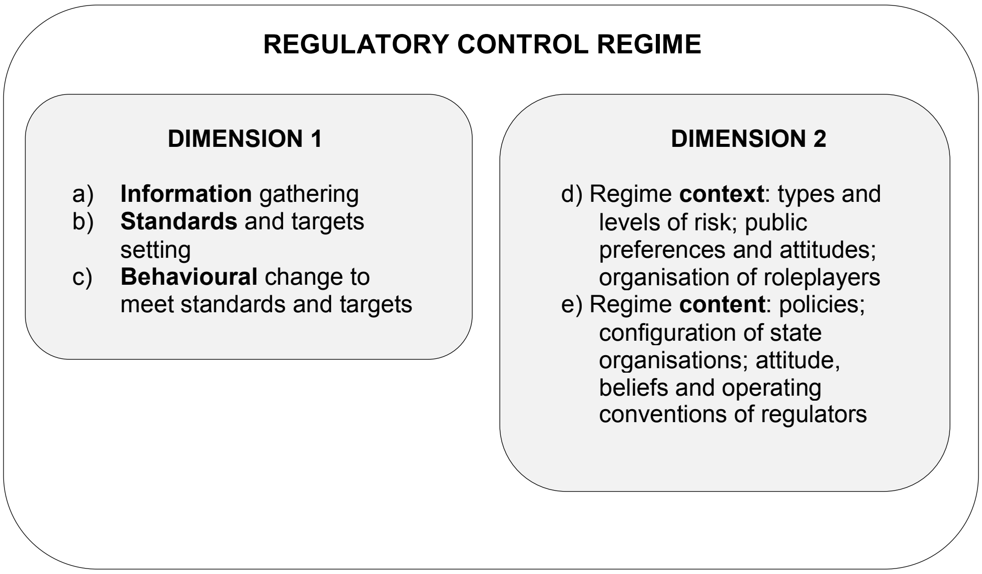

Figure 2.6 The anatomy of regulatory regimes (Source: Hood et al. 2001)

Dimension 1: Any control system comprises three essential elements: gathering information; setting of standards, goals or targets; and changing behaviour to meet the standards and targets. If any of these components are absent the control system cannot perform its function.

Dimension 2: Regulatory regime context and regulatory regime content. Regulatory regime context is the backdrop or setting against which regulation takes place. It includes the types and levels that the regulation has to address, the public preferences and attitudes towards the specific risk and the way in which the various roleplayers who are affected by the risk are organised. Regulatory regime content comprises policies, the configuration of state organisations directly involved in regulating the risk, and the attitude, beliefs and operating conventions of the regulators.

(a) Dimension 1: Information gathering

The gathering of information is central to all regulation, especially to risk regulation when issues of probability and consequence or incident severity are involved. During this step, politics play an important role and explain the wide variation in levels of regulatory monitoring of environmental pollution among EU member countries. The information gathered serves as a foundation for the formulation of new regulation. The information can be gathered by the regulating authority through several methods, including:

- The regulator conducts its own measurements, experiments and analysis. This can be achieved by imposing a legal requirement on industry roleplayers to report certain information or to pay someone to gather such information.
- It can be provided voluntarily by complainants, whistle blowers or individual persons or organisations.
- Information can be collected through physical surveillance using data-specific technology.
- The risk regulator may also build on the experience of other countries, which usually have access to valuable information and expertise from their own past experiences. This method has up to now been utilised by the South African government, by tapping into the information resources provided by the Health and Safety Executive of the UK.
- Another important way in which information can be gathered that is not mentioned by Hood et al. (2001) is evidence-based information collected from historical occurrences, such as the Seveso, Bhopal, Buncefield and other disasters.

(b) Dimension 1: Standard and target setting

Standards and targets in health and safety regulation are important, because this regulation encompasses issues related to the value of life and the levels of risk that are considered to be acceptable. These are contentious issues, which is why the South African Department of Labour has been struggling with the formulation of new Major Hazard Installation Regulations for the past four years. According to Hood et al. (2001) standards and targets may be set by the regulator in one or all of the following ways:

- Implementing a technocratic approach, by using technical data from the outcome of systematic testing
- Drawing on the know-how and experience of other countries
- Bargaining among all participants with different interests with the aim of producing a solution that represents a compromise between rival positions, such as greenhouse gas or occupational health and safety standards
- The regulator may select some arbitrary standard or target in a rather non-democratic manner and impose it on the roleplayers

(c) Dimension 1: Behavioural change

Hood et al. (2001) argue that changing the behaviour of individuals and the organisation is an issue that elicits a great deal of debate in the political and public domain regarding risk regulation and as such can become a highly problematic component of risk regulation. People and organisations are generally resistant to change, for various reasons. People may see change as a potential disruption of their conventional way of working and living, especially if there are large differences in cultural beliefs. Organisations may see change as a threat to their profitability and investment, which was already made in a particular regulatory regime. Hence, behavioural change is a difficult concept that any regulatory regime has to achieve. Hood et al. (2001) state that behavioural change can be accomplished in the following ways:

- A compliance-orientated approach can be followed, such as in EU occupational health and safety regulatory regimes.

- A deterrent doctrine can be followed, such as in the USA. This punitive approach naturally relies on the credibility of penalties or punishment.

- A doctrine of diplomacy, persuasion and education can be followed. This approach depends on the prevailing culture in societies.

(d) Dimension 2: Regulatory regime context

The type and level of risk that needs to be regulated is an important consideration and involves the inherent features of the hazard and the perception of the risk. It includes the following:

- The hazard or cause of the risk.
- How familiar and well-established the risk is.
- How easily the risk can be quantified.
- The timing and impact of the risk.
- The probability of occurrence of a major incident associated with the risk.
- The severity of the consequence of a major incident associated with the risk.
- The extent to which the risk can be managed through market processes in the absence of regulation, such as self-regulation, insurance, international standards that are mandatory for global trade (ISO-14001 and ISO-9001) and contracts that oblige industries to comply with certain minimum market requirements.
- How easily the risk can be mitigated.

Public preferences and attitudes, which are closely related to risk perception, have much to do with the media publicity received and public opinion about it. Regulation in a societal environment where the public is well informed about the risk and the advantages and disadvantages of the regulation, is easier to implement and monitored than in the absence of public information campaigns. Pressure groups also play an important role to create media coverage of the risk.

The organisation of roleplayers implies the manner in which risk-givers (creating the hazard) and risk-takers (exposed to the hazard) are structured. Risk regulation is strongly influenced by how well stakeholders are established in a group, and structured and mobilised.

(e) Dimension 2: Regulatory regime content

The content of the regulatory regime is largely determined by the regulator itself, its policies, the configuration of state organisations, the attitude and beliefs of the authority and the operating conventions of regulators. Much of this, of course, is dictated by the prevalent political climate in a country. The content comprises three essential elements, namely size, structure and style.

Size refers to the quantum of the regulation and comprises the following:

- The aggression with which risk is tolerated in standards, targets and behaviour-modification doctrines
- The scale of investment in state resources such as finances and labour to create the regulation and administer compliance
- The cost of compliance imposed on industry roleplayers

Structure refers to the way in which the regulator is organised in terms of resources, policies, guidelines and monitoring mechanisms. It may comprise a mix of state and private enterprise involvement. Once again, the political climate plays a very important role in the regulatory regime content.

Style refers to the attitudes, beliefs and operating conventions of the state authority. It may exhibit a policy of rule-bound command and control (such as in the air and space and weapons industry) or it may have a discretionary, more lenient, approach (such as in the enforcement of limits on road traffic speeding).

It is noted that Hood et al. (2001) place much emphasis on the process of development of new legislation, but their approach is lacking in two respects:

- The regulatory development process does not include post-implementation measures to determine whether the legislation is effective or not. These measures should include indicators such as social acceptance or rejection, behavioural trends and quantified testing of critical parameters that are linked to the goal of the legislation, i.e. to reduce the number of human injuries. Is the trend increasing or decreasing and is the legislation achieving what it was designed to achieve?

- The process does not include post-implementation monitoring measures, such as inspections as part of governance administration, to ensure successful implementation of the legislation. This is usually the neglected part of legislation development and implementation. To make a new law is easy; to enforce it successfully is more difficult. The administrative governance role should also include a continuous feedback system with recordkeeping to evaluate the successes and shortcomings of new legislation.

Levi-Faur (2010) describes a comprehensive conceptual framework for the study of regulatory governance as an interdisciplinary subject, by combining a state-centred perspective with a civil or private regulation perspective. It is suggested that the study of regulatory governance should extend beyond states, markets and societies and identify combinations of regulatory forms and the creation of autonomous regulatory platforms that can bridge the gap between global and national operational spheres. Levi-Faur (2010) makes three valuable points:

- The concept of self-regulation is promoted strongly.
- Regulatory governance should span over continents, to cover both local and international legislation. This is particularly valid for health and safety regulation, where the protection of human lives should be the same all over the world. Major hazard installations have the same potential impacts on communities, irrespective of the country of location.
- The continuous involvement of the civil sector is crucial for the proposed regulatory regime to be successful. It contains an element of self-regulation.

A very important aspect of regulatory policy is touched upon by Stiglitz (2012), namely inequalities in society. Although he focuses on economic inequality, the fundamental principles that the theory is based on remain applicable to health and safety regulation too. He describes inequality as the gap between what economic and political systems are supposed to achieve and what they actually achieve. He hypothesises that market forces are real, but that they are influenced by political processes. Markets are shaped by laws, regulations and institutions. Laws, regulations and institutional arrangements have distributive consequences, usually to the advantage of the political and corporate powers at the top and to the disadvantage of the rest of the nation. Another factor that determines societal inequality is societal norms and social institutions. Politics shape and endorse societal norms.

Stiglitz (2012) believes that an effective economic reform strategy would simultaneously increase economic efficiency, fairness to all and opportunity for all. This is an important consideration which any regulatory regime should be able to achieve. By applying the belief of the author one comes to the following conclusions, particularly against the background of regulations aimed at making hazardous installations safer:

- The regulatory management of society cannot be left to the markets to do. Specific intervention by politicians is necessary. The case of socio-economic inequality is used as illustration by Stiglitz (2012), but the principle is equally applicable to the health and safety regulation of industry. The danger here lies in the creation of unequal manufacturing entities with the resultant distortion of market competition.

- Regulatory dispensations distort the functioning of markets through the interaction of political and economic forces.

- In their explanation of the regulatory process Hood et al. (2001) did not place enough emphasis on the distortive effect that legislation can have on market forces.

Governance is the process of creating conditions for orderly rule and collective action (Stoker 1998). Hence, the deliverables of governance are the same as those of government, only the processes differ. Stoker (1998) identifies five salient aspects of governance, namely:

- Governance implies a set of institutions and actors that are drawn from inside, but also from outside government. This view concurs with that of Levi-Faur (2010) where he argues for the continuous involvement of the civil sector in regulatory development.

- Governance recognises the overlapping of boundaries and responsibilities in the attempts to solve social and economic problems. This aspect is important in the

South African context, where there are several different pieces of legislation that aim to govern the health and safety of people.

- Governance takes into account the power play in the relationships between the various institutions that are involved in collective action.
- Governance is about the interaction of autonomous networks of self-governing actors. This aspect also agrees with what Levi-Faur (2010) proposes about self-regulation.
- Governance creates the ability and capacity to get things done, which is not dependent upon the power of government. The role of government is seen as having the ability to provide guidance.

2.2.3 The sustainability theory

Jenkins (2009) defines sustainability as the *"capacity to maintain some entity, outcome, or process over time"*. Note that this definition encompasses life and human livelihoods and any activity that threatens life or livelihoods should be regarded as unsustainable and therefore unacceptable. The author states that the term *"sustainability"* also refers to the ways in which environmental degradation impacts on economic ecological and social systems. It means sustainability focuses on the mutual effects between environmental degradation caused by human activities and the threats posed to social systems presented by global environmental problems. Jenkins (2009) asks the question: "Can human activity successfully maintain itself and its goals without exhausting the resources on which it depends?" This question points to the purpose of a global human society, its powers and the risks it creates. The mitigation of society's environmental impact on the planet and risk requires deliberate changes across a spectrum of human activities, namely in the spheres of finance, politics, production, energy utilisation, transportation, communication and education; in fact, the entire spectrum of industrial activities can be included here. The challenge is that attempts to effect such changes could be in conflict with other goals of communities, such as poverty reduction and the protection of human rights.

Sustainability science inevitably involves the complex mutual interdependency of social and ecological systems. Economic development and growth must be integrated in a balanced manner with ecological integrity, social needs and responsibility to future generations. The principle of sustainability has changed the way in which global industries and markets function. It has gained impetus during the past two decades as an instrument to achieve many political goals, including climate change treaties, free market principles, environmental conservation and social spending.

What must be sustained? Jenkins (2009) believes that the answers to this question are divided into three approaches: strong, weak and middle:

- **Strong sustainability** gives priority to the preservation of ecological goods, like the preservation of biodiversity and the existence of species or the functioning of particular ecosystems such as wetlands. This view is therefore in line with the topical belief of environmental conservation as a vitally important livelihood requirement for future generations. From this perspective the protection of forests, as an example, would be essential, even if it required stopping development that would increase opportunities for future generations. This is an ecocentric (ecologically centred) view and requires moral decisions to take into account the value of ecological integrity as opposed to only considering short-term human interests.

- **Weak sustainability** disregards specific obligations to sustain any particular good or system and advocates only a general requirement to leave future generations no worse off than today. For example, this view would take into account the various benefits that forests provide and would then attempt to measure the future value of those benefits against the values created by human development. This view can be regarded as an anthropocentric (human-centred) position in environmental ethics.

  An interesting dilemma arises in that a strong sustainability view could be held from an anthropocentric perspective also by arguing that human systems depend on rich biodiversity or that human dignity requires access to natural beauty inherited from creation. In the same vein a weak view would not necessarily promote the exploitation of natural resources, even with the prospect of lucrative short-term profit. This is because there is a rational understating among the supporters of this view that opportunities for future generations depend on certain vitally essential ecological processes, such as clean air and water, to sustain biological life. Some ecological goods or systems will always be more valuable than the economic development that is proposed to replace them.

- **Middle (medium) sustainability** is the third approach, between strong and weak. This pragmatic view assumes that, while we may not have obligations to sustain any particular non-human form of life or ecological process as an environmental feature (the strong view), neither should we assume that current and future opportunities can be measured against one another (the weak view).

In their case study of the Nauru Pacific Island, Tietenberg & Lewis (2016) also discuss the concepts of strong versus weak sustainability. The authors use weak sustainability as criterion to determine whether a reduction in natural resource capital is balanced by financial capital as a means of preventing total capital from declining. The case study explains the importance of preservation of natural ecosystems and the implementation of additional measures to ensure long-term sustainability by maintaining the value of total capital. Strong sustainability, on the other hand, is defined by the authors as maintaining the value of natural capital.

The question that immediately comes to mind is: How can hazardous technological facilities be managed so that long-term, strong sustainability can be achieved? There is no short answer, but what can be concluded from the work of Jenkins (2009) and Tietenberg & Lewis (2016) is that technological facilities have to take protection of the ecosystem seriously into consideration in order to maximise natural capital. It requires a shift in focus from socio-economic system protection to include the protection of biophysical systems – a shortcoming in the existing South African MHI Regulations (2001).

Barry (1997) argues that the preservation of some opportunities for future generations requires the enduring existence of particular ecological goods. For example, the opportunity to decide whether or not forests are required for a decent human life depends on their preserved existence. This middle approach confirms that the sustainability theory, like any theory, is far from being fully developed. It effectively suggests that conditions must be sustained for the ongoing debate and research on the topic of sustainability.

According to Jenkins (2009) four different models have been developed to prioritise and integrate social responses to environmental and cultural pressures, namely economic, ecologic, political and religious models.

2.2.3.1 Model 1: The economic model

This model aims to sustain natural assets, monetary capital and opportunity. Solow (1993) suggests that sustainability should be seen as an investment dilemma in which monetary investment returns from the use of natural resources must be used to create new opportunities of equal or greater value. Monetary spending on poverty relief or on environmental protection takes away from this investment potential and therefore competes with a commitment to sustainability.

According to Sen (1999*)* options for the future are created by creating options for today's poor, because more options will promote greater development. This approach has a bearing on human decision-making in all spheres of life, because decisions are nothing but choices between alternative options.

2.2.3.2 Model 2: The ecology model

The ecological model focuses on the preservation of biological diversity and ecological integrity. The reasoning is that there is a difference between monetary capital and natural capital. As a result Daly (1996) argues that the creation of sustainable opportunity for the future requires strong conservation measures today to preserve ecological goods as natural capital for the future and to keep economies operating in respect of available natural resources. In this context spending on the poor might be regarded as a kind of investment in the future. This model has a strong emotional element. Communities tend to support ecological conservation efforts, but their support depends on several factors such as level of poverty, level of education and cultural beliefs.

2.2.3.3 Model 3: The political model

Political models endeavour to preserve human dignity within social systems (Jenkins, 2009). In this political model of sustainability, sustaining opportunity for the future requires investing in individual dignity today. For example, this model supports strong investment in poverty relief and healthcare. The ecological approach complements this model.

Like the middle view, the political model embeds a pragmatic approach that suggests we should maintain conditions for continuous debate about sustainability. In this view sustaining a political system of democracy effectively requires sustaining economic and ecological goods along with political goods such as human rights. Two considerations are important in this regard. Firstly, both the quality and the quantity of those goods is regulated by the needs of the political system, which thereby constrains sustainability commitments. Secondly, the political model is based on the assumption that political systems are ideal or flawless - which we all know from experience, is clearly not the case.

2.2.3.4 Model 4: The religious model

The newly developed religious model proposed by Jenkins (2009) aims at utilising symbolic and motivational resources for cultural change. It is possible that those spiritual commitments can motivate change and that religious communities possess powerful authority for cultural transformation. Sustainability requires meaningful cultural change. A sustainable ecology depends on society's moral consciousness, which is profoundly shaped by religion.

Religious symbols and practices have strong capacities for interpreting the complexity of life and generating holistic responses to sustainability issues. Part of the challenge of sustainability is to understand the mutual relations of humanity on a global scale. In this regard religions may have useful resources. If widespread environmental degradation can be interpreted as an alienation of humanity from the rest of the living earth, then spiritual practices may help to bridge this gap and reconcile humans with the needs of the environment.

The theoretical approaches to sustainable development since 1998 indicate a range of different views on various frameworks, as outlined by Ayre and Callway (2005). In the Northern Hemisphere the focus is on environmental protection issues such as climate change, biodiversity and the protection of species. In the Southern Hemisphere there is continuing concern about poverty alleviation, human health, development of enterprise bases and the achievement of the necessary economic growth.

At least three models have been developed so far to describe the theoretical concepts of sustainable development. Pioneering work has been done in this regard by Levett (1998). In his first model, called the Venn Diagram model, sustainable development is portrayed as a close interaction of three systems: social, economic and environmental, as shown in Figure 2.7. Four possible outcomes are identified in this system interaction model, namely:

- *Viable* development, where there is proper integration between the economy and environment systems.
- *Equitable* development, where there is proper integration between the economy and society systems.
- *Liveable* development, where there is proper integration between society and environment systems.
- *Sustainable* development, where the three systems – environment, society and economy – are integrated.

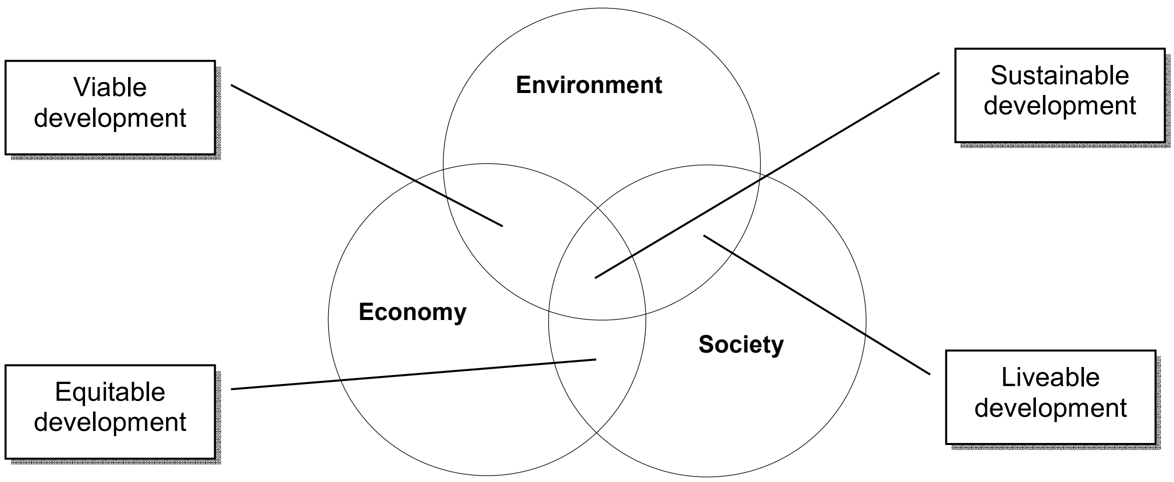

Figure 2.7 The Venn Diagram model of sustainable development (Source: Levett 1998)

Levett (1998) later revised this model and developed the Russian Doll model as shown in Figure 2.8. In the revised model, the environment is considered as the provider of all visible and invisible natural resources and therefore as the life support system of society. Economic activity should be focused on social progress, which has to be achieved within environmental constraints. Thus the community and the economy have a responsibility to protect the environment. The Russian Doll model reveals that factors affecting social and economic development are limited by the capacity of the environment, i.e. its ability to tolerate pollution or the utilisation of natural resources.

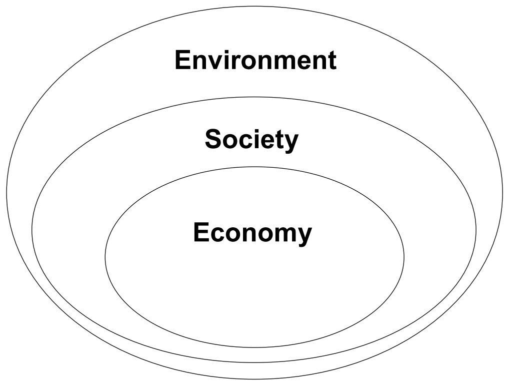

Figure 2.8 The Russian Doll model on sustainable development (Source: Levett (1998)

The Russian Doll model of Levett (1998) is endorsed by Dit Yvon (2013), who applies it in an analysis of sustainable development in a city context. Dit Yvon states that strong sustainability can only be achieved when natural capital (biophysical and socio-economic environmental health) cannot be substituted by a different type of capital. The Russian Doll model of Levett represents strong sustainability, because the good health and conservation of the surrounding environment is considered a prerequisite for sustainability. No price can be put on the value of nature. If such an attempt is made, for example if the cost of environmental conservation measures is considered too high, the resultant sustainability will be weak. This concept is especially true of the health and safety of societies as an important element of the environment, where major hazard installations may have severe impacts on the livelihood of people. This aspect is discussed further in Chapter 3 by way of three case studies.

The Russian Doll model of Levett was revised by Pei-Ing et al. (2014) and named the Night Owl model (see Figure 2.9).

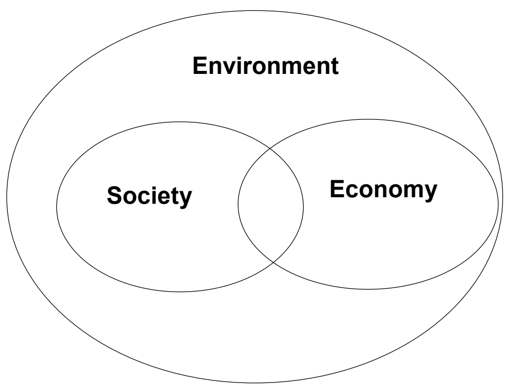

Figure 2.9 The Night Owl model on sustainable development as an alternative to the Russian Doll model (Source: Pei-Ing et al. 2014)

This alternative model focused on the interaction between society and the economy, which together negatively affects the environment. The Night Owl model differs from the Russian Doll model only in the degree of interaction between society and the economy. While the Russian Doll model portrays the economy to be entrenched by society, the Night Owl model considers only a partial interaction between the societal and economic systems.

A critical evaluation of these three models on sustainable development reveals that Levett (1998) and Pei-Ing et al. (2014) consider only three interactive systems, namely society, environment and the economy. However, two more systems should be considered as parts of the interactive process, namely technology and political systems. The political system is discussed by Jenkins (2009) as a critical component of the sustainability domain.

Starik and Kanashiro (2013) are of the opinion that global business, as well as society in general, is experiencing one of the most significant changes since the information revolution of the 1990s. The desire of individuals, organisations and societies to develop the capacity for environmental and socioeconomic long-term improvements of quality of life (the sustainability revolution) could even encompass the information revolution. It may be the most transformative cultural phenomenon since the industrial and agricultural revolutions. The information, industrial and agricultural sectors of society all vitally depend on a multitude of environmental and socioeconomic aspects.

Against this background, it is proposed that the models of Levett (1998) and Pei-Ing et al. (2014) be expanded to include technology as well as legal and political systems in the sustainability model. That would result in the model shown in Figure 2.10.

Dit Yvon (2013) makes out a case for the sustainable design of cities in France, which has an important bearing on this study as far as land use planning around major hazard installations is concerned. Dit Yvon (2013) considers the choice and design of sustainable development as an agreement, based on trust, between three entities:

- Scientists.
- Politicians.
- Society (citizens).

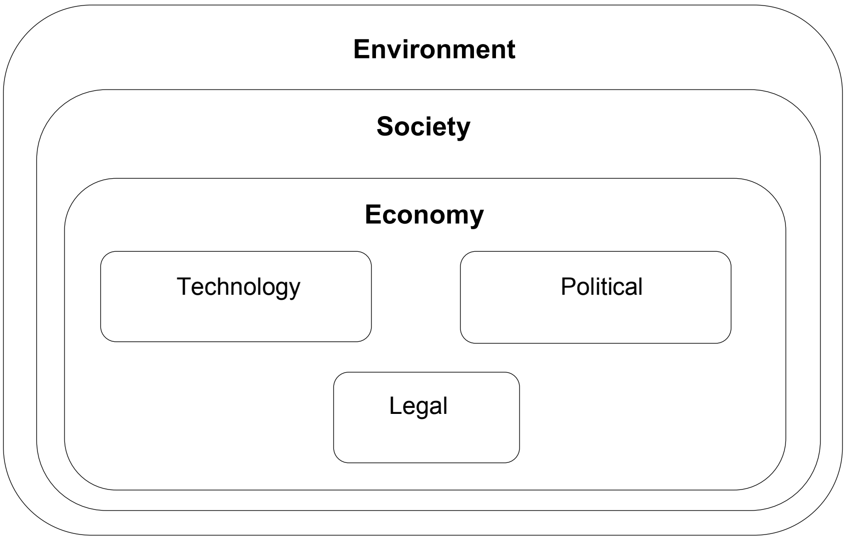

Figure 2.10 Alternative model for sustainable development that includes technology as well as legal and political systems. (Source: Levett 1998 and Pei-Ing et al. 2014. Adapted by author)

The tripartite alliance of Dit Yvon (2013), based on previous work by Shields et al (2002) is illustrated by cooperative processes and consultative participation approaches to sustainable development aspects. It is represented in Figure 2.11:

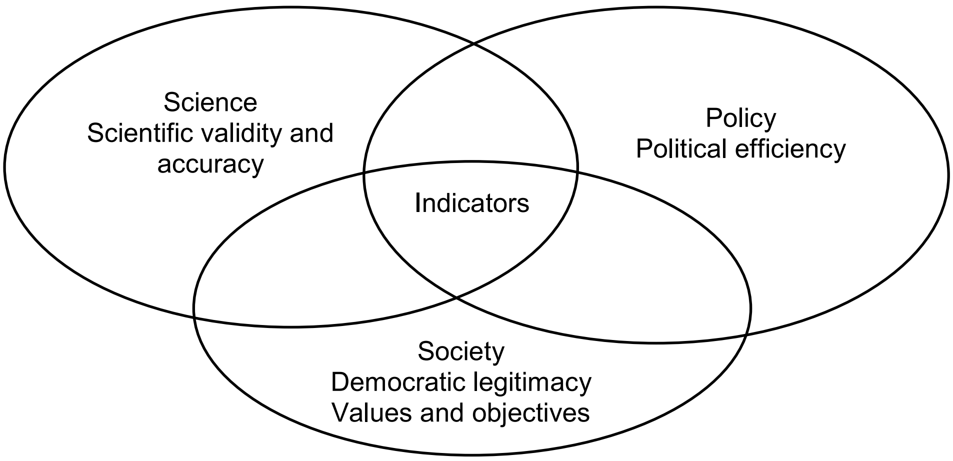

Figure 2.11 Indicators at the crossroads of science, policy and society (Source: Shields et al. 2002, as modified by Dit Yvon 2013)

The above model for sustainable development supports the alternative model proposed in Figure 2.5, as modified from Levett (1998) and Pei-Ing et al. (2014) where –

- scientists are substituted with technology;
- a legal component is added to represent existing legislation;

- the biophysical and socio-economic environments are added; and
- the technology, political and legal components of the system are integrated into the economic domain.

The integration of technology and the legal and political systems into the sustainable development model is of particular significance for this study. Firstly, major hazard installations are based on specific technology, which determines their hazardous nature and its profound impact on the health and safety of people. Rapid advances in technological development in an attempt to improve the environmental and socioeconomic quality of life are contributing to the current sustainability revolution, as described by Starik and Kanashiro (2013).

Secondly, the functioning of societies is primarily determined by political systems. Politicians create the culture in which communities live, through the rendering of essential services, creation of infrastructure, spending of taxpayers' money and, above all, the making of laws. The regulatory management of health and safety risks associated with major hazardous facilities is determined primarily by legislation, which falls within the political system. This legislation is the focal point of this study.

Holman (2005) considers policy formulation processes as linear and purely as indicators that act as input into the sustainable development process. Levrel and Bouamrane (2008) agree by stating that an indicator is both an action tool and a tool of proof with a political and a scientific function. However, this view differs from that of Cilliers (1998), who claims that, from a systems perspective, such inputs are nonlinear and random. The latter interpretation makes more sense, considering the variable nature of consultative contributions to policy formulation systems: Depending on the composition and power of lobbying groups and their large variability, policy outcomes may also vary randomly as political goals. There is no predictability in such systems. Holman (2005), however, admits that the linear characteristic of indicators presents difficulties, because it fails to explain the complex nature of governing frameworks, which results in unexpected policy decision outcomes.

While development of the term *"sustainability"* occurred in the biophysical and socio-economic environmental domain (Turner IIA, Kasperson, Matson, McCarthy, Corell, Christensen, Eckley et al. 2003; Skyttner 2005) it has become of equal importance for the health and safety risks that hazardous facilities present globally to human societies.

From this perspective sustainability should be viewed as a prerequisite for human survival in the short, medium and long term. All four models described above (economic, ecologic, political and religious) can be applied to industries where hazardous facilities are present. These technological facilities inherently have the potential to kill people – employees and members of the public alike.

From a systems perspective, as promoted by Cilliers (1998), Haigh (2002), Holden (2005), Weihrich (2008) and Chun et al. (2008), it is deduced that hazardous facilities interact in four distinct ways with societal systems:

- Existing technological facilities may interact with an existing or matured formal or informal society. An existing hazardous facility represents a plant that was built and commissioned in the past and is now in operation. An existing society represents a community, urban suburb or rural village that has reached maturity in terms of its potential for growth or expansion.
- Existing technological facilities may interact with a developing society. Societies usually find themselves in a fast growth, slow growth, stagnant or negative growth phase. Fast growth would occur in cases where new industrial development attracts jobseekers. Slow growth would occur where there is no incentive for people to settle in that particular locality and growth occurs only as a result of births and marriages. Societies may stagnate as a result of incentives to settle in other localities and the outflow is balanced by organic growth as a result of births inside the established community. Negative growth in a society means that the rate of increase in the population is less than the rate of diminishing. This may be the result of higher incentives to resettle in other localities or increased mortality due to health deficiencies.
- Developing technological facilities may interact with an existing (matured) society. Such facilities include new production plants being planned or under construction, or existing plants that are being expanded to achieve higher production rates.
- Developing technological facilities may interact with a developing society.

Note that the above interactions are not mutually exclusive, in other words a facility may be in a developmental phase while it interacts with both existing and developing societies. On the other hand, an existing developed society may interact with an existing facility that is in the process of being expanded or upgraded for the implementation of new technology. The interactive system is shown in Figure 2.12.

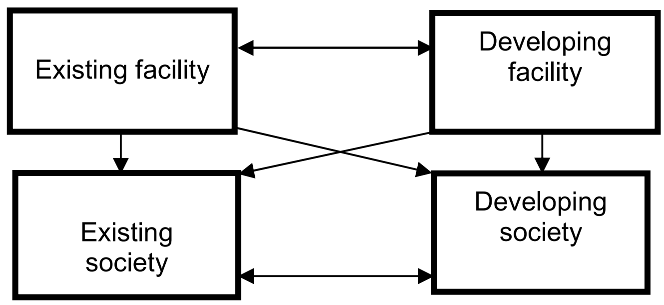

Figure 2.12 Phases of interaction of technological facilities with society (Source: Author)

The development of an optimised model for the regulatory management of health and safety risks associated with hazardous facilities has to take the facility-society systems interaction into consideration. The implementation of specific legislation is a regulatory management tool and should aim to achieve the goal of protecting societies against the hazards of such facilities. As agreed in the European Convention for the Protection of Human Rights and Fundamental Freedoms (2010) governments around the world have an obligation to protect the lives of their citizens through legislation.

The supplementary definition of Jenkins (2009) of sustainability as the "capacity to maintain some entity, outcome or process over time" is of particular significance for this study. *"Entity"* and *"outcome"* are interpreted within the technological facility-society system interaction as also meaning *"lives"* and *"livelihood".*

2.2.4 The vulnerability theory

WHO (2002) proposes a broad interpretation of the vulnerability concept as *"the likelihood of injury, death, loss and disruption of livelihood in an extreme event, and/or unusual difficulties in recovering from negative impacts of hazardous events – primarily related to people".* This supplementary interpretation emphasises that the main elements of vulnerability are those conditions that determine and increase the likelihood of injury, death, loss and disruption of the livelihood of human beings. WHO (2002) also concludes that human vulnerability is caused by the presence of a hazard. The concept of vulnerability of social groupings without a specific hazard that may impact on them, is meaningless.

Turner II et al. (2003a) did pioneering work on vulnerability analysis, focusing on global environmental change, the structure and function of the biosphere and the effects that humans have on them. The work that has been done so far in the field of sustainability science has created a better understanding of the reciprocating human-environment interaction. The objectives of the science are to increase knowledge and understanding of the needs of society on the one hand and sustaining the planet's life support systems on the other.

Turner II et al. (2003a) developed a vulnerability framework based on the concept that vulnerability is dependent on the condition and functioning of the coupled human-environment system, including the response capacities and system feedback to the hazards that the system is exposed to. The framework provides a general description of the concept of vulnerability and its interaction with other components of the social system.

The research of Turner II et al. (2003a) illustrates the applicability of the vulnerability framework through three case studies in different climatic regions: the tropical southern Yucatán, the arid Yaqui Valley of northwest Mexico and the pan-Arctic. These cases illustrate how the vulnerability of systems to environmental hazards and the coping capacities of affected people can be reshaped by external forces.

Note that although the vulnerability framework does not take human-induced risks resulting from major hazard installations into consideration, there are several distinct similarities between environmental and technological systems:

- Both systems have the potential for injury, death, loss and disruption of livelihood and/or unusual difficulties in recovering from hazardous events.

- In its broadest definition by Hugo et al. (2000) the environment encompasses industrial hazardous installations. These installations affect the entire system in which they operate, in particular the people.

- People are primarily involved. A major accident such as a fire, an explosion or the uncontrolled release of toxic gases at the major hazard installation will inevitably impact on communities in its surroundings.

- There is a continuous internal interaction between human beings (employees) and the major hazard installation in the form of planning, design, operation, maintenance and safeguarding.
- There is a continuous external interaction between human beings (communities) and the major hazard installation in the form of employment creation, hazard communication and land development.

The framework of Turner II et al. (2003a) is shown in Figure 2.13.

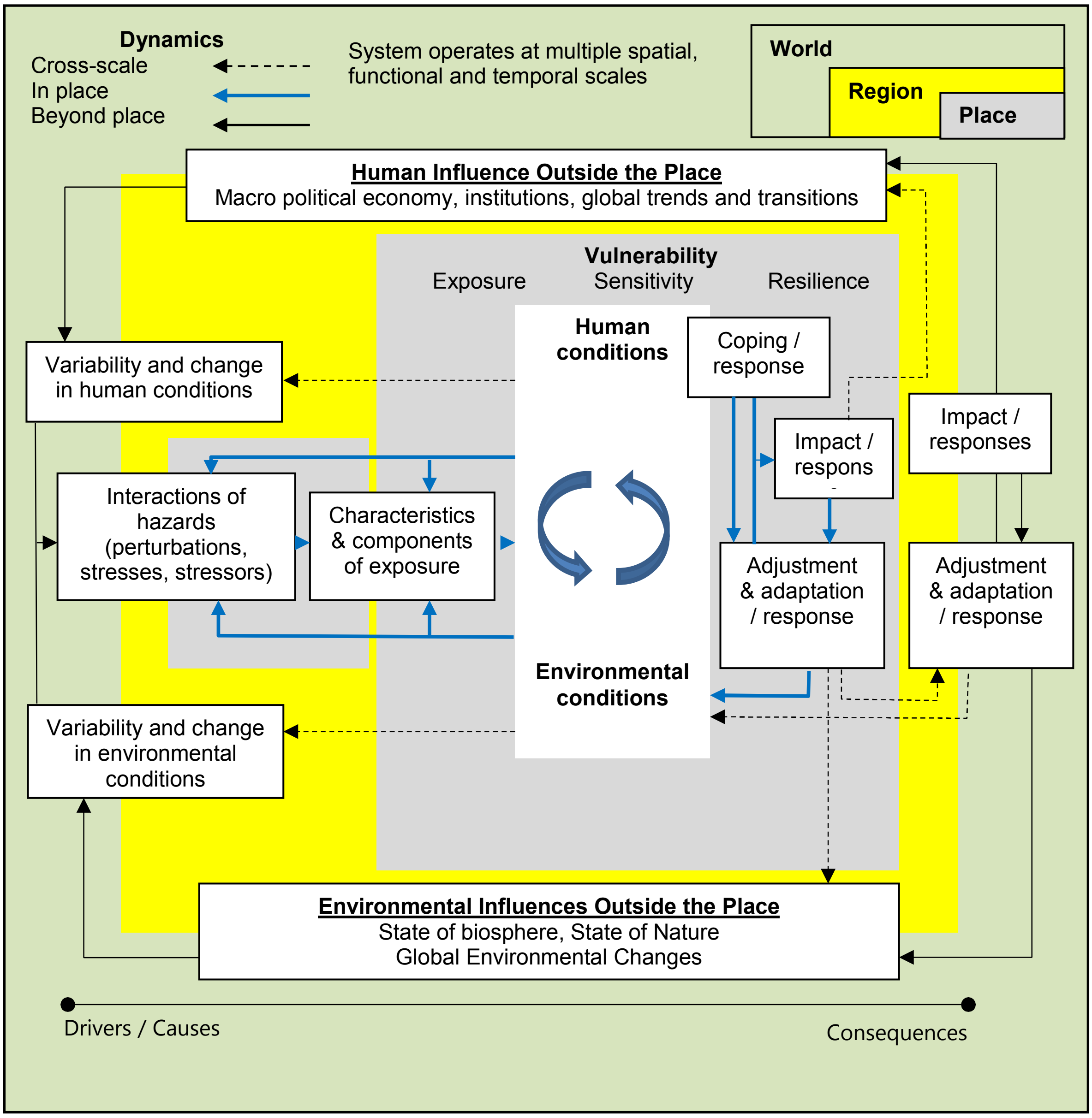

Figure 2.13 Vulnerability framework: Components of vulnerability identified and linked to factors beyond the system of study and operating at various scales. (Source: Turner II et al. 2003a. Reconstructed by author)

Turner II et al. (2003a) argue that nearly all concepts of vulnerability are viewed as an internal risk of a system or element at risk. The conditions of the exposed community that is at risk are seen as the fundamental characteristics of vulnerability.

The framework was specifically developed to investigate the relationships between the vulnerability of communities and a variety of climatic conditions, as described by Turner et al. (2003b). They concur that sustainability science focuses on the human-environment system to the benefit of different communities. Many of these communities have a need for an understanding of the vulnerability of people, places and ecosystems in the face of environmental change. The framework of Turner et al. (2003b) is equally applicable to hazards to which communities may be exposed as a result of technological facilities, where receptor groups may suffer as a result of major incidents such as large-scale fires, explosions or the release of toxic gases. The vulnerability of people in this scenario remains of central importance in their framework.

Birkmann (2005) believes that vulnerability is regarded as an internal side of risk and as an intrinsic characteristic of an element at risk can be applied to very different elements, such as communities and social groups, structures and the physical characteristics of buildings and lifelines, as well as ecosystems and environmental functions and services (ecosystem, environmental capital). It is therefore believed that vulnerability can equally be applied to industrial human-induced risks caused by major hazard installations. This deduction is not specifically mentioned by Birkmann (2005), but it flows logically from his assertion that vulnerability and risk are intrinsically connected.

It becomes clear that vulnerability relates to people and is always linked to a specific hazard in some form or other. Without a hazard, vulnerability becomes non-existent.
Birkmann (2005) emphasises this point and describes the historic development of the concept of vulnerability by means of different knowledge spheres, as depicted in Figure 2.14. The figure shows that the concept of vulnerability has been central to disaster management for a long time and that it evolved from a risk factor to a comprehensive concept that includes physical, social, economic, environmental and institutional features.

It is worth noting that Birkmann (2005) does not refer to the concept of resilience in the knowledge spheres as was done by Turner II et al. (2003a) in their model, but to coping capacity, adaptive capacity, susceptibility to the negative effects of a hazard and exposure to a hazard.

The development of the concept of vulnerability by Birkmann (2005) to the point where it is today, is supported by promoters of the sustainability theory such as Jenkins (2009), Ayre and Callway (2005) and Tietenberg (2016). By studying the latters' contribution to the theory of sustainability it becomes clear that the concepts of sustainability and vulnerability are intrinsically linked. The need for long-term sustainable development has become necessary as a result of the vulnerability of communities, in view of limited natural resources that are required for the livelihood of people.

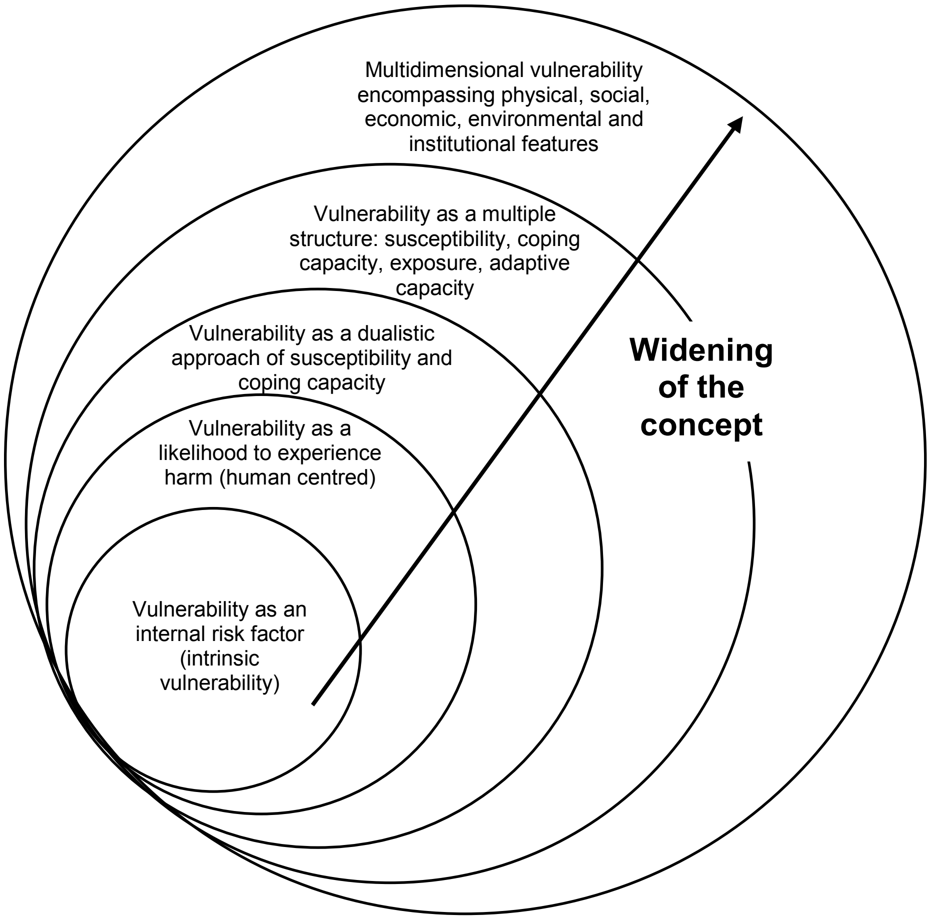

Figure 2.14 Key spheres of the concept of vulnerability. (Source: Birkmann 2005)

Cardona (1999 and 2001) and Bogardi and Birkmann (2004) developed a vulnerability framework, the BBC model, which introduces the concept of human vulnerability into the overall science of disaster management. The framework was developed with three considerations in mind:

- Establish a link between vulnerability, human security and sustainable development.
- Develop a holistic approach to disaster risk assessment.

- Develop a causal framework for measuring environmental degradation in the context of sustainable development.

The framework focuses on the vulnerability of people with specific reference to sustainable development against the background of environmental degradation. Of particular importance is the fact that the framework does not make reference to the concept of resilience, but to coping capacity, hazard exposure and risk susceptibility. The framework of Cardona (1999 and 2001) and Bogardi and Birkmann (2004) is shown in Figure 2.15, adapted to replace natural phenomena with hazardous facility and incorporate receptor resilience.

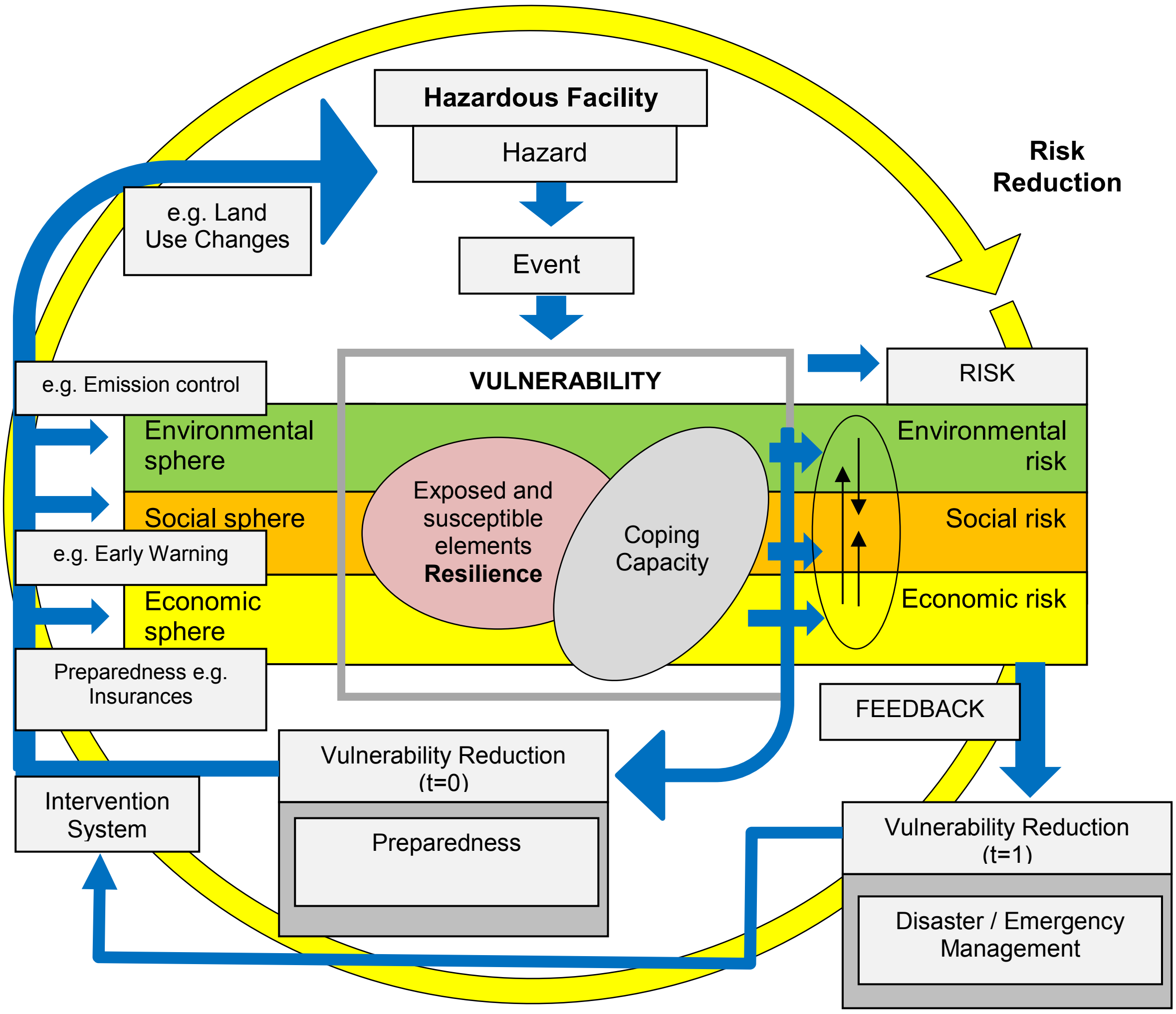

Figure 2.15 The BBC Conceptual Framework. (Source: Birkmann 2006. Originally from Bogardi and Birkmann 2004 and Cardona 1999, 2001. Adapted by author)

As is the case with the sustainability framework developed by Turner II et al. (2003b) the BBC framework places emphasis on the natural environment and considers damaging natural forces as the prevailing hazards. Technological human-induced disasters created by major hazard installations are not explicitly referred to in these frameworks. However, the two frameworks provide a sound base on which a model can be developed for the regulatory management of human-induced health and safety risks associated with hazardous facilities.

The BBC framework of Birkmann (2006) and others requires that vulnerability analysis go beyond the historical estimation of deficiencies and disaster impact assessment. This is a critical proviso, since interaction between the various components of a hazard and vulnerability system is dynamic. The framework views vulnerability within a dynamic process by taking into account coping capacities as well as potential preventative and mitigation intervention tools to reduce vulnerabilities in a feedback-loop system.

Also, vulnerability should not be viewed as an isolated component in the systemic disaster model. Vulnerability assessment must also consider the specific hazards and potential events that the vulnerable society, its economy and environment can be exposed to. The interaction of all the various components in the disaster management model has to be assessed. The BBC framework therefore emphasises the need to focus on the social, environmental and economic critical success factors of vulnerability. However, the technological, legal and political critical success factors have been excluded in the BBC framework and are probably assumed to be embedded in the environmental and economic critical success factors. If this is the case, it is a shortcoming in the framework. In fact, Birkmann (2006) and other authors state that additional frameworks can be integrated within the three sustainability critical success factors (social, economic and environmental).

Renaud (2006) reports that the BBC framework analyses vulnerability in a dynamic context and with the emphasis on the integration of the environmental critical success factor of vulnerability, by linking communities and specific services and the vulnerability of ecosystem components to hazards. The perspective of the BBC model of vulnerability is on the ability and behaviour of a person or group of people to change the impacts that disasters can have on them. The ability and behaviour of people depend on their threatened living conditions, which are a function of some dynamic pressures that have specific root causes.

EC (2011) explains the differences between the various vulnerability models and a holistic approach by stating that in the latter instance human and environmental insecurities are the result of a set of vulnerability factors and critical success factors. Vulnerability does not only infer people, but also the complex and nonlinear interactions of society and environment (as confirmed by Cilliers 1998, Coetzee & Van Niekerk 2012 and Weihrich 2008). These interactions occur not only from the global to the local system, but also from the local to the global system.

Unlike a conventional risk analysis, the main focus of the BBC framework is on three elements:

- The various vulnerable and exposed elements.
- The coping capacity of the affected population.
- The potential mitigation tools that can be used to reduce vulnerability.

EEA (2010) also reports that the potential of a hazard to cause a disaster mainly depends on how vulnerable exposed communities are to such hazards. Vulnerability should without doubt become a necessary element of any health and safety risk management system.

The conceptual frameworks put forward by Wisner (2002), Turner II et al. (2003a & b) and Birkmann (2005) have one thing in common: human vulnerability arises from the presence of a hazard, so that vulnerability becomes a function of a hazard. The higher the severity of the hazard in terms of its potential damaging effects on human lives, the higher the vulnerability becomes. This study is about hazardous technological facilities and their human-induced impacts on their employees and the societies around and near them. The question arises whether a hazardous facility could influence the vulnerability of a community near or around it. The answer to the question lies in the damaging effects that a hazardous facility could have, namely loss of life, injury or other health effects, property damage, loss of livelihoods and services, social and economic disruption and environmental damage. The concept is illustrated in Figure 2.16.

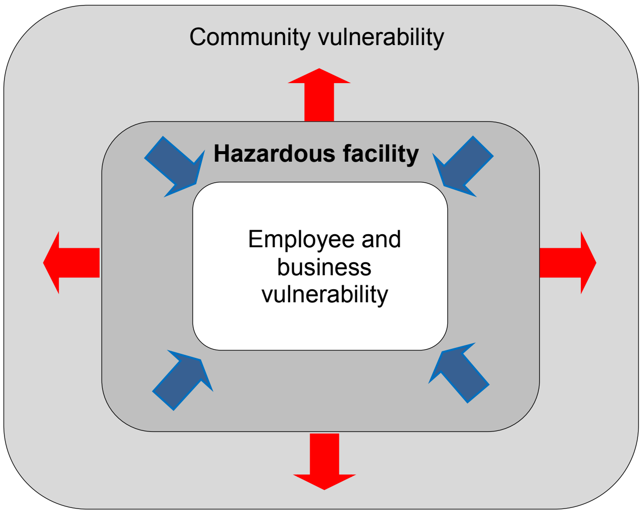

Figure 2.16 The simultaneous internal and external impact of hazardous facilities (Source: Author)

Communities are always susceptible to the damaging effects of a nearby hazardous installation, through health degradation, injuries or death. However, the impacts from the hazardous facility are also directed inwards towards the workforce at the facility as well as the business entity that owns or operates the facility as an economic productive unit. This is indicated by the arrows that point inwards in the figure.

Major hazard installations pose three main risks to human beings:

- The risk of the uncontrolled releases of toxic substances in the form of gases, liquids or solids. Of these three, toxic gases are by far the most dangerous (Gupta 2002).
- The risk of explosions from solids, gas clouds and the vapours or aerosols caused by flammable liquids (HSE 2011).
- The risk of fires from gases, liquids or solids (Batterman et al. 1998).

None of these risks are explicitly addressed in the three vulnerability frameworks discussed above. Schaller (2003) also reports that the vulnerability of communities is not assessed in countries such as France and Switzerland.

Schmidt-Thomé (2005) uses a systems approach to analyse the vulnerability of communities from a spatial planning perspective and comes to the conclusion that a multi-hazard risk assessment approach needs to be followed with regard to the health and safety risks posed by major hazard installations:

- The vulnerability of communities near major hazard installations has to form part of the overall risk assessment methodology. Vulnerability is considered by Schmidt-Thomé (2005) to be a combination of hazard exposure and coping capacity.

- The risk assessment should not focus on natural disasters only, but should also include technological disasters, because the two are interlinked: Natural disasters may lead to technological (Natech) disasters at major hazard installations.

The MOVE project of the European Commission (EC 2011) developed a framework that integrated vulnerability and disaster risk into a multi-key critical success factoral management framework. The objective of the MOVE framework is to identify elements of linked social-ecological systems that influence the outcome of vulnerability assessments. It is therefore an exploratory framework that is used to develop indicators of vulnerability.

The MOVE framework recognises two important elements:

- Hazards, as natural and socio-natural events that may have physical, social, cultural, political, economic and biophysical environmental impacts over a period of time in a given area. A natural hazard implies the potential of internal or external geodynamics or hydro-meteorological events that may impact on receptor elements. Hazards can originate from single, multiple or sequential sources, which implies Natech hazards as well, although the Commission does not identify them explicitly. According to the Commission a hazard is characterised by its location, magnitude, frequency and probability. If the hazard has the potential to cause environmental degradation as a result of human intervention in natural ecosystems, it is classified as a socio-natural hazard. Hazards can also be defined in spatial terms with a single actor such as a land-use development authority.
- Society, represented at international, national, provincial or local level as part of the environment. Society includes communities that are located near a potential source of health and safety risk such as a major hazard installation, or individuals who work as part of the employee force at a major hazard installation. The term society therefore has an external as well as internal focus.

The two framework elements, hazards and society, coexist in continuous interactions among them. This is the typical system approach as described by Skyttner (2005).

The European Commission (EC, 2011) is of the opinion that assessment of vulnerability has to be done through the inclusion of both the social and the ecological systems and their mutual interactions as open, linked processes. The MOVE framework is independent of hazard type and hence encompasses different aspects of vulnerability as well as providing a generalised structure for the comparative assessment of the different vulnerability aspects. As a result, it has been adapted for hazardous facilities, technological events as well as Natech events instead of natural and socio-natural events. The framework also addresses differences between a risk assessment and vulnerability assessment. The introduction of risk assessment in this framework is an improvement on the BBC Model of Cardona (1999 and 2001) and Bogardi and Birkmann (2004). Firstly, risk assessment is considered to be an important preventative action as part of the management of hazardous facilities in South Africa (MHI Regulations 2001).
The adapted MOVE framework of the European Commission (EC, 2011) is shown in Figure 2.17. Although the MOVE framework is applied to natural hazards, it illustrates that the vulnerability of an interactive system comprises six critical success factors that can be applied to technological hazards as well:

- Social: Human welfare including the mental and physical health and safety of individuals and communities
- Economic: Financial resources deployed and the potential financial damage to productive capacity
- Physical: Assets including structures in developed areas, infrastructure and open leisure spaces that can be affected by natural disasters. The locality of assets in receptor areas and deficiencies in coping capacity are important considerations in this critical success factor.
- Cultural: Religion, customary practices, artefacts and natural or urban landscapes
- Environmental: All socio-economic and bio-physical systems and their functions
- Institutional: Legislatory requirements and cultural rules as well as organisational form and function, including political processes

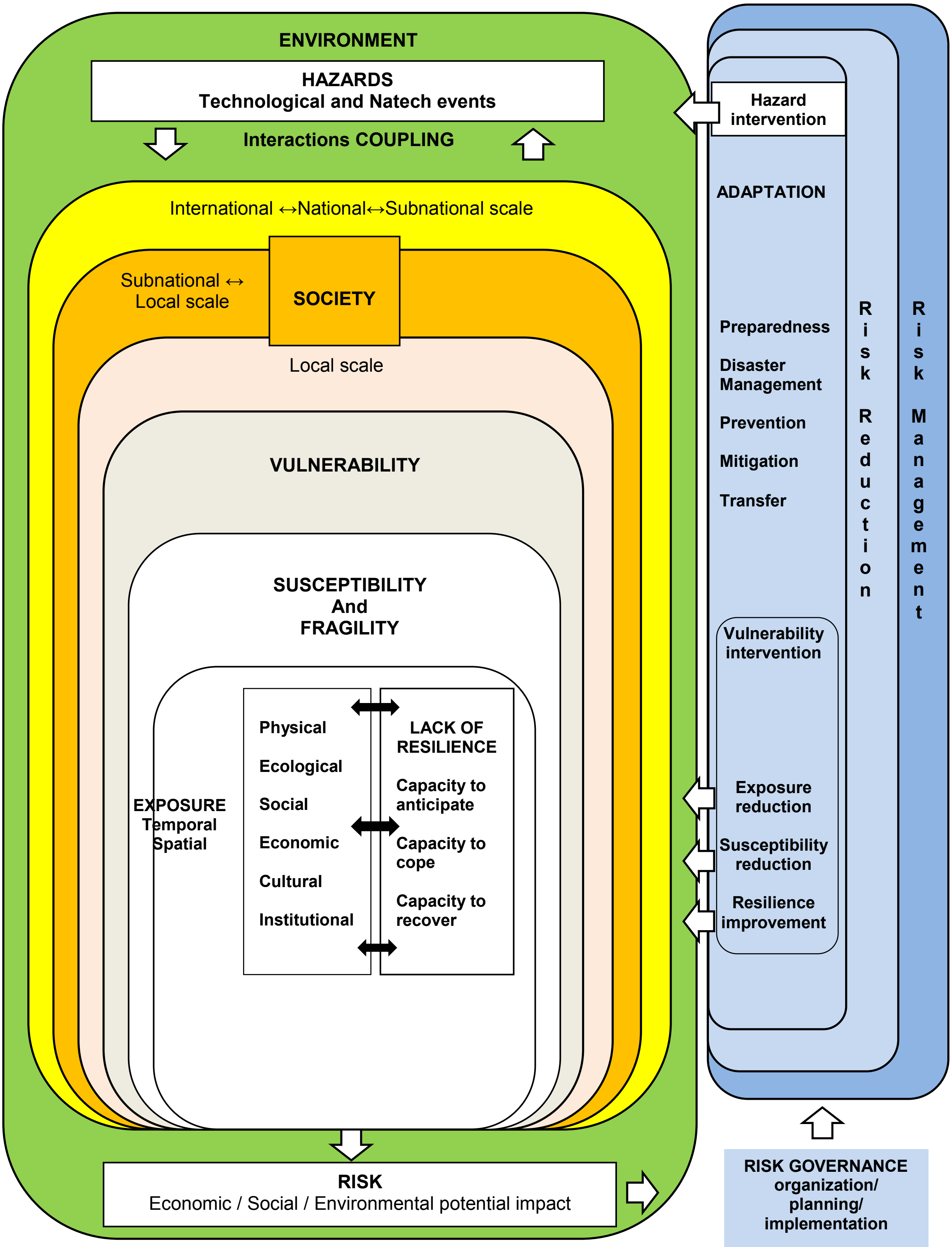

Figure 2.17 Theoretical framework for a holistic approach to disaster risk assessment and management (Source: EC MOVE Project 2011. Adapted by Author)

Secondly, the framework introduces the concept of resilience, or the lack thereof.

The measurement of vulnerability involves the degree of exposure, susceptibility, fragility and lack of resilience of a socio-ecological system that may be exposed to negative, destructive impacts. Three causal factors of vulnerability are identified in the MOVE framework:

- Exposure of human settlements and the environment in general to hazards that may create a disaster in the settlement area

- Susceptibility and/or fragility of society and ecosystems to suffer harm resulting from hazards that may pose risks to physical, ecological, social, economic, cultural, political and institutional systems

- Lack of resilience or human response capacities caused by limitations in access to the necessary resources of the social-ecological system. It also refers to a low coping capacity, i.e. the inability to respond to disaster stressors by absorbing the destructive impact. Also included here is the lack of capacity of humans to anticipate, cope and recover in the short term.

The MOVE project of the European Commission (EC 2011) considers the vulnerability of communities as an indispensable element of risk management. The EC contextualises *“vulnerability”* as *“a degree of susceptibility or fragility of elements, systems or communities including their capacity to cope under a hazardous condition”*. This interpretation emphasises three important aspects relevant to this study:

- The vulnerability of people that are exposed to health and safety risks posed by major hazard installations has to be integrated into the overall risk management process.

- Risk management is considered from an open, interactive systems perspective, as also promoted by Schmidt-Thomé (2005), Coetzee et al. (2012) and Skyttner (2005).

- The coping capacity of affected communities that are at risk of impacts from major hazard installations cannot be overlooked in the risk management cycle, which is a shortcoming in the model proposed by the Swiss Federal Office for Civil Protection, 2010.

It is necessary to explain the context in which the terms vulnerability, resilience and coping capacity are used in this study, since it forms a vital part of the development of the model. These concepts are not incorporated in this research in a generic sense, but in accordance with the theory of vulnerability.

Miller et al (2010) argue that resilience and vulnerability are central concepts in the analyses of social-ecological change and sustainability. Several relations exist between the two concepts, but "*they have been kept artificially separate by conceptual constructs, scientific traditions, and lack of interaction between the two academic communities involved*". The authors argue that, with the exception of isolated cases of disaster management, there is a continued lack of integration of resilience and vulnerability assessment methodologies and relevant input into major national and international policy and planning initiatives and processes in the study field of sustainability.

Further insight into the complex interaction of vulnerability and resilience concepts is provided by Gall (2013), who concluded that although great strides have been made towards the integration of resilience into disaster management doctrine, more research is needed to make theory practicably implementable.

The relationship between vulnerability and resilience was studied by Gallopin (2007) who introduced the concept of transformation of a system due to external (exogenous) or internal (endogenous) perturbations or processes. The author concludes that resilience and adaptive (coping) capacity are elements of vulnerability, but suggests that efforts should be made to develop specifications for the two concepts.

Frerks at al. (2011) confirmed that much confusion exists about the terms vulnerability and community resilience. It became clear from the arguments of these authors that vulnerability and resilience are inversely related. Furthermore, resilience and adaptive or coping capacity are similar, at least in its conceptual base.

The question remains: Are resilience and coping capacity different terms that describes the same concept? UNISDR (2009) considers the two terms as different, hence their different definitions. The UNISDR (2009) definitions leave the impression that coping capacity can be considered to create ex-ante as well as ex-post actions in the event of a full disaster, while resilience can be considered to create mainly ex-post actions, even if the hazard has not lead to a full disaster.

Colburn and Seara (2011) agree with Frerks et al. (2011) by stating that vulnerability, resilience and adaptive coping capacity are defined in complex ways with a variety of possible interrelationships. The authors identified a need for agreement, at least on national level, for the use and measurement of the concepts. Resilience can form part of adaptive capacity or vice versa. It may even be possible that resilience and adaptive capacity, collectively or severably, can form part of vulnerability.

Sungay et al. (2012) state that the terms vulnerability, resilience and coping capacity have been used *"in a variety of manners"* in the literature. The authors also refer to the definitions of resilience and coping capacity as contained in the UNISDR (2009) definitions, but conclude that resilience encompasses coping capacity, because the former also cover the recovery phase of disasters. This deduction is questionable – the *"management"* of disasters (UNISDR, 2011 definition of coping capacity) may also very well include the disaster recovery phase in its broadest sense. Sungay et al. (2012) refer to Billing and Madengruber (2006) who view vulnerability and coping capacity to be *"two sides of the same coin"* or in a more linear manner, as inversely proportional variables of the same disaster management system characterised by one or more very specific hazards.

This study concludes that the relationship between vulnerability and resilience has not yet been defined clearly in the literature. The author therefore hypothesises that the **vulnerability** (V) of a particular system to the effects of a disaster can be considered as a function of two separate system characteristics: the **resilience** (R) of the system to resist and recover from the effects of a disaster, as well as the **coping capacity** (C) of the system to manage the adverse effects of a disaster. In mathematical terms:

$V = f(R)$ and $V = f(C)$

More accurately,

V is inversely proportional to R and V is inversely proportional to C.

$V \propto 1/R$ and $V \propto 1/C$.

Therefore:

$V = k_1/R$ and $V = k_2/C$, where k_1 and k_2 are proportionality constants for resilience and coping capacity respectively, for a specific system or community component.

By integrating the two equations, we get

$V = K_i/(R_i.C_i)$,

where K_i is the vulnerability constant for a specific system, *i*, such as a specific component of a community that can be affected by a hazardous facility; R_i is the resilience constant and C_i is the coping capacity constant for system component *i* respectively. The vulnerability of the system that comprises *n* subsystems can therefore be described as a summation of the individual vulnerability constants for the individual subsystems:

$$V_{tot} = \sum_{i=1}^{n} \frac{Ki}{(Ri.Ci)}$$

Vulnerability can never be dissociated from the hazard concept. *Schmidt-Thomé (2005)* argues that vulnerability is a combination of hazard exposure and coping capacity. Therefore, in the above equation V_{tot} , K_i, R_i and C_i are all functions of a specific hazard, H_i.

Schmidt-Thomé (2005) does not clarify the combination in the form of a mathematical relationship and the author shall also not attempt to do so – it forms the subject of further research. Two examples are put forward, however, to clarify the concept of integrated vulnerability as proposed in this study:

<u>Example 1</u>: If the hazardous facility is a chemical factory that has the potential to release toxic gases, it may be surrounded by various different community sectors, such as hospitals, schools, a sport stadium, churches and informal housing. All these sectors have different resilience and coping capacity constants peculiar to each specific sector and will therefore have different vulnerabilities. A secondary school may have a higher resilience constant and higher coping capacity constant than a primary school and will therefore have a lower vulnerability.

<u>Example 2</u>: If the hazardous facility is a commercial aircraft, the passengers may comprise airline staff, babies, elderly people, children, males and females. In addition, the seating arrangement of the passengers varies throughout the aircraft. All these passenger groups will have different resilience constants and coping capacity constants, and therefore different vulnerabilities to an airline disaster.

Figure 2.18 further illustrates the concept.

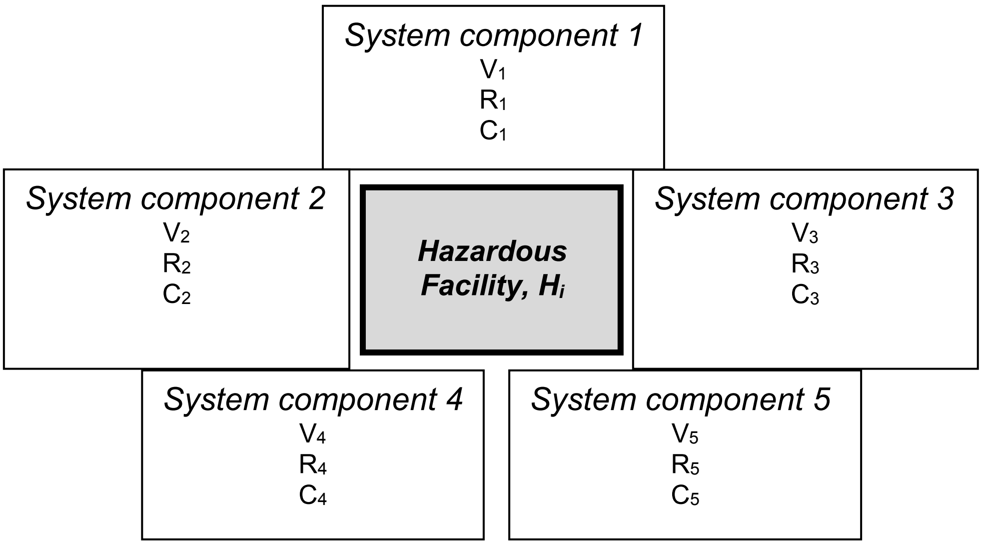

Figure 2.18 Vulnerability (V) of a system as a function of resilience (R) and coping capacity (C) of its discrete components (Source: Author)

The relationship between community and institutional vulnerability, resilience and coping (adaptive) capacity as applicable to technological hazards, and in particular whether resilience and coping capacity are different concepts or in fact the same, is a subject proposed for further research (See Chapter 10).

2.2.5 The disaster theory

Research done to date on disasters emphasises the *"trigger"* role of natural forces arising in nature, such as earthquakes and climate and biological factors (Wisner et al. 2004). Some researchers also focus on human response and the social, economic, legal and political consequences of disasters. Both these approaches assume that disasters mean a deviation from "normal" social functioning, and that disaster recovery implies a return to normality. While the significance of natural hazards as disaster trigger events can never be denied, it is vitally important to realise that the multitude of ways in which social systems operate and interact, can actually generate disasters by rendering people vulnerable. Historically the vulnerability concept of disasters began with a rejection of the assumption that disasters are *"caused"* in any simple way by external natural events. Today, the assumption that disasters are "normal" has become deeply entrenched in academic thinking.

Wisner et al. (2004) concluded that disasters caused by natural hazards such as meteorological tendencies, floods, drought, earthquakes and fires, are not the biggest threat to humankind. Despite the lethal reputation of these hazards, a much greater proportion of the world's population die or are adversely affected by seemingly minor or unnoticed events such as social unrest, hunger and illness. These events are considered normal in many countries of the world, especially in less developed countries.

Wisner et al. (2004) state that natural disasters have undoubtedly killed millions of people over many years, but it should not be the main focus while ignoring the millions who are exposed to serious life-threatening risks. They claim that many more lives are lost as a result of violent conflict, preventable disease and hunger. Under different economic and political circumstances those victims whose deaths are considered to be the outcome of natural causes, should have lived longer with a better quality of life.

Thus, according to Wisner et al. (2004), it is crucial to understand that disasters are not only due to the natural events that cause them. In contrast with natural environments, disasters are often the product of the interaction between social, political and economic environments, because of the way these have an effect on people's lives. Disasters should not be seen as some peculiar events that deserve an isolated and narrow focus. *"Natural"* disasters are closely interwoven with the social organisation that determines the effects of hazards on people. Natural hazards receive too much attention at the expense of the surrounding social environment. Disaster risk is therefore a function of the factors that determine the exposure of people to specific types of natural hazards, but it also depends on how social systems and power exertion impact on social groups. In order to understand disasters the types of hazards that might affect people must be known, together with the vulnerability of affected communities. This vulnerability is determined by social systems and power, not by natural forces.

The approach of Wisner et al. (2004) is important in this study, for the following reasons:

- Their work emphasises that disasters are caused not only by natural phenomena, but also by a variety of societal influences such as poverty, illness and social conflict. Industrial human-induced accidents are a further contributing factor to disasters, with varying degrees of severity. Cases in point are the Bhopal toxic release disaster in India (Sabharwal, 2014), the Somerset West sulphur fire in

South Africa (Batterman et al. 1998) and the Buncefield liquid petroleum depot fire in England (HSE, 2011).

- Disasters are seldom, if at all, caused by a single factor. There are usually a variety of causal factors. The reactor meltdown at Fukushima Daiichi nuclear power plant in Sendai, Japan (CNN 2011), illustrates this point. An earthquake caused massive ocean waves, which destroyed the critical cooling system infrastructure at the nuclear power plant. The same phenomenon of combined causality occurred at the Buncefield depot, where high-level alarms failed and psychological pressure on operators exacerbated the situation.

- Social, political, technological and economic factors are major contributors to natural and human-induced disasters, although the technological aspect is not addressed in the PAR model of Wisner et al. (2004). In fact, their model does not take human-induced technological disasters, such as Bhopal, Somerset West and Buncefield, into consideration at all. The model has therefore been adapted by replacing natural hazards (earthquake, high winds, flooding, volcanic eruption, landslide, drought, virus and pests) with technological disasters (explosion, fire and the release of toxic gas).

Wisner et al. (2004) stress that, in situations where multiple causes may prevail in a dynamic environment, it is hard to distinguish between the causal links of different dynamic pressures on unsafe conditions and the impact of root causes on dynamic pressures. Wisner et al. (2004) propose that societal forces should also be taken into consideration in the overall assessment of disaster causes, impacts and consequences. They therefore developed the well-known Pressure and Release model, based on their own earlier work in 1994. The model is shown in Figure 2.19.

Birkmann (2006) considers the different elements of the PAR framework to be dynamic and subject to constant change, which may make the task of identifying and verifying the causal links between root causes, dynamic pressures and unsafe conditions in a quantitative way, very difficult. He acknowledges the PAR model as an important approach that focuses on vulnerability and its underlying driving forces. The model is well known worldwide and is particularly useful in addressing the root causes of disaster situations. However, the PAR approach emphasises that the attempt to reduce vulnerability and risk involves changing political and economic systems, since they are viewed as the root causes of dynamic pressures. The PAR conceptual framework puts emphasis on national and global regulatory levels, but many dynamic pressures and unsafe conditions might also be determined by local conditions, such as major hazard installations in industries.

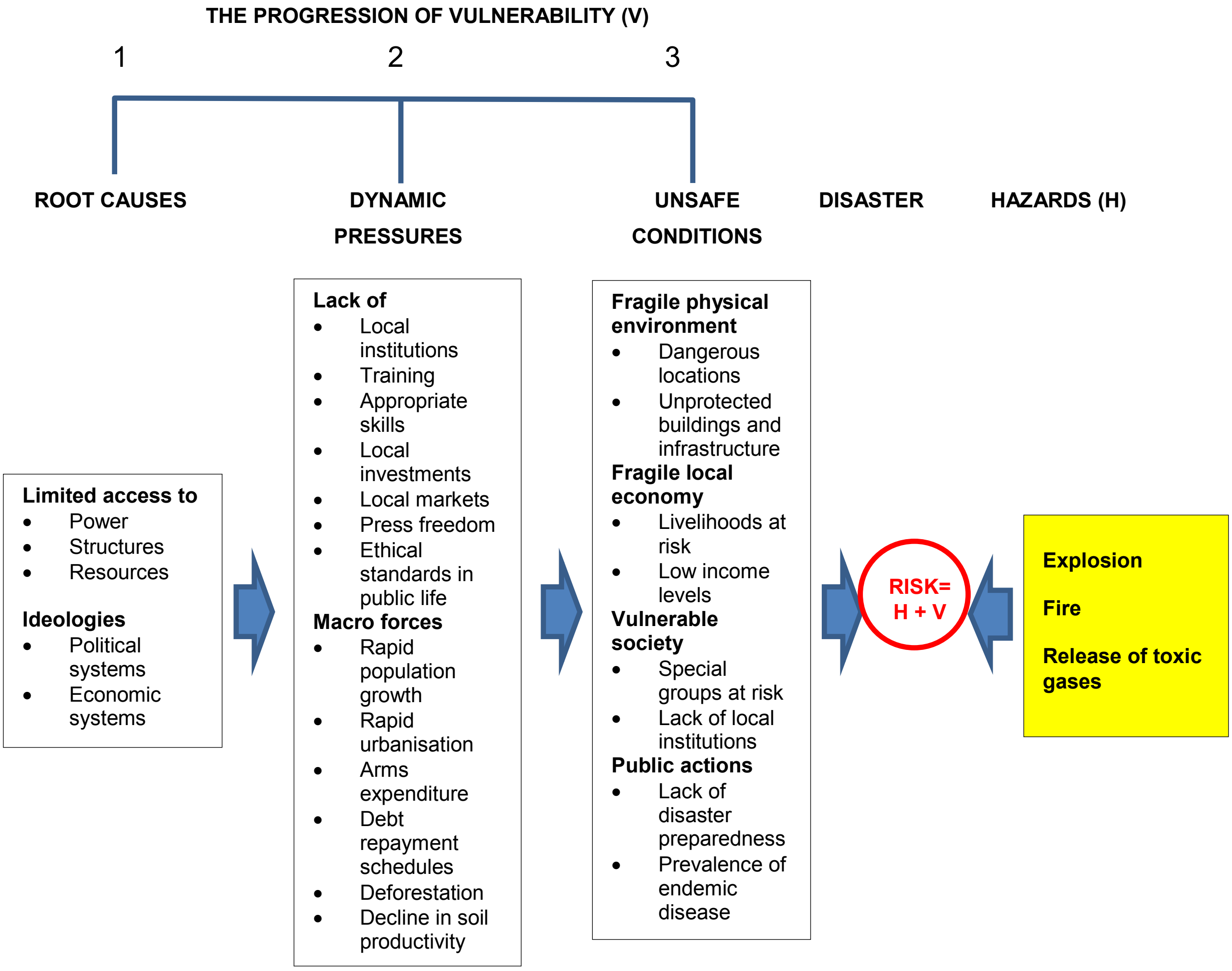

Figure 2.19 The Pressure and Release (PAR) model of disasters (Source: Wisner et al. 2004. Adapted by author)

The question arises: Can the PAR model of Wisner et al. (2014) be applied to human-induced disasters caused by major hazard technological installations? The answer is: No, not in the format that the authors proposed it.

Komaljot (2014) investigated the vulnerability of three villages situated near disaster prone industries in the district of Bathinda, India. These industries typically represent major hazard installations where human-induced accidents can occur. An explosion in the study areas can result in intense loss of human life, livestock, physical infrastructure and environmental damage. Komaljot's (2014) modified Pressure and Release model depicts disaster as a product of physical exposure and socio-economic pressure. The model distinguishes between three social components: root causes, dynamic pressures and unsafe conditions, and one component on the hazard side, namely the high-risk industries or major hazard installations. Economic, demographic and political processes that affect the allocation and distribution of resources between different groups of people, have been identified as root causes of community vulnerability. Vulnerability is expressed in unsafe conditions such as those induced by the physical environment, for example near hazardous industries.

Komaljot (2014) presented a modified version of the Pressure and Release model of Wisner et al. (2004), by adapting it to technological disasters. Komaljot conducted research in India, where the Bhopal event, a typical major hazard installation or technological disaster, occurred. The PAR model proposed by Komaljot is shown in Figure 2.20.

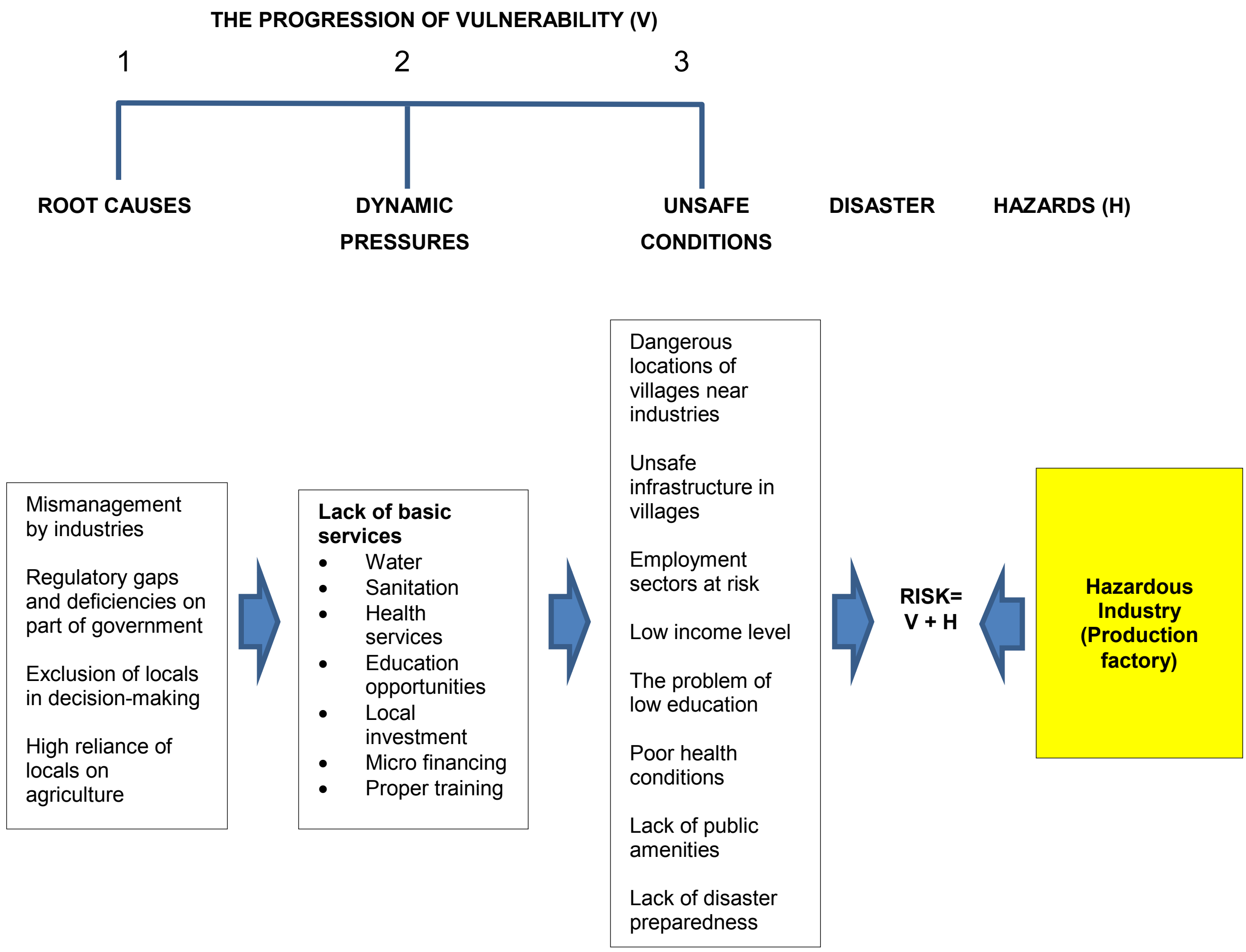

Figure 2.20 Pressure and Release model: Progression of vulnerability to industrial hazards (Source: Komaljot 2014)

Komaljot (2014) identified four root causes of unsafe conditions at a major hazard installation, namely:

- The mismanagement of plants with major hazard installations. It was found that generally the plants are highly profit-focused with little or no consideration for environmental conservation and maintenance of equipment. Pollution of the air, water and soil is a common phenomenon.

- Regulatory deficiencies on the part of government. Affected communities are not compensated by government for the impacts of pollution while government also fails to take a firm enough stance against polluting companies.

- Poor or no consultation with local communities that could be affected by an accident at a major hazard installation. According to Komaljot (2014) hazardous industries were established near populated areas in the district, but local communities were not consulted in this decision. It would appear that no formal environmental impact assessment process, with public consultation as a prominent feature, was followed.

- The high dependence of local communities on agriculture for their livelihood. Unfortunately environmental conditions have deteriorated as a result of pollution caused by nearby industries, making agriculture an unviable option for earning a livelihood. Some farmers have to use polluted water, discharged by a fertiliser company, for irrigation. This adversely affects crop yield and therefore puts farming and the entire local economy at risk. The situation is worsened by low education levels in the communities and the absence of technical skills, which make alternative occupations for them almost impossible.

The research done by Komaljot (2014) clearly points out the importance of the vulnerability of people in relation to hazardous industries. The affected communities face serious health and economic problems caused by nearby industries. Several dynamic pressures enhance the vulnerability of the affected communities:

- Lack of pure drinking water, education opportunities, social investment, local investment and financing.
- Insufficient provision of essential services such as sanitation, education and healthcare.

- In addition, high levels of poverty combined with a low literacy rate contribute to making the residents of these villages more vulnerable.

Awal (2015) applies the PAR model to investigate vulnerability to climate change hazards in Bangladesh. Awal integrates the progression of vulnerability with climatic disaster and states that a conceptual model like PAR as described by Wisner et al. (2004) provides disaster managers with a valuable framework for interpreting vulnerability to disasters and for applying appropriate mitigation measures. Awal argues that the PAR model predicts that disaster occurs at the tangent between two counter-forces:

- Forces of natural hazards.
- Processes that generate vulnerability.

It is when these two forces are combined that a disaster happens. The PAR model is therefore based on the understanding that a disaster occurs at the intersection of two counteracting forces: the processes that generate vulnerability on one hand, and the physical exposure to a hazard on the other hand. Increasing pressure can come from either side, but to relieve the pressure, vulnerability has to be reduced.

It is important to note that Awal (2015) considers natural disasters (climate change and its negative impacts) only and does not consider technological disasters that may originate from major hazard installations. In this context, it can be concluded that the PAR model equally well predicts that a technological disaster from a major hazard installation occurs at the tangent between two counter-forces:

- Forces of major hazard installations.
- Processes that generate community vulnerability: fires, explosions and the release of toxic materials.

2.2.6 The business continuity theory

Industries make an important contribution to the economy of a country, for example in terms of wealth creation and the employment of people as well as foreign exchange savings and generation (Smith, 2012b). This is also true for major hazard installations, which usually involve manufacturing process enterprises. While it is vital for the business to protect the health and safety of its employees and the communities around it, its own survival after a major incident is crucial. Considering the devastating effects that a major hazard installation can encounter and the consequential disruptive effects on the survival of the business per se (Buncefield: HSE 2008; Somerset West: Rajani, 2010; Bhopal: Union Carbide Corporation 2015) it is important to investigate theories on business continuity.

Smith (2012b) reports that national and international events of the past have led governments, regulators, insurers and other public and private sector institutions to understand the importance of the concept that organisation resilience and preparedness in terms of business continuity management are an essential part of the overall risk management strategy of an organisation. Complacency is a threat to business continuity in the face of the threats that arise in the current national and global business environment.

Business continuity is described by Smith (2012b) as the capability of the enterprise to maintain the delivery of products or services at predefined levels after a disruptive incident such as a major fire or explosion. This capability implies an internal focus on the business, contrary to the external focus on people when their health and safety is at risk.

Business continuity management has always been an important part of the risk management programme of enterprises. It forms an integral part of corporate governance. This is now fully recognised in the King III Code of Practice for Corporate Governance (IoDSA 2009) and applies to all business entities, state or private, irrespective of the manner in which they are incorporated or established. The King III Code is aligned with the corporate governance code of the United Nations (UN 2006).

In its description of business continuity management and the setting of standards required for it, ISO-22301 (2012) emphasises the importance of a framework for building organisational resilience against potential threats, to protect the interests of all stakeholders. This approach presents an important shift from traditional theories on vulnerability and sustainability (Wisner 2002; Turner IIA et al. 2003; Birkmann et al. 2006; EEA 2010 & EC 2011) in the sense that the focus is redirected internally towards the survival of the business itself and not communities although, clearly, the lives of people should always take precedence as prescribed by the European Court of Human Rights (2010) and the South African Constitution (Act 108 of 1996). The ISO-22301 (2012) and ISO-22313 (2012) standards prescribe that a business continuity management system should focus on the following objectives:

- Understanding of the needs of the organisation
- Understanding the necessity for the organisation to have a business continuity policy with associated objectives
- Implementing proper control measures to manage the capability of the organisation to endure disruptive incidents
- Monitoring and reviewing the effectiveness of the business continuity management system on a regular basis
- Striving for continual improvement as measured by the performance of the organisation against the business continuity management objectives

The standard requires that the business continuity management system of an organisation must have at least the following six elements:

- A business continuity policy.
- Proper planning for business continuity.
- Effective implementation of the business continuity system.
- Frequent assessment of the performance of the organisation against the business continuity objectives.
- Regular review of the entire system.
- A striving to continual improvement of the system.

Once again, the internal focus on the organisation is emphasised by the ISO-22301 (2012) and ISO-22313 (2012) standards.

The principle of business continuity is inextricably linked to business resilience and corporate crisis management (Smith 2012a) with resilience as one of the components of vulnerability. It is noteworthy that Smith does not refer to the coping capacity of a business, as is conventional in vulnerability theory (Turner II et al. 2003a; Birkmann et al. 2006).

Smith (2012a) proposes seven key planning actions that are involved in business continuity management:

- Incident and corporate crisis incidents.
- Recovery of technology, data, plant and equipment.

- Human resources.
- Corporate communication and public relations.
- Workplace recovery.
- Continuation of critical business activities.
- Site recovery.

Furthermore, Smith (2012a) stated that business continuity management systems comprise an integration of managerial, operational and technical functions in an organisation (Smith 2012a) as illustrated in Figure 2.21. The seven key constructs represent an internal focus on the organisation and lacks the important element of community and authority intervention. In the case of the Bhopal disaster (Union Carbide Corporation 2015) the Union Carbide chemical production plant was closed completely after the methylisocyanate gas release and brought the local company to a standstill. The figure of Smith (2012a) has thus been adapted to include an eighth construct, namely the vulnerability of the community and employees to a technological disaster, which could lead to a destructive authority intervention.

The key constructs designed by Smith (2012a) shows an internal or endogenous focus on the organisation. By focussing also on external communities in terms of their vulnerability to a disastrous incident, an exogenous approach is developed as advocated by Gallopin (2007).

Many organisations focus all their business continuity actions on information technology, because of its vital – and growing – importance in business operations. This approach leaves them exposed to a multitude of other, often hidden, risks. An organisation can never be fully in control of its operating environment, and all organisations face the risk of an incident that can seriously disrupt their operations, creating a corporate crisis. Apart from natural disasters, technological hazards are a reality for organisations, such as recorded for the Bhopal toxic gas release in India, the Exxon Valdez oil spill in Alaska and the Buncefield petroleum depot explosion and ensuing fire in England (Smith 2012a).

Maroney (2010) gives an explanation for the role of insurance in enhancing global financial stability. The primary function of insurance is to indemnify individual and corporate policyholders against financial losses caused by unexpected adverse events such as disasters. The insurance industry plays an important role in the global financial system and economy. Insurance is one of several financial instruments that owners and operators of hazardous facilities may use to facilitate disaster recovery and rehabilitation.

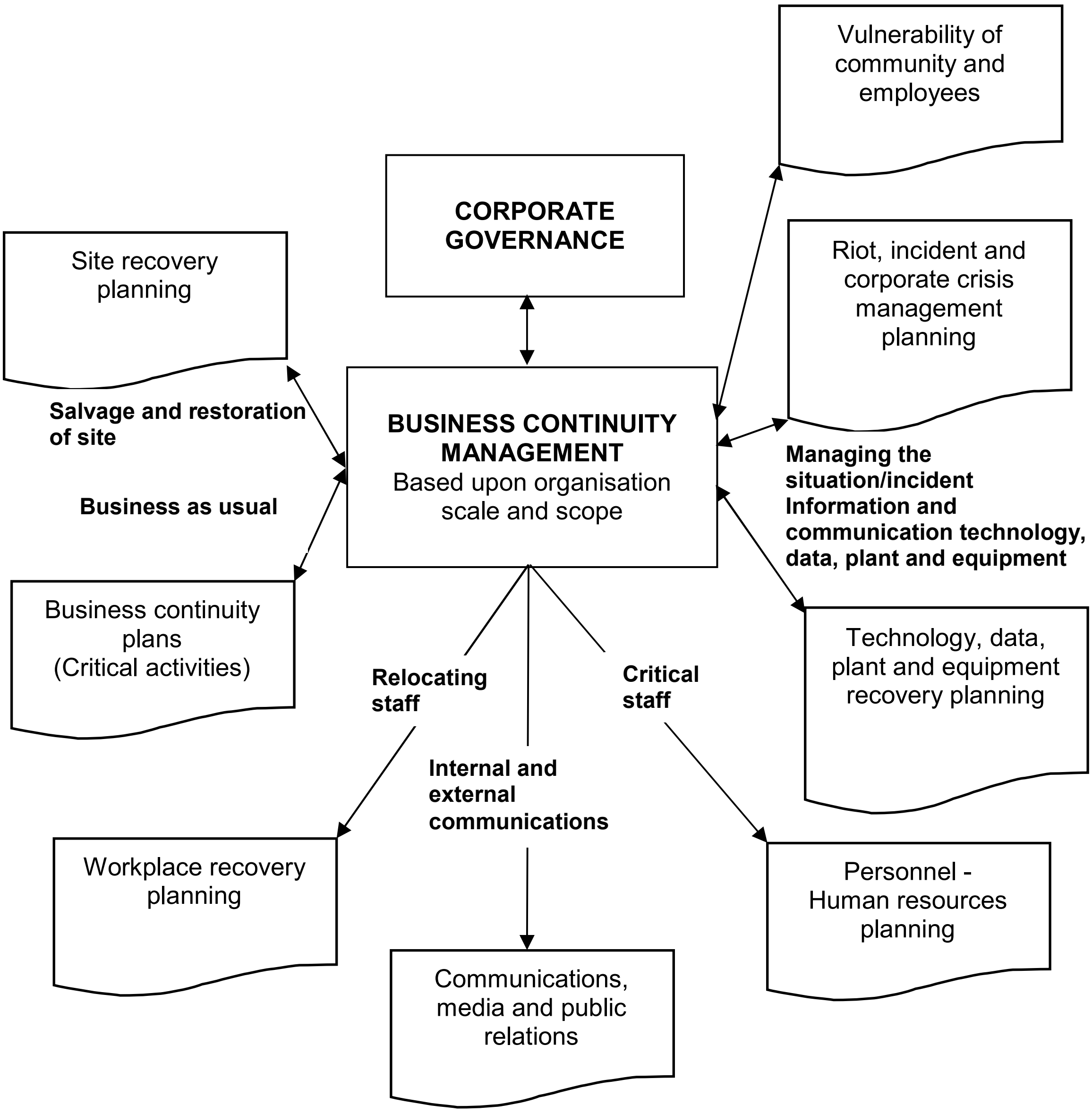

Figure 2.21 The key constructs of business continuity management (Source: Smith 2012a. Adapted by author)

Brainard (2008) notes that insurance serves a number of valuable economic functions that are largely different from other types of financial institutions. The indemnification and risk-sharing properties of insurance facilitate financial transactions and credit allowance by mitigating losses. Typically insurance provides protection against uncertain but potentially severe losses such as disasters. This revenue equalisation effect helps to avoid excessive and costly bankruptcies and facilitates lending to businesses such as hazardous facilities. The availability of insurance enables risk-averse policyholders and entrepreneurs to undertake high-risk and high-return activities more readily than they would do in the absence of insurance, which could generate higher productivity and economic growth. However, there is a downside to this approach: Owners and operators of hazardous facilities may rely entirely on insurance to take care of health and safety risks created by the facility and, in doing so, may adopt a laissez-faire attitude of negligence. In such a case, the risks of the hazardous facility may actually increase dramatically.

2.2.7 The critical success factor theory

The point of departure of this study was the identification of the critical success factors that would be needed in a regulatory management model. The aim was to apply the concept of critical success factors to such a model in the sense that the ideal regulatory model must comply with a *minimum* (hence the term *critical*) set of success factors that will enable the competent authority (the relevant government department) to produce legislation for the management of hazardous facilities that will yield the most effective outcome. If one asks the question, *"What must the legislation contain in order to be most effective?"* then the set of critical success factors gives the answer.

The definition of critical success factors given in BusinessDirectory.com (2016) is also given by Gates (2010), who describes critical success factors as a few key fields in which an enterprise has to perform consistently well in order to achieve its mission. "Mission" in this sense is interpreted as the goals or objectives of an enterprise (Cambridge Dictionaries Online 2016) and can be equally applied to a competent government authority that is tasked with the responsibility of developing health and safety legislation for the regulatory management of hazardous facilities.

According to Gates (2010) critical success factors can be derived through three main means:

- A document review in the organisation or competent authority, which can include broad-based literature research.
- An evaluation of the goals and objectives of key management personnel and an analysis of their critical success factors.

- Interviews with selected people about their specific functions and performance experiences and the obstacles that they face in their endeavours to reach their goals and objectives.

Alexandrova and Ivanova (2013) studied the application of the concept of critical success factors to the field of project management and referred to it as those essential functions that are required to ensure that projects are "managed consistently with excellence". They identified client satisfaction – which is growing in importance as a result of uncertainty of the environment and competitive market forces – as the main factor of project success. They conclude that the successful outcome of any project is not only determined by meticulous budget control and activity scheduling, but to a much larger extent by the final outcome of the project in terms of meeting the expectations of all stakeholders. In this study the regulatory management process can be considered equivalent to project management. In the final result, legislation can only be successful if all stakeholders are satisfied with its outcome.

Parmenter (2016) promotes the concept of critical success factors in businesses by stating that their survival and future prosperity depend on it. He concurs with BusinessDictionary.com (2016) and Gates (2010) in the definition of critical success factors by describing them as the *"list of issues or aspects of organisational performance that determine on-going health, vitality and well-being". "Organisation"* may well include a government department as the relevant competent authority for the formulation and implementation of legislation. The principle of critical success factors is therefore equally applicable to the design of the regulatory model in this study with regard to health and safety legislation for hazardous facilities.

In Figure 2.22 Parmenter (2016) illustrates how the critical success factor concept fits into the overall strategic planning process of an organisation. The figure has been adapted in the following manner:

- By replacing the mission, vision and values of the organisation with the strategic intent of the regulating authority.
- By replacing strategies (issues and initiatives) with a process of consultation with stakeholders.

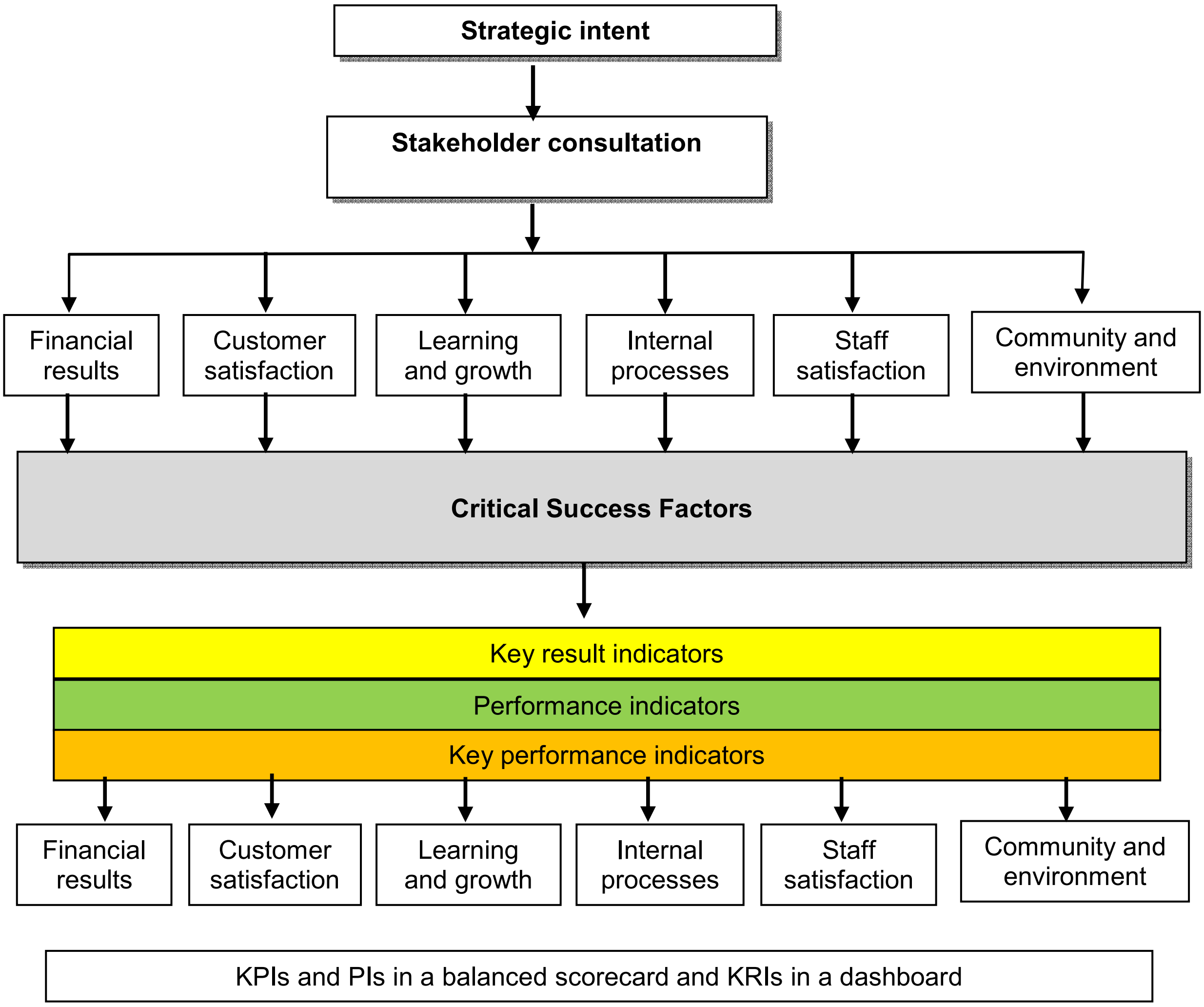

Figure 2.22 Critical success factors as part of the strategic planning process (Source: Parmenter 2016. Adapted by author)

Wronka (2013) conducted research among 300 respondents representing different social ventures operating in the Silesia region of Poland, to identify the critical success factors of social enterprises such as for-profit and non-profit business enterprises that serve a particular community.

Wronka (2013) quotes four different interpretations of critical success factors:

- The essential elements of an organisation's management system
- The exclusive characteristics of an organisation
- An exploratory instrument, used to sensitise the perception of management about the organisation
- The vital qualifications and resources necessary to achieve market success

The mission or ultimate business objectives of an organisation underpin these interpretations, in agreement with Gates (2010). It can consequently be drawn through to the process of regulation formulation as a project approach, similar to what Alexandrova and Ivanova (2013) propose.

Caralli et al. (2004) describe how critical success factors are applied in several different spheres of programme management in the federal government:

- Key concerns of senior management.
- Development of strategic plans.
- Focus areas in each stage of a project life cycle.
- Causes of project failure.
- Reliability of information systems.
- Business threats and opportunities.
- Productivity and performance of people.

Caralli et al. (2004) describe critical success factors as those essential support functions that an organisation must perform well in the long term to be able to achieve its mission. These success factors are present at every level of management. Critical success factors are inherited from the particular industry in which an organisation operates. The important point that the authors make, which is particularly relevant to this research, is that the critical success factor concept can be applied effectively in government management programmes, such as the regulatory management planning and implementation process, which is the focus of this study.

2.3 Chapter conclusions

Seven of eight theories that are relevant to the development of an optimised regulatory management model, were studied in this chapter. The eighth theory on natural technological disasters is addressed in Chapter 3. Although these theories were not explicitly developed for human-induced technological disasters, valuable insight was gained to a better understanding of the various essential success factors that need to be considered in the model development. In this regard the following aspects were found to be particularly relevant and useful in this research:

2.3.1 The open interactive approach between various system components in the regulation formulation process. None of the spheres of influence in the regulatory process can be considered in isolation as they inevitably have an impact on one another.

2.3.2 Current legislation regarding major hazard installations in South Africa requires a quantitative risk assessment, based on the probability estimation and consequence severity modelling of a major incident associated with the installation. This represents an endogenous or inward-focus approach with the focus entirely on the installation itself. The assessment of the vulnerability, resilience and coping capacity of communities around the installation (an exogenous approach) is not required at all.

2.3.3 The concept of vulnerability is applicable to three technological disaster receptors:

- The community around a hazardous facility
- The employees at or inside the hazardous facility
- The hazardous facility itself, which implies the processing equipment, storage facilities and transportation services equipment such as aircraft, ships, trains and road vehicles, which all have the potential to cause harm to people and assets.

2.3.4 By their very nature, hazardous facilities are always self-destructive. In case of a disaster, the trigger disappears until it is reconstructed or replaced. The installation itself is therefore vulnerable to the hazards posed by a major incident.

2.3.5 A very important aspect that the sustainability theory and business continuity theory brought to light is the risks that the company who owns the hazardous facility is exposed to. If a technological disaster occurs, production will be affected and revenue will decline as a result, not to mention the reputational damage that the organisation will incur. The model therefore needs to take into consideration that the business itself has to be one of the focal points in terms of disaster recovery.

2.3.6 A crucial aspect that regulation and control theory highlighted is the impact and wider system interaction of political forces. It becomes clear that no matter how well the regulatory management model is developed and implemented, it will always be subject to political interventions, which are varied, irrational and unpredictable in nature.

2.3.7 The critical success factor theory proves to find an important application in the development process of the regulatory management model. A set of critical success factors has to be developed, to act as standards with which the model has to comply.

Chapter 3

Natural-technological disasters

3.1 Introduction

The occurrence of natural-technological disasters around the world is considered to be of such relevance and importance for this study that a separate chapter is devoted to it.

In this chapter an overview is given of disasters that inherently have a technological origin, but the hazard was triggered by a natural disaster. This is typically the case with a major hazard installation that would function in a human-controlled environment, but was negatively affected by a natural disaster such as an earthquake, wild fire, flood, landslide, tornado or tsunami. The tsunami in Japan in 2011 that led to a major meltdown of the Fukushima Daiichi nuclear power plant is an important case in point.

Much research has been done on natural disasters and related aspects such as community vulnerability, sustainability and the disaster cycle. The first studies on natural-technological (Natech) disasters started in 2011, following the Fukushima disaster. These have become an active field of study by several researchers across the globe – a field that is certain to grow in importance in the future, because of the reality of natural-technological disasters and their enormous potential impacts on human safety and health.

3.2 The theory on natural-technological (Natech) disasters

Arellano et al. (2003) cite historical evidence that natural disasters have the potential to trigger technological disasters in a domino effect. This effect is illustrated in Figure 3.1.

The consequential events associated with natural disasters may present huge health and safety risks to communities that are not prepared for them. In Europe alone there are many vulnerable installations near rivers or located in earthquake areas or subject to other kinds of natural hazards.

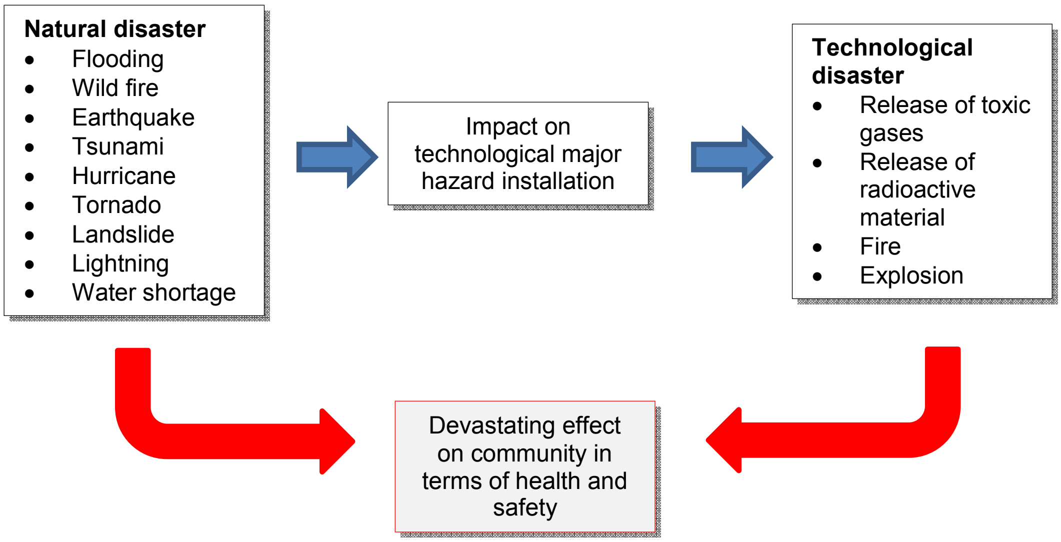

Figure 3.1 The domino principle that illustrates the causal effect of natural disasters on technological disasters (Source: Arellano 2003)

The floods across Europe in 2002 are an example showing the potential danger of Natech disasters in populated areas. For example, in the Czech Republic and in Germany, rapid response by Civil Protection Authorities to natural flooding events prevented disasters of large magnitude. As a result of the threat posed to the environment, including societies, by this domino effect, the NEDIES project has launched a research activity to assess Natech risk management in the EU and Candidate Countries, to identify needs and to render assistance in the prioritisation of strategies for Natech risk mitigation. The United Nations ISDR and the JRC of the European Commission contribute to this study field.

A workshop on natural-technological disasters was held in October 2003 in Italy where 15 countries were represented. The objectives of the workshop were:

- To create awareness of the risks posed by joint natural and technological disasters, by characterising the Natech phenomenon in relation to the various potential hazards in a specific region.
- To understand Natech disaster risk management in Europe.
- To provide an inter-disciplinary forum where experiences and methodologies pertaining to Natech disaster risk management could be shared.
- To identify needs and synergies in the area of Natech disaster risk management and to propose a strategy for future Natech risk reduction with the help of NEDIES and ISDR.

Steinberg and Cruz (2004) studied the effects of the earthquake in Kocaeli, Turkey, in 1999, which resulted in more than 17 000 deaths and at least 40 000 injuries. The earthquake recorded 7.4 on the Richter scale. Thousands of residential and business units were damaged. More than 350 industrial facilities in Kocaeli reported damage to their plants. In addition, the earthquake triggered large fires, the release of toxic gases from dangerous substances into the atmosphere and oil spills at several technological installations. The devastation among communities, initially caused by a natural disaster (earthquake), had serious consequential effects on technological major hazard installations, which in themselves created hazards of a different kind for the communities. All of a sudden, the emergency response plans aimed at containing the effects of the earthquake, had to be adapted to take care of victims who were exposed to hazardous materials in the air, soil and water. The earthquake disaster added a new critical success factor in the form of an added technological disaster.

The earthquake in Turkey confirmed that a seismic event of such scale has the potential to initiate multiple and simultaneous independent disastrous events, which cumulatively can result in devastating consequences. The main problems identified with respect to Natech risk management and emergency response include:

- Seismic design considerations were generally not adequate for health and safety mitigation measures at hazardous installations.
- Health and safety mitigation measures were designed based on the availability of lifelines, i.e. to prevent and respond to hazardous material accidents during the normal day-to-day operation of the plant.
- Emergency response plans for hazardous material releases considered one incident at a time. Single or multiple events from one or more sources were not considered, with the result that emergency preparedness was inadequate.

The Kocaeli earthquake further showed that the consequences of Natech disasters can be greater in large metropolitan areas, because there is a higher population density with additional infrastructure at risk (Steinberg & Cruz 2004). The assessment of community vulnerability to Natech hazards in large urban areas is a prerequisite for Natech risk reduction.

The study in Kocaeli, Turkey, confirms that the analysis of external hazards, such as earthquakes, must be incorporated in plant design. However, this has to be consolidated with technological risk management and emergency response measures designed to function in the absence of water or electrical power, which is common during earthquakes. Community disaster prevention and emergency preparedness must be adapted to potential Natech hazards so that rescue teams may be prepared to respond to such multiple emergencies.

Steinberg and Cruz (2004) made a very important recommendation, following their study in Turkey: The handling of Natech disasters requires that industrial and technological risk managers cooperate with those involved in natural disaster risk reduction. The EEA (2010) report agrees in this respect by emphasising the principle of an integrated risk management approach of prevention, preparedness, response and recovery instead of a response-oriented approach.

Greiving (2006) argues that spatial planning in cities has to incorporate risks that are caused by natural as well as technological hazards, to intensify efforts aimed at reducing the risk of loss of lives and assets from disastrous events. Spatial planning refers to planning for the development of land, especially in urban areas. The HSE (2011) refers to the concept as land-use development and developed specific guidelines for developers and owners of major hazard installations. The HSE makes a very important point, which falls within the ambit of this study, namely that the assessment of health and safety risks that threaten a certain area has to take the following into consideration:

- All relevant hazards
- The vulnerability of the area

Greiving (2006) claims that traditional spatial planning or land-use research focused only on single natural hazards caused by, among others, coastal flooding, river flooding, earthquakes and nuclear power plants.

Greiving (2002) and Schmidt-Thomé (2005) further maintain that land-use or spatial planning has to include a comprehensive risk assessment in order to fully protect the health and safety of communities. They report that such a spatial-oriented risk assessment methodology has four main characteristics:

- It has to have a multi-hazard focus to include both natural and technological hazards. It is must go beyond the sectoral risk considerations that are usually predictable in terms of natural disaster phenomena.

- Only those risks that have a spatial relevance are considered. This means that omnipresent health and safety risks such as epidemic diseases or traffic accidents are not considered in the assessment.

- Only combined risks that threaten the health and safety of a particular community as a whole are relevant and not individual risks such as driving in a car or smoking.

- An integration of risk components is necessary. This includes health and safety hazards and community vulnerability.

Schmidt-Thomé (2005) proposes a multi-risk approach as a coordinated assessment methodology aimed at assessing the all-encompassing risk potential of a certain area by means of accumulating all spatially relevant risks that are caused by natural and technological hazards. Figure 3.2 illustrates how the different risk components are interlinked in a systematic manner.

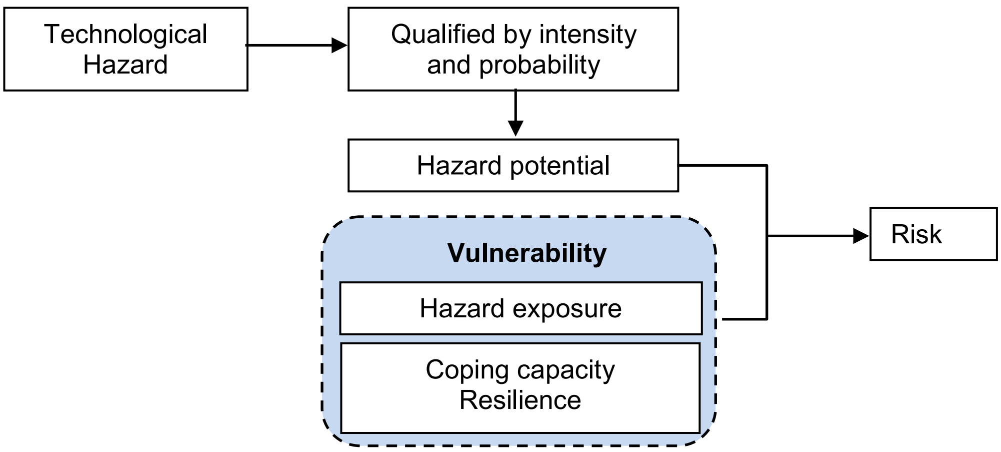

Figure 3.2 The all-inclusive components of risk (Source: Schmidt-Thomé 2005. Adapted by author)

Schmidt-Thomé (2005) does not refer specifically to technological hazards and does not take the resilience of receptor groups into consideration. Figure 3.2 has therefore been adapted accordingly.

The approach by Schmidt-Thomé (2005) is also found in Fleischhauer (2004). It brought about a whole new paradigm for the protection of the health and safety of communities, for two reasons:

- Proper land-use development, as promoted by HSE (2011) does not focus primarily on technological major hazard installations only, but include natural hazards too. The HSE focuses on technological hazards only, but takes meteorological tendencies into consideration.
- The vulnerability of communities, in terms of hazard exposure and coping capacity, also form part of land-use planning. This is not considered by HSE (2011) at all.

The main reason for this change in the approach to risk management is the awareness that risk potential is increasing and that it is not sufficient anymore to restrict risk policies to the response phase only of the emergency management cycle, as emphasised by Coetzee and Van Niekerk (2012).

Fleischauer et al. (2005) point out that, from a spatial planning perspective, sustainable development cannot take place unless the health and safety hazards to which communities are exposed are duly mitigated. They argue that little attention is paid to multi-risk approaches in spatial planning practices in Europe, except for France and Switzerland, where the multi-hazard approach has been established as part of land-use development planning practice. In France, the accumulated hazard potential is indicated on a regional scale by adding the different single hazards, but no consideration is given to the severity of the hazard. It highlights the critical importance of an elaborate risk prevention plan on local government level, which has long-term binding implications for land-use planning (HSE, 2011a). However, France does not assess the vulnerability of communities near technological major hazard installations.

In Switzerland, the urban land-use planning authority produces a series of single-hazard maps containing three hazard zones, designated as high, medium and low hazard potential (Fleischauer et al. 2005). These zones have specific residential development restrictions, for example no new development may take place in high hazard potential zones. These hazard zones are based on single-hazard risk assessments, mapped individually. The maps should be aggregated to obtain a multi-risk view of a particular area. Each area that may potentially be impacted by a certain natural hazard such as a flood, avalanche or landslide is designated to be a high hazard potential zone.

Land-use planning in Switzerland does not consider the cumulative effects of natural and technological hazards and excludes community vulnerability, as Schaller (2003) reports.

EEA (2010) states in its environmental overview report for the period 1998–2009 that an increasing number of disasters are experienced in Europe as a result of natural and technological accidents, with growing impacts. The report claims that these are caused by a combination of changes in Europe's land-use, technological and social systems. It also emphasises strongly that the potential for a hazard to evolve into a disaster primarily depends on how vulnerable communities are to such hazards in terms of hazard exposure and coping capacity. Well-formulated and effectively implemented mitigation measures can reduce the human health and safety as well as the economic impact of a disaster. The EEA (2010) reports that even events that do not reach a large enough magnitude to be classified as a disaster, may account for substantial direct and indirect financial losses. During the 12 years from 1998 to 2009 natural and technological disasters caused nearly 100 000 fatalities and affected more than 11 million people. However, technological disasters had particularly large impacts on ecosystems.

Most notable are industrial disasters triggered by natural disasters (EEA 2010). These Natech disasters are considered to become more important in future, for two reasons:

- There is an increased frequency and severity of extreme natural phenomena.
- There is an increased complexity and interdependence of industrial technological systems. The interactive, open systems approach of Cilliers (1998) and Weirich (2008) is supported in the EEA report (2010) and also reflected in the work of Chikere and Nwoka (2015).

Following the major oil spill caused by the Exxon Valdez oil tanker in 1989 in Alaska, regional communities around the Alyeska crude oil pipeline terminal in Alaska established an environmental forum as part of the disaster management initiative in the area. The forum, called the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC 2004) found that there are some common differences between naturally occurring disasters and technological disasters that are manmade, as outlined in Table 3.1.

Table 3.1 Common differences between naturally occurring disasters and technological manmade disasters (Source: PWSRCAC 2004)

Natural disasters	Technological disasters
Naturally occurring events such as hurricanes, tornados, floods or earthquakes that affect the environment and lead to financial, environmental and/or human losses.	Catastrophic events caused by humans that result in toxic contamination of the environment and lead to financial, environmental and/or human losses.
Typically follow a pattern of warning, threat, impact, rescue, inventory, remedy, recovery and rehabilitation.	Trapped at impact stage for an unknown period of time, but also have to deal with other stages all at once, sometimes in a very piecemeal fashion.
Individuals and communities may have ability to plan beforehand for the disaster and its aftermath, e.g. the community and most individuals in it are prepared to the best of their ability for a hurricane.	Usually no or minimal preplanning occurs and usually not at the individual level.
Outreach from others is immediate to help with the various stages; resources are offered to the community and individuals.	Outreach from others may be slow, waiting for an entity involved in the disaster to take responsibility; have to rely on community resources which may be scarce or inadequate to meet the demands of the event.
Therapeutic community: Community and individuals pull together, bond for the good of all-social connectedness, activities are coordinated and focused on fostering a return to pre-disaster conditions.	Corrosive community: Response is not as focused on community and individual recovery, outsiders with little or no connection to the community may be leading the recovery efforts, fears of the ongoing consequences of the disaster foster high levels of stress, anxiety and conflict; individuals have to seek out help, may be involved in long-term litigation, there is a lack of social connectedness, some individuals directly impacted may be eligible for recompense while others may not, creating community conflicts.
May experience ongoing stresses related to the secondary effects (the indirect consequences) of the disaster. This may include supply and housing shortages, job loss, economic impacts, ongoing disruptions in daily life, litigation, flood of media.	May experience ongoing stresses related to the secondary effects (the indirect consequences) of the disaster. This may include supply and housing shortages, job loss, economic impacts, ongoing disruptions in daily life, litigation, flood of media, conflicts among politicians and government entities.
After the disaster the individual and community can rebuild toward a pre-disaster state of being and toward closure; the ecosystem can begin recovery and re-growth.	Impacts of the disaster are long-term and often unknown and lack closure, possible ongoing physical health, mental health, economic and ecological problems/damage, lingering primary and secondary effects on the community and individuals.

The council is doing extensive research on disasters originating from natural versus technological origins (PWSRCAC 2004). It reports that disasters are not all the same and that their effects on individuals or communities are different and the impacts of the disaster depend on the ability of individuals and the community to cope with its short-term and long-term effects as well as their overall resilience.

Krausmann et al. (2011) analyse the impacts of natural hazards on chemical facilities and infrastructures. Such events have the potential to cause the release of hazardous substances and have been recognised as an emerging risk. Efforts are made to address the risks of Natech accidents by trying to understand their underlying causes and by developing methodologies and tools to assess these risks, with special attention to the risk of chemical accidents triggered by earthquakes, floods and lightning. Research in this field focuses on the development of methodologies for Natech hazard and vulnerability ranking, risk assessment, risk-based design, emergency planning and early warning systems.

According to Krausmann et al. (2011*)* between 2% and 5% of accidents with hazardous-substance releases reported in selected chemical accident databases were triggered by natural events. This may seem like a low incident rate, but the events had high impact potential in terms of fatalities, injuries and asset damage.

Other than technological disaster risk or natural disaster risk, Natech risk has a multi-hazard nature. It therefore requires an integrated approach to risk management. The simultaneous occurrence of a natural disaster and a technological accident, which require different response efforts, creates a situation in which infrastructure and resources needed for disaster mitigation are likely to have been destroyed. The release of hazardous materials may result from single or multiple sources in one hazardous installation or at the same time from several hazardous installations in the impact area where the natural disaster occurred.

Krausmann et al. (2011) found that legislation and standards for accident prevention in the chemical industry do not specifically address Natech risk, that methodologies for the assessment of Natech risk are scarce and that only limited guidance is available for industry and the authorities on the assessment of Natech risk. They propose a risk assessment methodology that explicitly focuses on the risk associated with the impacts of a natural disaster on technological hazardous installations such as chemical plants.

The aforementioned research done in the field of Natech risk has an important bearing on this study – the proposed regulatory model must provide for the assessment of risks associated with natural disasters and their impact on hazardous facilities.

Yong (2015) gives the following description of hazards that may affect human life on earth:

- Natural hazards that are not caused by human activities, such as earthquakes, volcanic eruption, tsunamis, storms, floods and landslides
- Human-induced hazards such as acid rain, soil erosion, water contamination, atmospheric pollution and ozone depletion

The description of human-induced hazards is in agreement with the term “technological” hazard used by Krausmann et al. (2011) and the definition used in this study. Human-induced hazards are created by technological major hazard installations.

Petrova and Krausmann (2011) point out that the period 2008–2010 experienced a high number and high severity of natural disasters. It demonstrates the serious vulnerability of modern society to the impact of natural disasters. In 2010 and the first half of 2011 natural disasters killed more than 320 000 people across the world.

Petrova and Krausmann (2011) conclude that a critical consequence of natural disasters is Natech accidents that occur when natural disasters trigger accidents at technological major hazard installations where the processing or storage of hazardous materials is involved, such as nuclear power plants, chemical facilities, oil refineries or petroleum pipelines. One of the most large-scale Natech accidents occurred on 11 March 2011 in Japan as a result of a massive 9.0-magnitude earthquake off the northeast coast of Honshu Island that caused a tsunami with a wave height of more than 30 metres. The estimated total damages exceeded US $210 billion (CRED 2011b), which makes the Tohoku disaster the most destructive in world history. It led to a number of Natech accidents, including accidents at the Fukushima 1 and Onagawa nuclear power plants as well as explosions and fires at a refinery in Chiba and at a petrochemical plant in Sendai. It also damaged or destroyed critical infrastructure such as electrical power generation, water supply and communication. The tsunami resulted in supply disruptions and severely impeded transport of people and goods. Such disruptions hamper the normal functioning of society through cascading events and also adversely impact emergency-response operations that rely on the immediate availability of lifelines.

According to Petrova and Krausmann (2011) a prominent characteristic of the impacts of natural disasters on technological systems, such as the abovementioned Tohoku earthquake and ensuing tsunami, is their synergistic outcome that leads to the simultaneous occurrence of numerous technological accidents and disruptions. If not properly planned for, it is almost impossible to manage the consequences of such linked disasters, because one has to cope not only with the impacts of the natural disaster, but also with the consequential effects of the technological accidents. It places a huge burden on rescue team operations and resource deployment. The potential consequences of a Natech accident are even more severe in the case of high population densities and high concentration of industrial facilities and infrastructure, especially major hazard installations in the disaster area.

Petrova and Krausmann (2011) state that the number and severity of impacts from natural disasters on technological major hazard installation systems are increasing globally. It seems as if nature puts people and the technosphere to the test with the following incidents:

- Flood-triggered Natech accidents in Europe in 2002.
- Hurricanes Katrina and Rita in 2005 and their impacts on offshore oil and gas production in the Gulf of Mexico.
- The Natech accidents in 2008 in the wake of the Wenchuan earthquake in China.
- The volcanic eruption in Iceland in 2010 that created havoc on world air traffic.
- The forest fires in the Russian Federation that threatened a nuclear research centre and oil refineries.

In this study a distinction is made between two different types of disasters, namely natural and technological disasters. Both types are caused by a trigger of some kind or other, of natural or human origin. The trigger-disaster relationship is presented schematically in Figure 3.3.

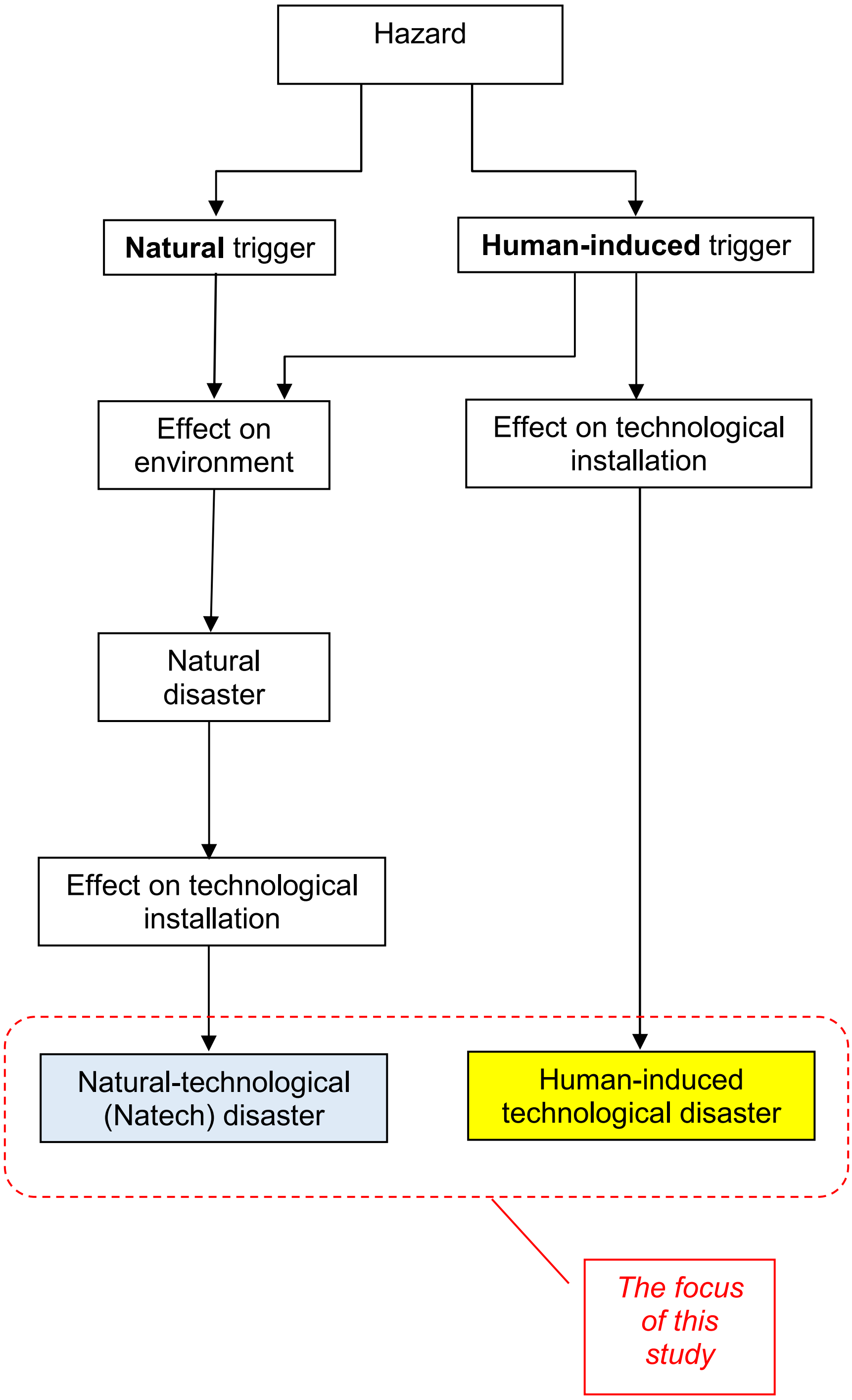

Figure 3.3 The occurrence of disasters through the trigger-disaster relationship as the focus of this study (Source: Own deduction)

The proposed model for the regulatory management of human-induced health and safety risks posed by hazardous technological facilities has to take the following objectives into consideration:

- The model must provide for disasters caused by natural or human-induced triggers.
- The model must provide for disasters caused by human installations that pose major hazards to society in the form of fires, explosions or the release of toxic gases.

The effect that natural disasters can have on technological installations, as studied by Krausmann et al. (2007), are particularly relevant to this study. The focus of the study is on human-induced risks, which incorporate hazardous facilities designed and constructed by humans. However, such facilities may be vulnerable to several disaster triggers, including natural disasters. Apart from natural disasters, such triggers may of course also come from human action such as the maloperation of the facility or sabotage.

3.3 The Fukushima Daiichi nuclear power plant Natech disaster

A well-documented incident that illustrates the concept of a Natech disaster, is the deep-sea earthquake that started 370 km northeast of Tokyo, Japan, on 11 March 2011 (Krausmann et al. 2011). This disaster resulted in a growing awareness of the cause-effect relationship between natural disasters and technological disasters.

The CNN news channel reported the sequence of events leading to the Fukushima disaster as follows (2011):

- *"March 11, 2011. At 2:46 p.m. an 8.9 magnitude earthquake takes place 231 miles northeast of Tokyo, Japan (8.9 = original recorded magnitude; later upgraded to 9.0). The Pacific Tsunami Warning Centre issues a tsunami warning for the Pacific Ocean from Japan to the USA about an hour after the quake.*

- *Waves up to 30 feet high hit the Japanese coast, sweeping away vehicles, causing buildings to collapse, and severing roads and highways.*

- *The Japanese government declares a state of emergency for the nuclear power plant near Sendai, 180 miles from Tokyo. Sixty to seventy thousand people living nearby are ordered to evacuate to shelters.*

- *March 12, 2011. Overnight a 6.2 magnitude aftershock hits the Nagano and Niigata prefecture (USGS).*

- *At 5:00 a.m. a nuclear emergency is declared at Fukushima Daiichi nuclear power plant. Officials report the earthquake and tsunami have cut off the plant's electrical power, and that backup generators have been disabled by the tsunami.*

- *Another aftershock hits the west coast of Honshu – 6.3 magnitude (5:56 a.m.).*

- *The Japanese Nuclear and Industrial Safety Agency announces that radiation near the plant's main gate is more than eight times the normal level. Cooling systems at three of the four units at the Fukushima Daini plant fail, prompting state of emergency declarations there.*

- *At least six million homes – 10 percent of Japan's households – are without electricity, and a million are without water.*

- *The US Geological Survey says the quake appears to have moved Honshu, Japan's main island, by eight feet and has shifted the earth on its axis.*

- *About 9 500 people – half the town's population – are reported to be unaccounted for in Minamisanriku on Japan's Pacific coast.*

- *March 13, 2011. People living within 10 km (6.2 miles) of the Fukushima Daini and 20 km of the Fukushima Daiichi power plants begin a government-ordered evacuation. The total evacuated so far is about 185 000.*

- *50 000 Japan Self-Defence Forces personnel, 190 aircraft and 25 ships are deployed to help with rescue efforts.*

- *A government official says a partial meltdown may be occurring at the damaged Fukushima Daiichi plant, sparking fears of a widespread release of radioactive material. So far, three units there have experienced major problems in cooling radioactive material.*

- *March 14, 2011. The US Geological Survey upgrades its measure of the earthquake to magnitude 9.0 from 8.9. The new reading means the quake is the fourth strongest earthquake since 1900.*

- *An explosion at the Daiichi plant No. 3 reactor causes a building's wall to collapse, injuring six. The 600 residents remaining within 30 km of the plant, despite an earlier evacuation order, have been ordered to stay indoors.*

- *The No. 2 reactor at the Daiichi plant loses its cooling capabilities. Officials quickly work to pump seawater into the reactor, as they have been doing with two other reactors at the same plant, and the situation is resolved. Employees scramble to cool down fuel rods at two other reactors at the plant, No. 1 and No. 3.*

- *Rolling blackouts begin in parts of Tokyo and eight prefectures. Downtown Tokyo is not included. Up to 45 million people will be affected in the rolling outages, which are scheduled to last until April.*

- *March 15, 2011. The third explosion at the Daiichi plant in four days damages the suppression pool of reactor No. 2, similar to an explosion occurring at No. 1 over the weekend. Water continues to be injected into "pressure vessels" in order to cool down radioactive material.*

- *March 16, 2011. The nuclear safety agency investigates the cause of a white cloud of smoke rising above the Fukushima Daiichi plant. Plans are cancelled to use helicopters to pour water onto fuel rods that may have burned after a fire there, causing a spike in radiation levels. The plume is later found to have been vapour from a spent-fuel storage pool.*

- *In a rare address, Emperor Akihito tells the nation not to give up hope and that "we need to understand and help each other". A televised address by a sitting emperor is an extraordinarily rare event in Japan, usually reserved for times of extreme crisis or war.*

- *After hydrogen explosions occur in three of the plant's reactors (1, 2 and 3) Chief Cabinet Secretary Yukio Edano says radiation levels "do not pose a direct threat to the human body" between 12 to 18 miles (20 to 30 kilometres) from the plant.*

- *March 17, 2011. Gregory Jaczko, head of the Nuclear Regulatory Commission, tells US Congress that spent fuel rods in the No. 4 reactor have been exposed because there "is no water in the spent fuel pool", resulting in the emission of "extremely high" levels of radiation.*

- *Helicopters operated by Japan's Self-Defence Forces begin dumping tons of seawater from the Pacific Ocean on to the No. 3 reactor to reduce overheating. Radiation levels hit 20 millisieverts per hour at an annex building where employees have been trying to re-establish electrical power, "the highest registered (at that building) so far", (TEPCO).*

- *March 18, 2011. Japan's Nuclear and Industrial Safety Agency raises the threat level from four to five, putting it on a par with the 1979 Three Mile Island accident in Pennsylvania. The International Nuclear Events Scale says a Level Five incident means there is a likelihood of a release of radioactive material, several deaths from radiation and severe damage to the reactor core.*

- *April 12, 2011. Japan's nuclear agency raises the Fukushima Daiichi crisis from Level 5 to a Level 7 event, the highest level, signifying a "major accident". It is now on par with the 1986 Chernobyl disaster in the former Soviet Union, which amounts to a "major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures".*

- *June 6, 2011. Japan's Nuclear Emergency Response Headquarters report that reactors 1, 2 and 3 at the Fukushima Daiichi nuclear power plant experienced a full meltdown.*

- *June 30, 2011. The Japanese government recommends more evacuations of households 50 to 60 km northwest of the Fukushima Daiichi power plant. The government said higher radiation was monitored sporadically in this area".*

The above sequence of events illustrates the catastrophic consequences that a natural disaster (earthquake) can have on a technological installation (nuclear plant).

3.4 Chapter conclusions

This chapter highlights the following points:

3.4.1 Worldwide there is a renewed awareness of the linkage between natural disasters and consequential technological (Natech) disasters.

3.4.2 This study takes the integrated risk management approach into consideration as a new approach compared with the traditional post-disaster response approach. It is particularly important to take note of pre-disaster planning with regard to the potential for natural disasters to trigger technological disasters.

3.4.3 Land-use spatial planning has to include Natech risks and vulnerability assessment, including hazard exposure and the coping capacity of communities in preparation for natural and technological disasters.

3.4.4 This research acknowledges the fact that natural disasters can trigger technological disasters. The human intervention that has the potential to trigger a technological disaster, as the foundation of this study, remains the focus point of the regulatory management model, in three ways:

- Hazardous facilities are always designed by humans.
- Hazardous facilities are always constructed by humans.
- Hazardous facilities are always operated by humans.

Chapter 4

The impacts of human-induced disasters as illustrated by three case studies

4.1 Introduction

In this chapter three cases of human-induced disasters are analysed: one in India, one in South Africa and one in England. The cases selected involved the uncontrolled atmospheric release of toxic methyl isocyanate and sulphur dioxide gases, and a petrol vapour cloud explosion and ensuing fire at a liquid petroleum storage depot. All three incidents had far-reaching effects on the surrounding communities.

The three cases were analysed in order to find answers to the following questions:

- What was the main cause of the disaster?
- What was the extent of the disaster?
- Was the vulnerability of the surrounding communities properly assessed prior to the disaster in terms of coping capacity, resilience and required recovery measures?
- Was adequate effective legislation in place to prevent such disasters?
- Was the use of land around the hazardous installation properly planned to avoid the impacts of a major incident on community settlements?

4.2 Case study 1: The Bhopal disaster in India, 1984

4.2.1 Unfolding of the disaster

Union Carbide India Limited owned and operated a chemical plant in Bhopal, central India. On 3 December 1984 methyl isocyanate gas leaked from a storage tank, causing the death of approximately 5 200 people and permanent or partial disabilities to several thousands of others on and around the plant (Union Carbide internet website 2015). About 41 tons of the chemical was released into atmosphere in a gaseous phase and more than 300 000 people were affected with life-long misery and genetic defects passed on to next generations (Gupta 2002).

A Union Carbide Corporation investigation team arrived in Bhopal, but could not begin with its investigation because the Indian Central Bureau of Investigation had taken control of and sealed the plant, seized records of the plant and prohibited interviews with relevant plant employees. The methyl isocyanate unit had been shut down six weeks before the incident and the storage tank from which the gas was released had been isolated at that time.

Samples were taken of the residue in the storage tank. The analyses showed that a large volume of water had been introduced into the methyl isocyanate tank, which caused a violent exothermic chemical reaction that forced the pressure release valve to open and release the deadly gas into the atmosphere. The incident occurred despite the fact that the system had been designed and operated to keep out even trace amounts of water. No water had ever entered any of the tanks during the five years the plant had been in operation.

Two and a half years after the tragedy, Union Carbide Corporation issued the findings of its scientific and legal investigations, which had come to the conclusion that the cause of the disaster was sabotage through the direct entry of water into the storage tank via a hose connected to the tank. This conclusion by Union Carbide was supported by the independent investigation conducted by Ashok S. Kalelkar of Arthur D. Little, Inc. engineering consultants. Only an employee with the appropriate skills and knowledge of the site could have tampered with the tank. The water could only have been introduced into the tank deliberately, because process safety systems would have prevented water ingress into the tank. The methyl isocyanate storage tank and ancillary equipment were designed to prevent a large amount of water from entering the system.

Kalelkar (1988) was a member of the independent investigating team of the engineering consulting firm Arthur D. Little Inc. that was appointed for the Bhopal disaster. His concluding remarks were as follows:

"By their nature, large-magnitude incidents present unique problems for investigators. In the case of the Bhopal incident, these problems were compounded by the constraints placed on the Union Carbide investigation team by the Indian Government and, most significantly, by the Bhopal as a Case Study –

Union Carbide Corp. prohibition of interviews of plant employees for over a year. Had those constraints not been imposed, the actual cause of the incident would have been determined within several months. Because the investigation was blocked, a popular explanation arose in the media as to the cause of the tragedy. A thorough investigation, which included scores of in-depth witness interviews, a review of thousands of plant logs, tests of valving and piping, hundreds of scientific experiments, and examinations of the plant and its equipment, was ultimately conducted over a year later. That investigation has established that the incident was not caused in the manner popularly reported, but rather was the result of a direct water connection to the tank."

Dharmendra et al. (2014) came to a quite different conclusion from that of Kalelkar (1988). They reported that on the nights of 2 and 3 December 1984, the Union Carbide plant in Bhopal began leaking due to runaway reactions, rising temperature and pressure and a lifted safety atmospheric valve. About 25 to 27 tons of methyl isocyanate spread through the city of Bhopal, exposing half a million people to the gas. The authors listed the following causal factors:

- Systems for the prevention or control of the toxic gas release were out of service. The root causes were lack of safe operating procedures, poor plant maintenance and a lack of funds.
- The reactor cooling system was inoperative. The root cause was a serious lack of proper plant management and the absence of adequate supervisory inspections.
- The scrubbing system to absorb the released vapour was not immediately available. Again, the root causes were lack of safe operating procedures, poor plant maintenance and a lack of funds.
- The flare system to burn vapours getting past the scrubber was out of service. This was probably the most serious oversight. Combustion of the harmful methyl isocyanate vapours could have reduced the risk of toxic effects on the community substantially and reduced the number of fatalities among the communities, probably to zero.

Peterson (2009) gave a description of the economic ambitions of the Indian government at the time of the Bhopal disaster, which are important to understand in order to see the existence of the Union Carbide plant in perspective. When India attained independence from Great Britain in 1947, its new political leaders endeavoured to build wealth for the country by encouraging the development of modern industries. The citizens, state-owned enterprises and private firms gave strong support for this initiative.

The Indian government expressed a strong preference for Indian enterprise in its Resolution on Industrial Policy in 1948, but at the same time it was willing to allow some collaboration with foreign firms:

"… *while it should be recognized that participation of foreign capital and enterprise, particularly as regards industrial technique and knowledge, will be of value to the rapid industrialization of the country, it is necessary that the conditions under which they may participate in Indian industry should be carefully regulated in the national interest. Suitable legislation will be introduced for this purpose."*

The subsequent legislation included limits on foreign shareholding in Indian firms, so that multinational companies could not own 100% of their Indian subsidiaries, but had to share ownership with Indian nationals. It also gave preference to collaboration where the foreigners owned technology not available in India. The Indian government wanted to determine the conditions on which the country could acquire technology by law. Its first preference was to import technology *"at the lowest cost"* without paying licence fees on imported technology for more than five years. However, foreign companies were unwilling to make deals with Indian state-owned and private firms on such conditions. As an alternative the Indian government implemented a system that required subsidiaries of foreign firms to be part-owned by Indian nationals. In addition, local Indians had to be trained in all aspects of business operations and technologies, any business operation using foreign technology had to be licensed by the state and the government specifically had to approve the type and duration of employment of foreigners hired as managers, technical specialists or employees.

The USA Union Carbide company established a subsidiary in India, Union Carbide (India) Limited (UCIL), even before the country's independence, primarily as a maker and seller of dry cell batteries under the Eveready trademark. In the 1960s UCIL decided to expand into the production of fertilisers and pesticides. This followed a request from the government, which encouraged firms to supply local farmers with the chemicals needed to cultivate new hybrids of rice, wheat and cotton. India had suffered serious food shortages in the early to middle 1960s as a result of drought. The greater drought-resistance of the newly created hybrid crops made them very attractive to a government concerned with feeding a growing population and increasing the supply of locally grown cotton for the growing textile industry.

UCIL established its Agricultural Products Division in the mid-1960s. At that time the largest concentration of Indian chemical plants was located in Chembur near Bombay, an area that local citizens named the “gas chamber” due to the extensive air pollution that was caused by the plants. At that stage there was relatively little industrial development in Bhopal, but both the central government and the state government of Madhya Pradesh (with Bhopal as its capital) were anxious to bring manufacturing industry to the area to stimulate the local economy. Thus UCIL’s plans for a chemical plant and an agricultural products Research and Development Centre were received favourably. The state government of Madhya Pradesh even provided the land for the proposed chemical plant on a favourable 99-year lease. The UCIL plant brought with it the prospects of job creation at good salaries, not only for engineers and technicians, but also for lower-level employees. From the start, UCIL executives made dedicated efforts to maintain healthy relations with local political leaders.

The rural population of Madhya Pradesh was increasing at a rate of 2% per annum during the period 1960–1970. Bhopal became one of the fastest-growing cities in India during this time, as unemployed citizens from the surrounding countryside streamed in, looking for jobs. At the same time the state government was keen to establish a strong industrial base in Bhopal. As in other Indian cities and typical of areas with high population density, growth and development were chaotic and land development planning often followed after people had already settled on unoccupied areas of land and built themselves vary basic shelters. The resulting informal shelters were usually narrow strips of dilapidated structures with mud walls and wood or sheet metal roofs. The units were located along already constructed roads and were separated by narrow alleys. There was a lack of proper basic infrastructure such as piped water, sewage, electricity and access to public transportation, even in the more established areas of town. Telephones were limited and usually to be found in government buildings only, but they were often out of order. Electricity supply was unreliable and frequent interruptions occurred during the day and night. In 1984 there were only 1 800 hospital beds and 300 doctors to serve the whole of Bhopal.

When UCIL started with the construction of its plant in 1968–69, the population of Bhopal was around 300 000 with large areas next to the plant still unpopulated, despite being closer to the centre of the city and to some established neighbourhoods with hospitals and a railway station. As other industries developed nearby, a reliable electricity supply was connected to the plants. These developments made the area more attractive to unemployed people. Also, the state government owned much of the unoccupied land around the plant, which made the area attractive to squatters and to opportunists posing as landowners who rented shacks to others. The risk of getting them resettled was less compared with private landowners.

Plans for the development of Bhopal City were drawn up in 1958–63, but were never implemented. In 1975, the Madhya Pradesh government adopted a new Master Plan for Bhopal designating areas for residential and other developments and establishing a "hazardous industry" district in an area about 24 km from the centre of town.

UCIL had been producing pesticides at its plant since 1969, by diluting concentrates to the strength needed for agricultural use. In October 1975 the company obtained a licence from the central government to produce up to 5 000 tons of Sevin, a carbaryl-based pesticide using a methyl isocyanate process. It was necessary to add new facilities in the existing factory to implement more complicated production processes. During a review in 1976 the state planning board classified the plant as "general industry" rather than "hazardous industry". This decision authorised both the existing plant operations and the new construction to proceed at the existing location.
In the 1981 Indian census the population of Bhopal was estimated at 896 000 people. In 1984, when the city population stood at around 900 000 people, the state government acceded to the reality of settlements around the UCIL plant by issuing certificates confirming squatters' ownership of about 50 square metres of land where their shack was built. This decision was motivated by the following factors:

- The desire of the political party in power to secure votes in future elections
- A realisation that the settlers could not be moved
- A desire to reduce the pressure from persons posing as legitimate landowners

Many residents in the area had tapped into the electric grid illegally, but neither the state nor the city government was willing to install piped water or sewers in the densely populated area. The authorities did not make any attempt either to curb the enormous industrial and household pollution of the adjacent lakes.

The UCIL company was successful in its role to dilute and package concentrated chemical fertilisers and pesticides for customer use, which was a simple operation. Pressure from the Indian government and efforts by the company to have the plant scaled up to full production of chemicals were plagued with difficulties. UCIL's initial plans were to produce Union Carbide's carbaryl pesticides using an alpha-naphthol process formulated by its chemists in 1969. However, it proved much more difficult than expected to scale up to the volumes that would be needed to produce a pesticide economically on-site. The new alpha-naphthol unit failed soon after construction was completed in 1978 and an additional $2 million had to be spent on reconstruction. The reconstructed unit again failed soon after its commissioning in 1981. The plant had to import alpha-naphthol from Union Carbide in the USA.

After reviewing production costs in 1981, Union Carbide suggested that UCIL should also import the methyl isocyanate, but the Indian government, which had approved the project in the expectation of boosting local production in the Bhopal industrialised area, rejected the application. At the same time the government set a cut-off date of January 1985 for alpha-naphthol imports. This effectively established a tight deadline for UCIL to get the process to work. By 1982, as construction of the methyl isocyanate unit was nearing completion, the market changed and UCIL and Union Carbide realised that the plant was not economically viable anymore. Local demand for UCIL's pesticides had dropped significantly since 1977, because Indian farmers moved to cheaper local products. In the USA and Western Europe new generation carbofuran pesticides were under development, to infiltrate and win the Sevin market. The Bhopal plant showed a modest profit in 1981, but it operated below capacity and at a loss after that. UCIL and Union Carbide considered various alternatives and UCIL eventually agreed to accept Union Carbide suggestions for selling all or most of the plant. By the third quarter of 1984 the plant was operating at about 20% of its capacity.

4.2.2 Simulation of the disaster

Kothari et al. (2014) used the ALOHA dispersion modelling software developed by the US Environmental Protection Agency and the US National Oceanographic and Atmospheric Administration (EPA and NOAA, 2015) to model the effects of the toxic release of methyl isocyanate around the Union Carbide plant in Bhopal. The software has received international recognition and is used by many countries around the world as a valuable instrument in disaster planning and management.

Batterman et al. (1998) referred to the valuable use of the ALOHA software in the Somerset West sulphur stockpile fire in 1995 in South Africa. Koch (2015) applied the ALOHA gas dispersion modelling software to simulate typical severe toxic concentration releases of ammonia and chlorine gas in the atmosphere, in his study to determine the preparedness of emergency first responders of Ekurhuleni Municipality.

Sharan et al. (1994) report that existing models for the dispersion of air pollutants can be classified into two groups:

- Analytical models to simulate Gaussian plumes and puffs
- Numerical models

Gaussian dispersion models assume that atmospheric winds are constant in space and time and may therefore fail in an urban environment where obstacles and turbulence at ground level may be encountered. These models do not make provision for low wind speeds or stable conditions either. The model results are therefore applicable only to a specific locality at a specific time. Sharan et al. (1994) further report that the planetary boundary layer plays a vital role in the dispersion and transport of air pollutants. The boundary layer shows large time-based and spatial variations, which directly influence the dispersion mechanisms of xenobiotic molecular species. Such variations become substantial in coastal areas and over irregular terrain and can produce misleading results.

Sharan et al. (1994) therefore propose the use of numerical models to study the structure of planetary boundary layers in the absence of sufficient or correct meteorological data. These numerical models are useful to describe the dynamics, the thermodynamic and turbulent structure of the boundary layer for different atmospheric stabilities, including low and high wind speeds. The authors applied the Lagrangian Particle Dispersion model to the Bhopal scenario. The model predicts a Barrow plume downwind near the centreline of the affected areas of the communities. However, the model failed to produce sufficient mixing of layers to direct the methyl isocyanate cloud groundwards. It may also not produce horizontal dispersion patterns.

The numerical model reportedly used by Sharan et al. (1994) has a number of shortcomings:

- The numerical model only predicts the size and direction of the toxic plume. It does not predict concentration values of methyl isocyanate at specific safety distances from the source point.

- The model does not make provision for varying emission concentrations of methyl isocyanate or the duration of toxic gas release.

- The model does not allow for a comparison of airborne methyl isocyanate concentration with acceptable exposure levels such as STEL or AEGL, linked to varying safety distances according to varying exposure levels.

- The model gives good predictions of atmospheric boundary layer conditions, irrespective of the xenobiotic molecular species that is emitted.

Using the latest version of the ALOHA software (version 5.4.6 of February 2016) the author repeated the modelling. ALOHA software is well understood and easy to apply, and has received international approval (Dharmendra et al. 2014). From a regulatory point of view ease of application and consistency between different simulation software applications are important. The assumptions, errors and uncertainties of the ALOHA software model are generally well understood.

Gaussian-plume models play a major role in the regulatory arena. ALOHA software uses Gaussian-plume models for the dispersion modelling of toxic gases. The Gaussian-plume formula is derived by assuming *"steady-state"* conditions, i.e. the Gaussian-plume dispersion formulae do not depend on time, although they do represent an integrated time average. The meteorological conditions are assumed to remain constant during the dispersion from source to receptor, which is regarded to be instantaneous. Although emissions and meteorological conditions can vary from hour to hour, the ALOHA model calculations in each hour are not a function of those in other hours. Due to this mathematical derivation, Gaussian-plume models are generally referred to as steady-state dispersion models.

The results of the modelling are shown in Table 4.1. The following model parameters were used in the simulation:

- Wind speed: 3 m/s
- Wind direction: NE

- Ambient temperature: 25 °C
- Cloud cover: 50%
- Humidity: 50%
- No inversion conditions
- Release rate of methyl isocyanate: 30 tons in 60 minutes
- Geographic coordinates of the Union Carbide plant:
  - N 23.281409
  - E 77.410372
- Acute exposure guideline levels for methyl isocyanate:
  - AEGL-3: 0.2 ppm, 60-minute exposure
  - AEGL-2: 0.067 ppm, 60-minute exposure

Table 4.1 Dispersion modelling for methyl isocyanate atmospheric release at the Union Carbide plant in Bhopal, India (Software source: ALOHA with own calculations)

SITE DATA
Location: BHOPAL, INDIA
Building air exchanges per hour: 0.63 (unsheltered single-storied)

CHEMICAL DATA
Chemical name: METHYL ISOCYANATE   Molecular weight: 57.05 g/mole
AEGL-1 (60 min): N/A   AEGL-2 (60 min): 0.067 ppm   AEGL-3 (60 min): 0.2 ppm
IDLH: 3 ppm   LEL: 53000 ppm   UEL: 260000 ppm
Ambient boiling point: 37.2 °C
Vapour pressure at ambient temperature: 0.58 atmospheres
Ambient saturation concentration: 616,265 ppm or 61.6%

ATMOSPHERIC DATA (MANUAL INPUT OF DATA)
Wind: 3 metres/second from NE at 3 metres
Ground roughness: urban or forest   Cloud cover: 5 tenths
Air temperature: 25 °C   Stability class: D
No inversion height   Relative humidity: 50%

SOURCE STRENGTH
Direct source: 500 kg/min   Source height: 0
Release duration: 60 minutes
Release rate: 500 kg/min
Total amount released: 30 000 kilograms

THREAT ZONE
Model run: Heavy gas
Red: greater than 10 kilometres --- (0.2 ppm = AEGL-3 [60 min])
Orange: greater than 10 kilometres --- (0.067 ppm = AEGL-2 [60 min])
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

The model result was superimposed on an aerial photograph of the area where the Union Carbide plant was located in Bhopal in the Madhya Pradesh State of India, as shown in Figure 4.1.

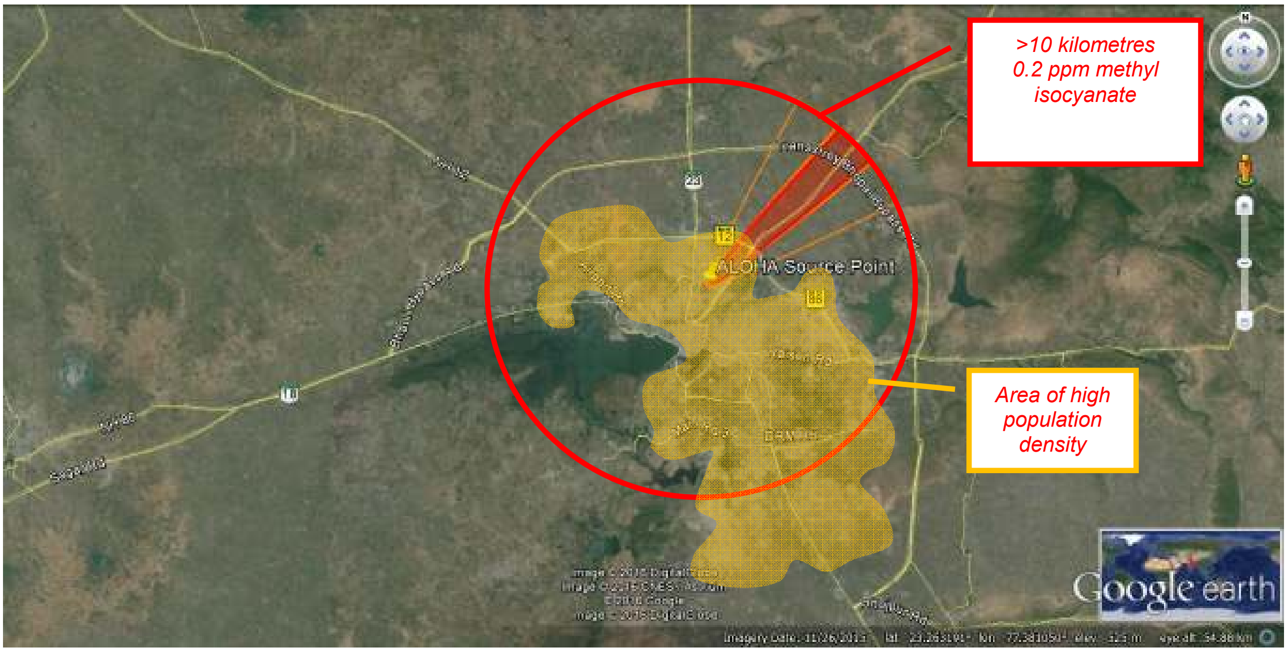

Figure 4.1 Surface area around the Union Carbide plant in Bhopal affected by the uncontrolled release of methyl isocyanate (Software source: ALOHA with own calculations)

The figure illustrates that communities within a radius of 10 kilometres and more around the Union Carbide plant would be affected by the release of methyl isocyanate at an atmospheric concentration of 0.2 ppm (parts per million). At this exposure level, it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

According to the report from the engineering consulting firm Arthur D. Little Inc. the root cause of the disaster was sabotage: A skilled worker introduced water into the methyl isocyanate storage tank, which released the deadly gas into the atmosphere following a violet chemical reaction. It illustrates that a human-induced action can take the form of a deliberate sabotage action, quite different from human error.

The extent of the disaster was enormous. Methyl isocyanate was dispersed into the atmosphere for distances exceeding 10 kilometres, at an airborne concentration higher than the lethal limit of 0.2 ppm. As can be seen in Figure 4.1, a vast, densely populated area was affected by the gas release.

There was no evidence that the vulnerability, coping capacity and resilience of the surrounding communities were properly assessed prior to the disaster. Although the company implemented a communication campaign among local communities to warn them about the lethal dangers of methyl isocyanate, it was of little or no help when disaster struck. Community members had nowhere to escape, considering the large area that the gas cloud covered among poor people in an area of high population density.

4.2.3 Lessons learnt from the disaster

Dharmendra et al. (2014) cite four lessons to be learnt from the Bhopal disaster:

- Reduce the inventory of hazardous materials such as methyl isocyanate. The severity of a technological disaster is a direct function of the quantum of hazardous materials stored and handled at a hazardous facility.
- Keep all safety-related equipment in good working order.
- Keep residential areas away from hazardous plants.
- Ensure proper management of the plant.

4.3 Case study 2: The Somerset West sulphur fire in South Africa, 1995

4.3.1 Unfolding of the disaster

Batterman et al. (1998) document the disaster incident well. As a result of trade sanctions against South Africa, the stockpiling of solid sulphur had to be done in South Africa, because sulphur was considered as a strategic raw material in the manufacture of sulphuric acid and fertiliser. In the late 1960s, AECI Ltd began storing sulphur at its Somerset West factory in the Western Cape province. The stockpile comprised 15 000 tons of sulphur in 1967, which was increased to 30 000 tons in 1981. In the beginning housekeeping practices included regular controlled burning around the stockpile for firebreaks, grass cutting and the return of eroded sulphur at the foot of the stockpile. Stockpiling was discontinued in 1988 and the pile was gradually depleted until 1996. Immediately prior to the December 1995 fire the pile contained 15 710 tons of solid sulphur.

Sulphur was stored in nine discrete heaps, three metres high. The stockpile surface area covered about 60 000 square metres and was covered with a sulphur ‘‘blanket’’ about 0.3 metres thick. A road, railroad siding and storm canal bordered the stockpile. Several firebreaks surrounded the property, except on the eastern side, designed to protect explosive magazines and a munitions factory on the nearby Somchem property north of the sulphur stockpile. Firebreaks were ploughed every year. There was no fire protection plan for the sulphur stockpile. The closest water hydrant was one kilometre away, but the water supply was insufficient for proper fire control. Fire-fighting facilities included an internal company fire team of two field personnel, the Stellenbosch fire station 25 kilometres away and the Strand (Somerset West) fire station two kilometres from the stockpile.

On 13 December 1995 the sulphur stockpile was set alight by a veld fire under influence of strong winds. It was estimated that more than 14 000 tons of sulphur dioxide (SO_2) was released into the atmosphere for 20 hours. High and persistent winds, typical of the Western Cape region, significantly reduced the effectiveness of fire-fighting activities and increased the severity of impacts. Adjacent urban and agricultural areas were seriously affected by the toxic sulphur dioxide cloud. Thousands of people were evacuated from the nearby town of Macassar located about four kilometres downwind. Several deaths were caused by the toxic dispersion. Apart from human impacts, severe damage was caused to plants and some animal deaths occurred up to about 30 kilometres from the site. The sulphur dioxide concentration estimated in the community of Macassar reached seriously dangerous levels, exceeding 100 ppm.

The UK Independent newspaper (1996) reported at the time that environmentalists raised fears of a “South African Bhopal” as a result of the sulphur fire. Activists claimed that the AECI company – a subsidiary of the Anglo American Corporation – was refusing to pay fair compensation to the victims of the disaster. It further reported that the cloud of toxic gas was so thick that it was considered to close down Cape Town International Airport, 22 kilometres away. Vineyards 15 to 20 kilometres away were damaged. Many people thought the smoke was coming from teargas. One female victim interviewed shortly afterwards said*, “I coughed until my chest hurt. I ran to the tap to wash my face, but the smell was too strong to be teargas.”*

At the time, the South African Environmental Justice Networking Forum believed that compensation payments from AECI had been *“completely arbitrary and unfair”.* Claims assessors were apparently offering most victims between R250 and R500 compensation. *"There is no independent attempt to put a price on things. They are just offering people money, and because of the poverty and the need for immediate cash, people are taking it ... People are getting totally different pay-outs for the same damage,"* a forum spokesman said.

Members of the local community near the disaster area were angry that some farming families had received millions of rand in compensation and accused AECI of racism. AECI said the average pay-out was R700 per affected person and that 4 500 of an expected 8 000 claims had been settled at that stage, which gave an estimated total claim figure of R5.6 million. Most of these claims were for damage to gardens, curtains and carpets, where synthetic fibres reacted chemically with the sulphur dioxide, and for the looting of personal and household goods during the evacuation of homes and workplaces. AECI said there were no arbitrary decisions on claims and that varying degrees of damage and loss required different pay-out amounts. *"It is very difficult to generalise when you are dealing with 8 000 claims but there is a pattern,"* they said.

Medical compensation became a serious point of contention among affected community members. The community wanted guarantees that their entire medical costs and possible future treatment costs would be paid by AECI. They wanted a medical clinic set up in the township to monitor the long-term effects of the victims' exposure to sulphur dioxide gas.

The Somerset West sulphur fire was the first disaster in South Africa where a large number of people were exposed to sulphur dioxide fumes in such close proximity. Doctors generally had very little knowledge about the possible long-term consequences of exposure to the gas. The Justice Networking Forum (Independent 1996) said that asthma sufferers were badly affected and many people who had previously been healthy were beginning to develop asthma-like symptoms. There were also fears for the unborn children of pregnant women exposed to the gas. The AECI company had said in a statement that it did not anticipate problems with them paying healthcare cost to victims, but it first wanted to evaluate the results of its health study before it could agree on a compensation figure. The affected community doubted the study, because they had not been consulted and claimed that the study was restrictive with the terms of references set unilaterally by the company. The insurers of AECI expected at the time to pay R25 million for immediate claims.

The Mail & Guardian (1997) reported in South Africa that the Desai Commission of Inquiry had found AECI negligent with regard to the sulphur fire at its Somerset West stockpile. The newspaper reported that the commission noted that from the establishment of the stockpile in 1967 to the time of the fire in December 1995, no steps had been taken by AECI to assess the fire risk and no precautionary measures had been put in place by the company. In his report to the Minister of Environmental Affairs (Desai Commission 1997) Judge Siraj Desai said that, as far as the safety of the stockpile and surrounding communities was concerned, AECI had forgotten about the sulphur pile and had allowed it to contaminate the surrounding area without control.

The commission found that there had been five fires at the stockpile between 13 December and 16 December 1995, with the last four fires caused by re-ignition of hot spots from the previous fires. The final fire on 16 December resulted in the evacuation of the nearby town of Macassar. In that fire 7 250 tons of sulphur was burned, producing about 14 500 tons of toxic sulphur dioxide released into the atmosphere. Several people died after inhaling toxic fumes and local farmers suffered huge crop losses as a result of acid rain.

The question that arises is: What are the long-term health effects of the Somerset West sulphur fire? City Press reported as follows in 2011, 15 years after the disaster:

"Two weeks ago, 52-year-old Magdalene Hess was rushed to the Hottentots Holland Hospital in Somerset West, Western Cape, after suffering a severe attack of asthma. "I could not breathe. I have regular attacks, but this was the worst. I could feel death coming for me," she said as she lay recovering in the crowded ward. She spent three days in the intensive care unit. Hess had never suffered from asthma before more than 16 000 tons of sulphur, stockpiled at the AECI chemical and explosives factory in Somerset West, ignited on December 16, 1995.

The blaze was estimated to have emitted 14 500 tons of sulphur dioxide in 21 hours. Thousands of residents of the poor working-class suburb of Macassar were evacuated and reports indicated that two men, both asthma sufferers, died as a - result of the fumes. Fifteen years later, Hess is one of thousands of residents of -

Macassar and adjacent Firgrove whose health has significantly deteriorated since the fire. Anecdotal evidence points to an unusually high incidence of respiratory illnesses and skin and eye allergies plaguing residents since the fire.

Exposure to high levels of sulphur dioxide is known to be fatal and the levels of it in Macassar were at times measured at over the Immediately Dangerous to Life or Health (IDLH) level of 100 parts to a million. And yet the affected Macassar residents are still struggling to get compensation from AECI, even though the company is alleged to have paid out millions to affected farmers in the area. Residents say the farmers received immediate pay-outs.

"The farmers easily got R20 million for loss of crops and animals, but AECI's lawyers struggle to give us R3 000 for the inconvenience. We are just brown people," said vice-chair of the Macassar Community Forum, Albert Williams.

It would appear AECI moved to minimise compensation claims in the days after the disaster. George Liddle, former chairperson of the now defunct Macassar Disaster Action Committee, said that in the days after the fire, AECI offered compensation to residents who came to its offices. He said pay-outs ranged from R50 to R1 000 and recipients had to sign a waiver that relinquished their rights to submit any future claims. "Most residents were unaware they were signing away their rights," he said.

"People just accepted cash with no legal advice. Some of these people were illiterate. One father accepted a few hundred rand for his entire household."

In 1997 the Desai National Commission of Inquiry found AECI had been "casually negligent" as it had not taken any steps to assess the fire risk or establish precautionary measures. The Department of Trade and Industry, which owned the stockpile, was also found to have been negligent.

Liddle said the commission agreed that AECI would pay out a fixed fee of R3 000 to residents for inconvenience. Many are still waiting to receive their money. In July last year, frustrated at the long wait, the Macassar Community Forum approached attorney Rob Green, the founder and chairperson of Family Law Clinics of South Africa. Green said part of the problem might have been that the Macassar Disaster Action Committee had previously approached seven law firms and some residents retained their own lawyers, which might have caused overlaps and confusion. The lawyers he was now approaching for clarity "were not being very cooperative.

The University of Cape Town (UCT) conducted one set of follow-up medical evaluations from 2001 to 2003. Another UCT study published last year indicated that residents who had reported persistent lower and upper respiratory system disease after the fire had experienced significant deterioration in their health (Rajani 2010)*. Despite the Desai Commission's request that follow-up evaluations be carried out on the effects of the fire, no known recent follow-up environmental studies had been conducted in the affected areas. Moses Randitsheni, the media liaison officer of the Department of Environmental Affairs, said nobody in the department was familiar with the case.*

Asked for comment, Walkers Attorneys Incorporated director John O' Leary, who acts for AECI and its insurer, said the matter could not be discussed due to legal processes. AECI said it had nothing further to add, and no comment was forthcoming from the Department of Trade and Industry despite repeated requests for information".

The study by Rajani (2010) was aimed at determining the health-related quality of life in Macassar residents with persistent lower respiratory symptoms (PLRS) and/or asthma, six years after the sulphur stockpile fire disaster in Somerset West. A cross-sectional analysis of responses from affected residents was conducted six years after the incident. Information was obtained from a dataset of 4 000 respondents to an interviewer-administered questionnaire that included medical history, respiratory symptoms and health-related quality of life. The study used information for three different time points: prior to, and one year and six years after the fire and revealed the following:

- A total of 246 records of residents, 74 with PLRS/asthma and 172 without PLRS/asthma, were analysed.
- The mean age of the symptomatic group was 49 years and 47 years in those without symptoms.
- Approximately 60% of the residents were current and ex-smokers in both groups.
- A greater proportion were women (61.3%) and 68% of women reported PLRS/asthma.

- The mean scores were significantly lower for the symptomatic group in the Physical Functioning (24 vs. 39), Role Physical (33 vs. 48) and General Health domain (24 vs. 37).

- Residents with PLRS/asthma were more likely to experience a significant decline in their Role Physical (OR = 1,97; CI 1,09–3,55) and General Health (OR = 7,07; CI 2,88–17,35) at year 1 and General Health (OR = 3,50; CI 1,39–8,79) at year 6, compared to the asymptomatic group.

- Residents with co-morbid RUDS (reactive upper airways dysfunction syndrome) demonstrated even stronger associations for General Health (OR = 7,04; CI 1,61–30,7) at year 1 and at year 6 (OR = 8.58; CI 1,10–65,02).

- The study highlights the long-term adverse impact on health-related quality of life among residents with lower and upper airways disease following a sulphur stockpile fire disaster.

A major concern in a chemical disaster, whether it be atmospheric dispersion of toxic gases, or soil or water pollution, is delayed deaths and injuries, which are more difficult to assess. These can be quite significant. The public potentially affected by accidents is, most of the time, either inside or adjacent to a major hazard installation site or near transportation routes, which facilitates quick evacuation. However, dispersed populations may be affected through water or food chain contamination (OECD 1996).

The Code of Practice of the International Labour Organisation for the prevention of major industrial accidents (International Labour Organisation 1991) recognised the risks associated with industrial installations where hazardous substances are produced and stored. Increasing production, storage and use of these substances created a need for control in order to protect employees, the public and the environment. The Code of Practice contains the following eight components, which have a bearing on this research for the formulation of a model for the regulatory management of hazardous installations:

- Definition and identification of major hazard installations in terms of the specific hazardous substances on site and their allowable storage quantities. The substances are classified as very toxic and toxic chemicals, flammable gases and liquids, and explosive substances. The quantum of the hazardous substances handled or stored on site is clearly important, because a major incident involving these substances is a function of its mass. If an analogy is drawn with the Somerset West disaster, the bigger the sulphur stockpile, the higher the risk of a toxic gas cloud formation in case of a fire.

- Information about the installations that includes a safety report, detail about the design and operation of the installation, identified hazards, safety management, precautionary measures and emergency planning.

- Assessment of major hazards such as uncontrolled events that can result in fires, explosions and the release of a toxic substance. The consequence of a major accident must be assessed, including its likelihood (probability) and possible domino effects from one installation to another.

- Control of the causes of major industrial accidents, through good design and operation, maintenance and regular inspections.

- Safe operation of major hazard installations. It should include responsibility for operating and maintenance, training of operators, operating procedures and the recording and analysis of near misses.

- Emergency planning as a collaborative exercise between the operator of the hazardous installation and the competent authorities such as local emergency services, although the emergency response planning function lies with the operator of the installation. The focus must be on the protection of people, both employees and the public around the installation, property and the environment.

- Siting and land-use planning, by ensuring that there is sufficient separation between the hazardous installation, other hazardous installations, residences and facilities such as airports and water reservoirs, which are vulnerable to impacts from the hazardous installation. Proposed developments near major hazard installations should take account of the vulnerability of individuals at the development, for example children, disabled people and elderly people.

- Inspection of major hazard installations by external competent authorities and an internal team composed by the operator of the hazardous installation. The internal safety inspectors must be independent from the production section.

There is a distinct similarity between the Code of Practice of the International Labour Organisation (1991), the UK HSE Comah Regulations (UK Health and Safety Executive. 2010) and the South African Major Hazard Installation Regulations (2001). As far as the vulnerability of surrounding communities is concerned, it is important to note that reference is made only to new land-use developments near existing hazardous installations and new hazardous installations near existing communities. The vulnerability of existing communities near existing hazardous installations, such as the Macassar community near the sulphur stockpile, is not addressed.

BOC Gases (1996) give the following warning statements in its MSDS for sulphur dioxide:

- Corrosive and irritating to the upper and lower respiratory tract and all mucosal tissue.
- Initial symptoms of exposure include nose and throat irritation, becoming steadily worse, suffocating and painful. The irritation extends to the chest causing a cough reflex which may be violent and painful and may include the discharge of blood or vomiting with eventual collapse.
- Other symptoms include headache, general discomfort and anxiety.
- Chemical pneumonitis and pulmonary oedema may result from exposure to the lower respiratory tract and deep lung areas.
- Repeated or prolonged low-level exposures may cause corrosion of the teeth.
- Reproductive toxicity and developmental changes in newborns have been observed in experimental animals exposed to sulphur dioxide.
- Sulphur dioxide is mutagenic in experimental cell assay systems.
- The STEL value of sulphur dioxide is 5 ppm. STEL is the average concentration to which people can be exposed for a short period (15 minutes) without experiencing irritation, long-term or irreversible tissue damage, or reduced alertness. The number of times the concentration reaches the STEL and the amount of time between these occurrences can also be restricted (ACGIH 2016).

4.3.2 Simulation of the disaster

By using version 5.4.6 (February 2016) of the ALOHA gas dispersion software, the release of toxic sulphur dioxide at the burning sulphur stockpile was modelled by the author.

The following model parameters were used:

- Wind speed: 10 m/s.
- Wind direction: SE.
- Ambient temperature: 25 °C.
- Cloud cover: 50%.
- Humidity: 50%.
- No inversion conditions.
- Release rate of sulphur dioxide: 185 kg/s (Batterman et al. 1998).
- Geographic coordinates of the Union Carbide plant:
  - S 34.074692
  - E 18.802422
- Acute exposure guideline levels for sulphur dioxide:
  - AEGL-3: 30 ppm, 60-minute exposure.
  - AEGL-2: 0.75 ppm, 60-minute exposure.
  - AEGL-1: 0.2 ppm, 60-minute exposure.

Results of the modelling are shown in Table 4.2.

Table 4.2 Dispersion modelling for atmospheric sulphur dioxide release at the sulphur stockpile (Software source: ALOHA with calculations by author)

SITE DATA Location: SOMERSET WEST, SOUTH AFRICA Building air exchanges per hour: 1.97 (unsheltered single-storied) CHEMICAL DATA Chemical name: SULPHUR DIOXIDE CAS number: 7446-9-5 Molecular weight: 64.06 g/mole AEGL-1 (60 min): 0.2 ppm AEGL-2 (60 min): 0.75 ppm AEGL-3 (60 min): 30 ppm IDLH: 100 ppm Ambient boiling point: –10.3 °C Vapour pressure at ambient temperature: greater than 1 atmosphere Ambient saturation concentration: 1 000 000 ppm or 100.0% ATMOSPHERIC DATA (MANUAL INPUT OF DATA) Wind: 10 metres/second from SE at 3 metres Ground roughness: urban or forest Cloud cover: 5 tenths Air temperature: 25° C Stability class: D No inversion height Relative humidity: 50% SOURCE STRENGTH Direct source: 185 kg/sec Source height: 0 Release duration: 60 minutes Release rate: 11 100 kg/min Total amount released: 666 000 kilograms Note: This chemical may flash-boil and/or result in two-phase flow. THREAT ZONE Model run: Heavy gas Red: 6.2 kilometres --- (30 ppm = AEGL-3 [60 min]) Orange: greater than 10 kilometres --- (0.75 ppm = AEGL-2 [60 min]) Yellow: greater than 10 kilometres --- (0.2 ppm = AEGL-1 [60 min])

The model result has been superimposed on an aerial photograph of the area where the AECI sulphur stockpile was located in Somerset West in Western Cape, as shown in Figure 4.2.

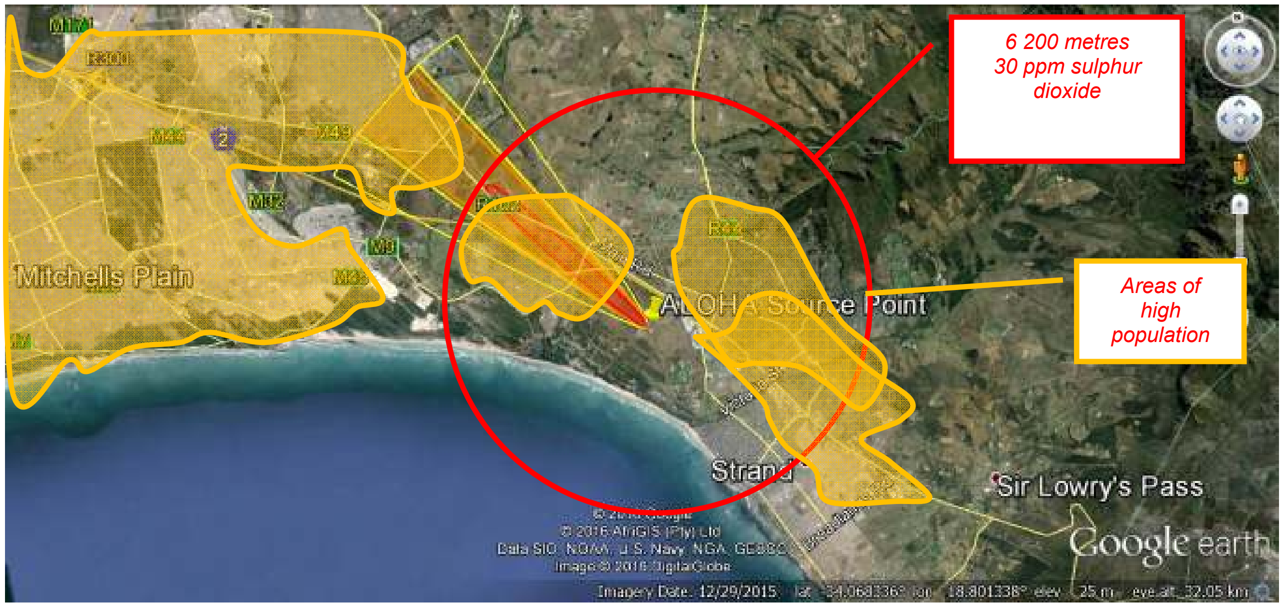

Figure 4.2 Surface area around the AECI sulphur stockpile in Somerset West affected by the uncontrolled release of sulphur dioxide (Software source: ALOHA with calculations by author)

Batterman et al. (1998) reported that assessments of toxic gas dispersion and exposure had been conducted for a variety of incidents over the years, which revealed knowledge gaps and uncertainties. This is naturally the case when modelling has to be done of an incident where little real-time data was available at the time and the risk assessor had to rely on witnesses and assumptions.

Batterman et al. (1998) discuss several provisos in the modelling of the sulphur dioxide gas release at Somerset West:

- It was assumed that only sulphur dioxide had been emitted by the sulphur fire. Emissions of gaseous sulphur trioxide and sulphuric acid, both of which are more toxic than sulphur dioxide, were also possible.
- Carbon monoxide and particulate emissions, mainly granular sulphur and soot, may also have been important.
- Emissions from the preceding brush and grass fires were not assessed.
- Other sulphur dioxide sources in the area were not considered, such as coal fires used for cooking in the low-income households of Macassar.

- The meteorology of the disaster area was complex. Meteorological data that prevailed at the site for the duration of the fire is necessary to accurately model the meteorological conditions during the sulphur dioxide emissions. Nappo (1982) defines representativeness as "the extent to which a set of measurements taken in a space-time domain reflects the actual conditions in the same or different space-time domain taken on a scale appropriate for a specific application". Batterman et al. (1998) attempt to comply with the modelling guidance provided by the US EPA (1996), but a major concern remains whether the meteorological data used in toxic gas dispersion modelling adequately represents atmospheric dispersion conditions at the time of the disaster. Such concerns always exist if meteorological data is obtained at a locality other than that of the actual source. There is always room for improvement measures as well as models that provide better reconstruction of complex flow fields and large, multisource emitters like fires. It can be safely assumed that the surface area of the emitting fire plays a major role in the sulphur dioxide dispersion patterns with varying degrees of turbulence and thermal radiation flux.

- Another uncertainty was created by predictions of toxin concentrations and their validity. While the predictions appeared reasonable on paper based on the available data, it must be borne in mind that the monitoring information is sparse and sometimes insufficient for model validation. Simulation models and procedures have to be validated using predetermined quality-assured data sets. Accidents cannot provide such opportunities.

- Other attempts to model xenobiotic species dispersion and human exposure resulting from chemical accidents have had mixed success, primarily due to the scarceness of data and the inherent limitations of the model. A typical example is the model used by Sharan et al. (1995) to simulate dispersion of methyl isocyanate during the Bhopal disaster. The software could not sufficiently simulate gas and air mixing to match the affected area as confirmed by actual mortality statistics. Vermeulen and Freiman (1998) derived vertically averaged concentrations for the sulphur fire that were far below those predicted by Batterman et al. (1998) as experienced at ground level. This is mainly due to rough spatial resolution in their model. While a conventional but well-validated plume-type model such as ALOHA provided reasonable predictions for the sulphur fire, model input data must be selected with care. Batterman et al. (1998) recommend a suitable sensitivity analysis to make provision for modelling variations.

4.3.3 Lessons learnt from the disaster

Several learning points emerged from this incident at Somerset West:

- The vulnerability of communities near the sulphur stockpile, such as Macassar, was not assessed prior to the disaster in terms of coping capacity, resilience and recovery requirements. This is probably the most important lesson to be learned from the disaster. The same lesson was learned from the Bhopal disaster in India.

- If there is a possibility that a toxic airborne gas might develop near a community and it is expected to last for some hours, immediate evacuation of the community must be considered as an immediate response action. Atmospheric gas dispersion models should be used to simulate the development and movement of the toxic gas cloud as an early warning instrument. This is especially important in the case of a vulnerable community such as Macassar, with high poverty levels.

- Community evacuation was not implemented in Macassar until late Saturday night, after the sulphur dioxide cloud had developed into a fatal concentration. In such a vulnerable community, where people lived in shacks, the strategy of remaining indoors for a prolonged period was not effective.

- A potential fire at the sulphur stockpile and a need for community evacuation should have been anticipated, considering the risk of nearby veld fires.

- The on-site emergency plan of AECI had major deficiencies and was not known to the civil defence authorities. Fire emergency actions were uncoordinated and consequently inefficient.

- Communication with affected communities was inadequate, both before the disaster as part of a comprehensive emergency response plan, and after the disaster as part of recovery operations.

- Fire hydrants had an insufficient water supply capacity. AECI took no steps to regularly assess the risk of fires, take precautionary action and design mitigation measures.

- There was a serious lack of adequate communication facilities between the various agencies involved in fire-fighting. There was no direct line of communication between the point of fighting the fire and the operation control centre from where the overall coordination of the emergency response took place.

- Adequate community involvement in the emergency response system was lacking.

- The training of emergency medical personnel in the handling of hazardous substances was insufficient.

- The fire and toxic gas dispersion had a traumatic effect on nearby communities. The health management system failed to address the needs of the community on the levels of preparedness, intervention and follow-up, which resulted in a reactive, unstructured emergency response.

- There are clear indications that exposure to sulphur dioxide gas has long-term health effects (Rajani, 2010) on victims, especially those who suffered from asthma prior to exposure.

- On-site emergency response planning was not sufficient. Fire-water supply was inadequate and fire-fighting equipment was insufficient. Sulphur dioxide plume modelling had not been done to anticipate the impact of a large sulphur fire on nearby communities.

- Land-use around the stockpile site was not planned properly. When the site was originally earmarked for sulphur stockpiling, the area was largely unpopulated. As time went on, Firgrove and Macassar residential developments were established 2.5 kilometres from the storage site. This should never have been allowed.

- The vulnerability of surrounding communities, including Firgrove, Macassar, Stellenbosch, Somerset West and Strand, were not assessed on a continuous basis. It is also unclear whether AECI implemented a communication campaign to raise and maintain awareness among community members about the potential risks of a sulphur fire.

- The sulphur fire had widespread impacts on humans, animals and plant life.

- The Major Hazard Installation Regulations in force in 1995 were inadequate.

- In addition, the commission stated that the new legislation should incorporate, as far as possible, the principles in the Convention and Code of Practice of the

International Labour Organisation relating to the Prevention of Major Industrial Accidents (ILO 1991; 1993).

4.4 Case study 3: Buncefield liquid fuel depot fire in the UK, 2005

4.4.1 Unfolding of the disaster

The Buncefield oil storage depot is a tank farm in Hemel Hempstead, Hertfordshire, England. The depot is classified as a *“top tier”* site under the COMAH Regulations of 1999 (UK Health and Safety Executive 2010). Under these regulations, all hazardous sites are classified as lower tier or top tier, based on a volume threshold for the storage of each particular hazardous substance. Top tier sites are more hazardous than lower tier ones. The Buncefield depot is authorised to store about 240 million litres of hydrocarbon fuels and is the fifth largest liquid petroleum fuel distribution depot in the UK. Fuel is transported to the depot via three liquid petroleum pipelines.

The pipelines that supply the depot transport fuels in batches. The various grades of fuel are stored in dedicated storage tanks according to the fuel type. The fuel is then uploaded from the depot by road tankers for delivery to end users. Aviation turbine fuel is supplied from the depot to Heathrow and Gatwick airports via two pipelines. The Buncefield depot is of strategic importance for the supply of fuels to London and the south-east part of the UK.

In December 2005 a major explosion and fire occurred at the fuel depot. The UK Health and Safety Commission subsequently set up an independently chaired Major Incident Investigation Board (MIIB) led by Lord Newton of Braintree (HSE 2011). The Board was given a broad set of objectives in its terms of reference and published eight reports until 2008. These reports address the root causes of the loss of containment of fuel on 11 December 2005. It took the COMAH Competent Authority Investigation Team more than four years to complete the investigation.

A slug of unleaded petrol was received at the depot via pipeline into one of the depot storage tanks, Tank 912, on 10 December 2005. The tank had a capacity of 6 million litres and was fitted with a computerised tank gauging system, which measured the rising level of fuel in the tank. The tank level was shown on a monitor in the depot control room. At 03:05 on Sunday 11 December the automatic tank gauging system stopped registering the rising level of fuel in the tank, although the tank continued to be filled from the supplying pipeline. The three-level gauging system alarms – user level, high level and high-high level – could not operate, because the tank reading was always below these alarm levels. As a result the control room supervisor was not alerted to the fact that the tank could overfill. The level of petrol in the tank continued to rise unchecked and without any alarm begin raised. The tank was also fitted with an independent high-level switch that was set at a higher level than the automatic tank level gauging system alarms. The switch was supposed to stop the tank-filling process by automatically closing a valve on the pipeline and sound an audible alarm in case the petrol in the tank reached an undesirable and dangerous high level. This switch also failed to register the rising level of petrol. The final alarm did not sound and the automatic pipeline feed shutdown was not activated. By 05:37 on 11 December 2005 the level within the tank exceeded its storage capacity and petrol started to spill out of vents in the tank roof. Closed circuit television camera records showed that soon after that a white vapour started to rise from the bund around the tank. In the wind-still conditions this vapour cloud, which was likely to have been a mixture of hydrocarbons and ice crystals, gradually spread to a radius of about 360 metres around the storage tank, including areas outside the boundaries of the depot site, to an adjacent car park and towards the northern part of the depot complex where aviation kerosene storage tanks were situated. The vapour cloud was observed by members of the public off site and by tanker drivers on site, who alerted employees at the depot. Around 06:00 the fire alarm button was pressed, which sounded the alarm and automatically started a fire-water pump. A vapour cloud explosion occurred almost immediately, probably ignited by a spark from the fire-water pump. By the time the explosion occurred, more than 250 000 litres of petrol, about 0.1% of the total depot storage capacity, had escaped from the tank.

The severity of the vapour cloud explosion was worse than anticipated. The devastation of assets at and around the fuel depot was enormous. Although there were no fatalities, more than 40 people were injured. The ensuing fire, the largest seen from an industrial accident in the UK, rapidly engulfed more than 20 fuel tanks on the depot grounds and on adjacent sites. The fire remained burning for several days. Fire crews from all over England arrived at the depot and attempted to put it out. Fuel and fire-fighting chemicals flowed from leaking bunds down drains and along natural storm-water drainage lines, both on and off the site. The environmental, social and economic impacts were substantial. The effect of the incident on human lives was considerable. No lives were lost, but several people had to recover from the financial and psychological effect that the explosion had on them. The human effects may have been even larger if the event had not taken place early on a Sunday morning, when there were relatively few people in the adjacent industrial area.

Following the Buncefield incident, Rivers et al. for the HSE (2007) formulated a new set of standards for the design and operation of storage depots where fuel vapour clouds could form during spillages from tank overfilling. The emphasis is on storage tanks where volatile fuel products in particular are stored, such as petrol, and not so much on tanks where other fuels are stored, such as non-volatile diesel or fuel oil.

Mannan (2009) analysed the incident at Buncefield depot in order to gather information on the process that led to the eventual devastating fires at the storage tanks. A succession of events led to the spillage of large quantities of petrol from a bulk storage tank in Buncefield, near the Heathrow airport in the UK. An attempt was made to provide a technical analysis of the causes behind the extent of the flammable vapour cloud that may have formed and the mechanism by which the overpressure shockwave was generated. Mannan (2009) also refers to some of the past incidents involving open-air vapour cloud explosions and the apparent similarities with the Buncefield depot fire.

A vapour cloud explosion occurs when a large amount of flammable vaporising liquid or a gas is rapidly released to form a vapour cloud that disperses in the surrounding air (AIChE-CCPS 2000). The vapour cloud can originate from a storage tank, a chemical process, transport tankers or a pipeline. The surrounding air in the cloud provides the oxygen for the fuel to react explosively when the cloud comes into contact with an ignition source. If the vapour cloud is ignited before dilution to a concentration below its lower flammability limit could take place, a vapour cloud explosion and flash fire will occur, which will inevitably flash back to the source of vapour release.

Apart from its devastating explosion power, a vapour cloud poses the added risk of being non-stationary – it can drift for several hundreds of metres under ideal meteorological conditions to a point of ignition, which can be quite remotely located from the original source of the cloud's release, such as an overflowing storage tank. Lenoir and Davenport (1993) investigated several vapour cloud explosion incidents. They found that vapour cloud explosions were responsible for 37% of property losses for claims exceeding $50 million (1991 monetary value).

Mannan (2009) explains that the mechanism of a petrol overflow and drop from the top of the storage tank height leads to vapour formation. By the time the spilled petrol reaches the tank bund, most of it has been converted to vapour. The turbulence of the spillage created air and therefore oxygen entrainment. After ignition, the well-mixed fuel-air vapour cloud attains higher flame speeds caused by the congestion and turbulence, which further increases the intensity of the overpressure shock wave.

The type of liquid hydrocarbon and the nature of the liquid spillage plays a significant role in determining the size of the vapour cloud and the quantity of aerosol droplets that may be entrained in the vapour. For example, spillage of a liquid from a hole in the tank near the ground would produce relatively low volumes of vapour and liquid droplets as compared to liquid releases from a height.

As described in Gant and Atkinson (2007) Buncefield petrol storage tank number 912 was a fixed-roof tank with a number of open breather vents close to the edge of the tank at a spacing of around 10 metres around the perimeter. When the tank was overfilled from the pipeline feed, liquid flowed out of the open vents, spreading a little before it reached the tank edge. A proportion of the leaking petrol was directed back onto the wall of the tank and a proportion flowed over the edge of the tank. There were also wind girders along the sides of the tank wall to support the structure and make it rigid. Petrol spilling close to the tank wall would have hit this girder and been deflected outwards, away from the tank wall. This outward spray of petrol then intersected the cascade from the top of the tank. The petrol spray typically would extend to a significant area around the tank perimeter (Gant & Atkinson 2007:23). As the mixing sprays of the overflowing petrol fell downwards, petrol strings were formed, which then started dividing into large droplets to form an aerosol cloud. Some of the initial liquid petrol fragments rapidly shattered to form a range of secondary droplets that became aerosol droplets of various sizes.

While the liquid petrol fragmentation was occurring, air (and therefore oxygen) was entrained into the liquid petrol spray and vapour was also being produced from the low-boiling liquid petrol evaporating and mixing with the air. Some liquid droplets remained suspended in the vapour as it impacted on the bund wall or other tanks within the bund. Individual falling petrol droplets dragged the air within the falling stream downwards and air was drawn in through the sides to compensate, causing more mixing of liquid petrol and oxygen. The splash zone at the base of the tank was an additional area where vapour and very finely divided liquid droplets were vigorously mixed for some time. Inevitably, given the distillation properties of the released petrol, there would have been vaporisation, with its rate of formation enhanced by the drop from height and the droplet formation. For the release of about 300 tons of petrol from Tank 912 and the spillage scenario described above, it was quite likely to have expected the formation of the flammable aerosol/vapour cloud size that formed in reality.

The energy of the explosion of the petrol vapour cloud and the resulting overpressure are dependent on the mass of flammable mixture (which is a function of the quantum of spilled fuel), the duration of the spillage and the fact that it was falling in droplets from a height. The BMIIB report (2008) mentions the vapour cloud covering 80 000 square metres. Gant and Atkinson (2007:50) estimated that the vapour cloud was probably larger:

"The CCTV footage taken in the minutes leading up to the explosion at Buncefield showed a visible low-lying mist spreading out from HOSL Bund A and covering a wide area, roughly 500 to 400 metres in extent. The final images recorded before the explosion show that the mist layer had reached over 4 metres deep immediately adjacent to HOSL Bund A and between 2 and 3 metres deep in the main Northgate and Fuji car park areas. The extent of the mist layer correlates reasonably well with evidence of burn damage."

The Gant and Atkinson report (2007) indicated that the cloud covered an area of at least 200 000 square metres, as a conservative estimation. The extent of the cloud was also substantiated by witness accounts, which included seeing the mist, smelling the petrol and cars revving on their own even when the ignition was turned off, as a result of a flammable petrol-air mixture entering the air intake of the engine. The witness statements and CCTV footage seemed to confirm the findings of the authors, that the cloud could have covered an area as large as 200 000 square metres. The actual size of the cloud is somewhat immaterial: It was a very large cloud, both in absolute and relative terms, and an important reason why the explosion was so massive.

There is documented evidence from earlier incidents of much smaller flammable vapour clouds producing violent explosions, as described in Lenoir and Davenport's (1993) list of previous incidents:

- Portland, Oregon, 1954: glass breakage to 3.2 kilometres.
- Pernis, Netherlands, 1968: diameter of the vapour cloud was 90–140 metres and windows were broken several kilometres away.

- Laurel, Maryland, 1969: broken windows at up to 4.8 kilometres away.
- Baton Rouge, England, 1971: window breakage at up to 4.8 kilometres.
- Climax, Georgia, 1974: directional blast, possibly detonation, producing window breakage at up to 11 kilometres.
- Rosendaal, Netherlands, 1975: windows broken to a range of 900 metres.
- Pitesti, Romania, 1978: windows broken at up to 9.5 kilometres.
- Texas City, USA, 1979: windows broken at up to 1–2 kilometres.
- Newark, New Jersey, 1983: windows broken at up to 5.6 kilometres.
- Romeoville, Illinois, 1984: windows damaged at up to 9.6 kilometres.

The report by Gant and Atkinson (2007) also states:

"As described in the first progress report, eyewitness accounts and CCTV footage show a white mist or thick fog on the north and west sides of the HOSL West site, spreading out from bund A (around Tanks 910, 912 and 915). By the time of the main explosion, the edge of this cloud had almost reached Boundary Way to the west of bund A and wisps of mist had just started to arrive at the tanker loading gantry to the south. To the north, it had flowed beyond Cherry Tree Lane. To the east, the mist can be seen on CCTV at the BPA site, but not further east at the HOSL East site."

The BMIIB Third Progress Report (2008) discusses the formation of the vapour cloud and the mechanism that causes it to be visible on the CCTV:

"The free fall of fuel droplets through the air also leads to entrainment of air and mixing between the air and fuel vapour. Calculations based on a simplified composition of unleaded petrol suggest that the ambient air already at 0 °C and fully saturated with water vapour, would have cooled below zero by a further 7–8 °C from fuel evaporation. As a result, roughly half the initial water content of the air would precipitate as an ice mist, and this mist would persist even as the vapour is diluted. This is consistent with the cloud of mist highly visible on CCTV cameras. It supports the contention that the mist can be used as an indicator for determining the size of the fuel/air vapour mixture created by the overfilling and how it was dispersed."

It can be assumed that the average height of the vapour cloud was at least 2 metres (Mannan 2009) and that estimates of the area covered by the vapour cloud vary between 80 000 and 200 000 square metres. Based on CCTV footage and witness statements it seems that the vapour cloud was larger than 80 000 square metres, but probably somewhat smaller than 200 000 square metres. A conservative estimate of the area covered by the vapour cloud can be taken as 150 000 square metres, which would render the volume of the vapour cloud between 160 000 and 300 000 cubic metres.

Meteorological data indicate that on the morning of the incident the weather was calm, cold, stable and humid. The weather on the night of the release was classified as Stability F (Pasquill 1971) with a wind speed of close to zero (BMIIB 2008). The investigation report states that when the liquid petrol spilled over from the roof of the tank, evaporation of the more volatile fractions would lower the temperature of the vapour cloud, causing temperatures to drop to below 0 °C and perhaps as low as –10 °C in the surrounding gas phase. A rapid drop in temperature caused the water vapour to condense out of the air and form fog. Strong turbulent mixing took place within the bund due to the liquid petrol spray, which mixed the fog with the petrol vapour (BMIIB 2006). Energetic breakup of the droplets produced a significant quantity of smaller aerosol droplets, which were then entrained with the vapour-air mixture. Some of the larger droplets dropped down due to gravitational force and accumulated in the liquid pool, while the smaller droplets were entrained in the vapour-air mixture.

The presence of aerosol droplets in the floating cloud increased the severity of the vapour cloud explosion, because the cloud contained much more energy per unit volume. The phenomenon of aerosol formation is reported by Bai et al. (2002), who confirmed that aerosol dynamics were to be expected in the Buncefield incident.

Lechaudel and Mouilleau (1995) also report the possible formation of flammable aerosol. They conclude that the characteristics (such as distillation and flash point) of the flammable liquid spillage play a significant role with regard to the size of the vapour cloud and the quantity of aerosol droplets that may be entrained in the vapour – spillage of a flammable liquid from a hole in the tank near the ground would produce relatively low volumes of vapour and liquid droplets as compared to liquid releases from a height.

4.4.2 Simulation of the disaster

In order to confirm the devastating effect of a vapour cloud explosion from Tank 912 at the Buncefield depot, a simulation was done using the TNT Equivalency Model prescribed by AIChE-CCPS (2000) using the following model parameters (HSE 2011):

- Wind speed: Windless
- Wind direction: None
- Ambient temperature: 25 °C
- Cloud cover: 50%
- Humidity: 50%
- No inversion conditions
- Quantity of petrol spilled: At least 250 000 litres (185 000 kg)
- Percentage of spilled petrol converted to vapour: 80% (148 000 kg)
- Geographic coordinates of the Buncefield depot:
  - N 51.763377
  - E 0.425400

According to AIChE-CCPS (2000) the TNT equivalent mass of the explosive vapour cloud is given by:

$$W = (\eta.ME_c)/E_{TNT}$$

Where

W = equivalent mass of TNT in kg
η = empirical explosion efficiency (unitless)
M = mass of explosive fuel in kg.
E_c = heat of combustion of explosive fuel in kJ per kg
E_{TNT} = heat of combustion of TNT in kJ per kg
$W = (0.05)(148\ 000\ \text{kg})(46\ 000\ \text{kJ/kg})/(4\ 652\ \text{kJ/kg})$

Therefore

$$W = 73\ 172.8\ \text{kg TNT}$$

The model results are given in Table 4.3.

Table 4.3: Simulation of the explosive effect of a petrol vapour cloud explosion for an overpressure shock wave of 1 psi (Software source: AIChE-CCPS with calculations by author)

Input data:		
TNT mass:	73172,8	kg
Distance from blast:	750	m
Calculated results:		
Scaled distance, z:	17,9313	$\sqrt[3]{(m/kg)}$
Overpressure calculation:	(only valid for z > 0.0674 and z < 40)	
a+b*log(z):	1,478442	
Overpressure:	6,96	kPa
	1,0095	psi
Impulse calculation:	(only valid for z > 0.0674 and z < 40)	
a+b*log(z):	1,070326	
Impulse:	17,63503	Pa s
Duration calculation:	(only valid for z > 0.178 and z < 40)	
a+b*log(z):	0,805618	
Duration:	5,751267	ms
Arrival time calculation:	(only valid for z > 0.0674 and z < 40)	
a+b*log(z):	1,524853	
Arrival time:	43,922	ms

Similarly, the impact distances from the centre of the explosion for different overpressure values were calculated as:

- Overpressure of 5 psi: 240 metres.
- Overpressure of 10 psi: 162 metres.

These impact distances correlate well with the value of 360 metres reported by HSE (2011). The effect of the different overpressure values are estimated by Kent et al. (2007) in Table 4.4.

Table 4.4: The anticipated effect of explosion shock waves with different overpressure values (Software source: AIChE-CCPS with calculations by author)

Overpressure, Psi	Impact distance, metres	Anticipated effect
1	750	Partial demolition of houses. Houses made uninhabitable.
5	240	Nearly complete destruction of houses.
10	162	Probable total destruction of buildings. Heavy machine tools (3 200 kg) moved and badly damaged. Very heavy machine tools (5 500 kg) survive.

The results of the simulated safety distances for the petrol vapour cloud explosion have been superimposed on an aerial map of the Buncefield fuel depot and are shown in Figure 4.3, which illustrates that the demolition effect of the petrol vapour cloud explosion was widespread and included adjacent structures and facilities, most notably the Maylands car park and aviation turbine fuel storage tank. This conclusion agrees with that made by the incident investigating team (HSE 2011).

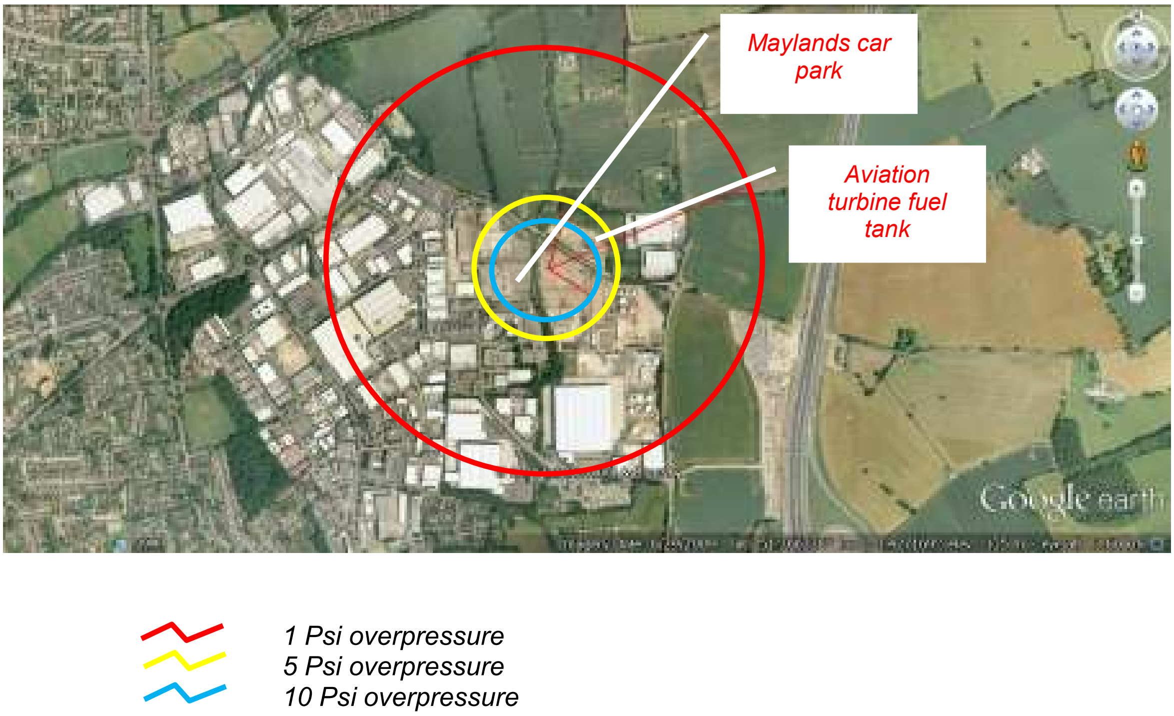

Figure 4.3 Overpressure shock wave safety distances around Tank 912 at Buncefield depot where the petrol vapour cloud explosion originated (Source: Author)

Alonso et al (2006) emphasise that vapour cloud explosions are serious hazards in chemical industries. Since the Flixborough 30-ton cyclohexane cloud explosion of 1974, causing the death of 28 people and severe damage to infrastructure, much research has been done on this subject. They argue that, for vapour cloud explosions, the TNO Multi-Energy model is often used to determine overpressure and positive phase duration time as a function of safety separation distance, similar to the TNT Equivalency Model. The multi-energy concept is based on the empirical evidence that the explosive potential of a vapour cloud is primarily determined by the obstructed and/or partially confined parts of the cloud.

Obstructed regions are determinative to the intensity of overpressure shock waves caused by vapour cloud explosions. These regions are typically defined based on a review of the site layout plan. However, there will always be a degree of subjectivity which will lead to some variation in the definition of the obstructions, depending on the perspective of the person who performs the simulation (Shaba & Cavanagh 2014). These obstruction or confinement parameters are not considered by the TNT Equivalency Model.

In the case of Buncefield it was almost impossible to determine the pre-explosion geometry, density, cloud shape and position of the vapour cloud relative to the fire pump. The exact locality of the vapour cloud at the point of ignition and consequently the obstructions and confinements that the cloud was exposed to are therefore unknown parameters.

All one can do in such a case is to make assumptions, which will invariably differ from analyst to analyst. For this reason, the TNT Equivalency Model was used as a first approximation of the effect of the petrol vapour cloud explosion that occurred at Buncefield.

4.4.3 Lessons learnt from the disaster

- The incident investigation team found that design and maintenance failures with regard to tank overfill protection systems and liquid containment systems had been the technical causes of the initial explosion. The resultant flash fire and the soil and water pollution had been caused by water-insoluble hydrocarbons. In addition, some management deficiencies were also identified:

- Management systems relating to tank filling were both deficient and not properly followed, despite the fact that the systems were independently audited.

- The site was fed by three pipelines, over two of which control room employees had little control in terms of flow rates and timing of receipt. Employees did not have sufficient information readily available to them to monitor the storage of incoming fuel accurately. Throughput had increased at the site, putting more pressure on site management and employees by degrading their ability to manage the receipt and storage of fuel. The pressure on employees was made worse by a lack of engineering support from their head office. Over time, these human pressures created a culture where keeping the depot process operating was the primary focus, while operational safety did not get the attention, resources or priority that was necessary.

- The investigation report did not identify any new information about the prevention of major industrial accidents, but merely reinforced existing process safety management principles that have been known at the depot for years.

4.5 Chapter conclusions

4.5.1 The Bhopal disaster

The Bhopal disaster revealed the following conclusions that are relevant to this study:

- A proper vulnerability assessment was not done on the communities that surround the plant, in terms of coping capacity, resilience and recovery measures.

- The case is a clear illustration of a human-induced disaster. Much has been recorded in the literature about the cause of the disaster. It was initially speculated that the water ingress into the methyl isocyanate storage tank was caused by poor equipment maintenance and neglect of safety procedures (Sabharwal 2014). However, the report by Kalelkar (1988) and the latest reports by Union Carbide (2015) point to sabotage by a skilled worker who had a thorough knowledge of the plant. Be it as it may, the disaster was caused by human action.

- The plant was established in a very poor area of Bhopal with a high population density (Sabharwal 2014). These are prime determinants of human vulnerability to an industrial accident. A proper vulnerability assessment would have highlighted the risks for the communities adjacent to the plant.

- Union Carbide (2015) reported the cause of the gas leak as sabotage. In addition to human error as a main factor for the triggering of industrial disasters, the role of sabotage should not be underestimated. This threat has become more and more relevant in recent times with the rise of urban terrorism such as the Paris incident in November 2015 (CBS New York/AP 14 November 2015).

- Gupta (2002) reported that there had been numerous plant failures prior to the major release of methyl isocyanate in 1984, but these were ignored by the plant management. The company initiated a communication campaign to warn surrounding communities of the risk of a fatal gas leak, but it was of limited use, because community members had nowhere to escape. Production and profitability took precedence over human health and safety.

- Adequate legislation was in existence at the time of the accident, but the Indian government was more interested in attracting foreign investment and promoting exports than in taking adequate preventative measures against disasters. In addition, the plant had implemented cost-cutting measures and was operating under substandard safety measures (Sabharwal 2014).

- Political forces played a major role in the settlement of people near the major hazard installation, when the party in force used shack ownership certificates to elicit favourable votes in future elections.

- Proper land-use planning around the Union Carbide plant was not done. Sabharwal (2014) reported that the plant was bordered by heavily populated slum neighbourhoods. Peterson (2009) reports the same.

- In retrospect, the decision of the state planning board to classify the plant as “general industry” rather than “hazardous industry” was a major mistake. Needless to say, the safety requirements at the plant were consequently watered down. Once again, it was a political decision based on voter support.

4.5.2 The Somerset West disaster

The Somerset West sulphur fire incident is of particular significance to this study for the following reasons:

- This case is a good illustration of a Natech disaster that occurred locally as researched by Krausmann et al. (2011). A grass fire was started by a flashover from an electrical power line and under a strong wind rapidly spread towards the sulphur stockpile.

- It illustrates the vital importance of community vulnerability when the risks of a major hazard installation are assessed. Although the affected communities of Macassar, Mitchell's Plain, Strand and Heldervue were populated after establishment of the sulphur stockpile, continuous risk assessment should have pointed out that these communities have become critically vulnerable to a fire at the stockpile.

- A significant finding of the incident investigating commission was that South African legislation for the regulatory management of the storage of hazardous chemicals was inadequate. It was recommended that the Major Hazard Installation Regulations be revised against the background of the Somerset West disaster to include both new and existing installations, and that emergency plans should incorporate a regulatory role for civil defence authorities. The commission also recommended that the new legislation should include the principles in the Convention and Code of Practice of the International Labour Organisation relating to the Prevention of Major Industrial Accidents.

4.5.3 The Buncefield disaster

The Buncefield disaster provided the following insights relevant to this study:

- The vulnerability of nearby communities and facilities was not assessed as part of the emergency response planning at the depot. Aspects such as community coping capacity, resilience and recovery were not considered.

- The incident has a direct bearing on the operation of liquid petroleum fuel depots around the world and South Africa in particular, with its six oil refineries and more than 20 large storage depots across the country. The risk of storage tank overfilling is certainly the highest for pipeline-fed depots, but is of equal importance for depots where storage tanks are filled from rail or road tankers. The mitigating factors of rail and road tanker supplies are the immediate presence of operating personnel and the low feed rate into the storage tanks, which means that tank overfilling can be seen quickly and immediate corrective actions can be taken, such as shutting down feed pumps. Part of the action research done in this study entailed consulting work done for NERSA with regard to licence conditions that should be imposed on liquid petroleum storage depots under the Petroleum Pipeline Act (2003). During this process it was highlighted that the biggest health and safety risk associated with pipeline-fed depots is that of storage tank overfilling. Lessons learned from the Buncefield explosion and fire as contained in the recommendations of the task group under Rivers et al. (2007) are likely to be incorporated into the licence conditions of petroleum depots in South Africa.

- Some causes and implications of human error and the role of management at major hazard installations are clearly shown in the Buncefield incident investigation reports. These factors are not only applicable to petroleum depots, but to all major hazard installations, even in manufacturing.

- Regular inspections by the competent authority at major hazard installations are essential to create and maintain awareness of potential hazards, but cannot replace the day-to-day supervision and management procedures at the site. These remain the responsibility of the operator at the site.

Chapter 5

Regulatory arrangements in South Africa and worldwide

5.1 Introduction

Fourteen Acts and regulations in South Africa that govern the health and safety of people, as well as a disaster management framework used to guide disaster management in the country are examined in this chapter. Only the salient points of each Act are examined against the background of its relevance to the objectives of this study, because the aim of the study is not to examine the detail of the acts *per se* from a juridical point of view. The following aspects are investigated with regard to the existing health and safety legislation in South Africa:

- Does the cluster of legislation have a common goal, namely the safety of people (employees and members of the public) and the protection of assets?
- Is legislation scattered among various independent government departments, each with its own political driving forces?

South African legislation for the governance of major hazard installations is then compared with some similar international legislation:

- United Kingdom.
- European Union.
- United States of America.
- France.
- Malaysia.
- The European Court of Human Rights.

5.2 Current regulatory measures in South Africa for installations or facilities that can pose a threat to the lives of people

Table 5.1 gives a summary of South African legislation that governs the health and safety of people, employees and the public.

The various Acts listed in the table are analysed in terms of three critical success factors, namely:

- The aim of the Act.
- The scope and application of the Act.
- The state department responsible for the administration of the Act.

Table 5.1: Summary of South African legislation that governs hazardous environments and facilities

Legislation	Nature of legislation		Regulating authority
	Disaster prevention	Disaster mitigation	
1. Occupational Health and Safety Act (Act 85 of 1993) and the Major Hazard Installation Regulations of 2001	•		Department of Labour
2. Mine Health and Safety Act (Act 29 of 1996)	•		Department of Mineral Resources
3. National Environmental Management Act (Act 107 of 1998)	•		Department of Environmental Affairs, on national and 9 provincial levels
4. National Nuclear Regulator Act (Act 47 of 1999)	•		Department of Energy
5. National Road Traffic Act (Act 93 of 1996)	•		Department of Transport
6. National Railway Safety Regulator Act (Act 16 of 2002)	•		Department of Transport
7. Disaster Management Act (Act 57 of 2002)	•	•	Department of Cooperative Governance and Traditional Affairs
8. Safety at Sports and Recreational Events Act (Act 2 of 2010)	•	•	Department of Cooperative Governance and Traditional Affairs

Table 5.1: Summary of South African legislation that governs hazardous environments and facilities *(continued)*

Legislation	Nature of legislation		Regulating authority
	Disaster prevention	Disaster mitigation	
9. National Health Act (Act 61 of 2003)	•	•	Department of Health
10. Fire Brigade Services Act (Act 99 of 1987)		•	Department of Cooperative Governance and Traditional Affairs
11. Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)		•	Department of Labour
12. Civil Aviation Act (Act 13 of 2009)	•		Department of Transport
13. South African Maritime Safety Authority Act (Act 5 of 1998)	•		Department of Transport
14. Petroleum Pipelines Act (Act 60 of 2003)	•	•	Department of Energy
15. Disaster Management Framework under the Disaster Management Act (Act 57 of 2002)	•	•	Department of Cooperative Governance and Traditional Affairs

5.2.1 The Occupational Health and Safety Act (Act 85 of 1993) and the Major Hazard Installation Regulations of 2001

5.2.1.1 The aim of the Act

The Act provides for the health and safety of persons at work (employees) and for the health and safety of persons who are directly involved in the use of the plant, equipment and machinery. In addition, the Act provides for the protection of persons other than employees against hazards to health and safety that may arise from the activities of employees.

It is important to note that the health and safety of two groups of people are protected in this Act and the Major Hazard Installation Regulations:

- Employees in the work place, who are directly involved in the handling and operation of hazardous materials, equipment and facilities.
- Members of the public, who are not directly involved in the workplace at all, but whose health and safety may be affected by activities in the work place. These people include members of communities near or around the work place and major hazard installation, or people who visit the facility for whatever reason.

5.2.1.2 The scope and application of the Act

- The Act applies generally to the employees of an employer, not explicitly excluding mines, as well as members of the general public in South Africa. The Major Hazard Installation Regulations (2001) under this Act regulate installations or facilities that can pose a threat to the health and safety of employees and members of the public. Mines are not explicitly excluded from this Act, but the Department of Labour and the Department of Mineral Resources are adamant that each department should administer its own legislation autonomously without interference from the other department. This presents an unhealthy governance dilemma and is driven by political power motives.
- The Act makes provision for the promulgation of the Major Hazard Installation (MHI) Regulations of 2001, which form the basis of all major hazard installations and facilities in South Africa. However, it excludes nuclear facilities, which are governed by the Nuclear Regulator under the Department of Energy, and railway stock in transit, which is governed by the Railway Safety Regulator under the Department of Transport. Once again, it creates a dilemma of cross-functional governance that excludes the Department of Labour on matters that affect the safety of people and assets.
- The Act makes it mandatory to have Health and Safety Committees established at all workplaces. This principle in a way implies self-regulation as proposed by Levi-Faur (2010) whereby employees have the right to demand safe and healthy working conditions and are given the authority to execute that right through their own elected committees. It is a workable and practical system of regulation, which

has been applied successfully in South African industry for many years. These committees have an open reporting line to inspectors of the Department of Labour.

- The MHI Regulations make provision for detailed risk assessments on major hazard installations to be performed by a competent authority and inspections carried out by the Department of Labour. The contents of the risk assessment are prescribed by the Regulations and must be based on the probability and severity of the risks associated with the installation. The risk assessor must be accredited by SANAS and registered as an Approved Inspection Authority (AIA) by the Department of Labour. The institutionalised Health and Safety Committees in workplaces also have the responsibility to see to it that major hazard installations in their working environment are designed, operated and maintained in a safe manner, in accordance with the outcome of the abovementioned risk assessment. However, these committees do not concern themselves in any way with the vulnerability of communities near the major hazard installation. This is considered a shortcoming in the regulations.

- A very important provision in the MHI Regulations is the power granted to local authorities to approve or not approve a new major hazard installation, taking the relevant bylaws of the local authority into consideration. These powers are closely related to existing or future land development where the safety of existing or future communities can be affected by a major hazard installation. None of the other pieces of legislation contains any prescription in this regard in relation to major hazard installations. Other than that, this Act does not provide for formal approval or the permitting or licensing of a major hazard installation.

5.2.1.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Labour.

5.2.2 The Mine Health and Safety Act (Act 29 of 1996)

5.2.2.1 The aim of the Act

The Act makes provision for the protection of the health and safety of employees and other persons at mines. “Other” persons are not defined and can therefore be interpreted as “non-employees”, which include members of the public present at the mine, such as visitors, clients, contractors and suppliers. Furthermore, the Act does not stipulate the boundaries within which the health and safety of employees and members of the public should be protected. For example, does the protection of people include the adverse health effects on residents who live near a source of toxic gas at the mine's smelter operations, such as sulphur dioxide, or residents who are exposed to drinking water contaminated with uranium, or radioactive dust containing radon?

The protection of the health and safety of people at mines must be achieved through the following means:

- Promote a culture of health and safety. It can only be done among employees, who are in control of the operation of facilities, equipment and installations at the mine and from which members of the public are excluded.

- Provide for the enforcement of health and safety measures by the Mine Inspectorate that is responsible for the implementation of the Act. This implies that the authority has a supervisory and inspection function (Gunningham 2014), which includes the enforcement of penalties and initiation of criminal prosecution in case of transgression of the provisions of the Act. Such measures are only applicable to the employees and management of mines and exclude members of the public.

- Provide for appropriate systems of employee, employer and State participation in health and safety matters. It implies a system of consultative decision-making and participation by all roleplayers, except members of the public.

- Establish representative tripartite institutions to review legislation, promote health and enhance properly targeted research. The term "tripartite" refers to government, the business sector (mines) and labour unions, but does not explicitly include community organisations, which can be construed as an infringement of the prescriptions of the National Economic Development and Labour Council (NEDLAC Act 1994) as the vehicle of government, labour, business and community organisations to cooperate, through negotiation and the joint finding of solutions on economic, labour and development issues and other challenges facing South Africa. NEDLAC performs its duties in four main areas:
    - Public finance and monetary policy.
    - Labour market policy.
    - Trade and industrial policy.

  - Development policy.

- Provide for effective monitoring systems and inspections, investigations and inquiries by the competent authority.

- Improve health and safety. It is not stipulated here who the target group should be, but it is assumed that this aspect refers to employees and people at the mine. Once again, no reference is made to communities or members of the public.

- Promote training and human resources development among employees.

- Regulate the duties of employers and employees to identify hazards and eliminate, control and minimise the risk to health and safety. No reference is made to public receptor groups whose health and safety may be affected by the hazards.

- Entrench the right of employees to refuse to work in dangerous conditions. This statement does not refer to members of the public.

- Give effect to the public international law obligations of the Republic relating to mining health and safety. Note that the ILO Code of Practice (1991) for the prevention of major industrial accidents is certainly implied in this statement of the Act, but that the Act nevertheless does not refer to protection of the public, as the ILO Code prescribes.

5.2.2.2 The scope and application of the Act

The Act applies to employees, specifically at mines, as well as members of the general public on the premises of mines. Communities outside the boundaries of mines are not included in this Act.

The Act makes it mandatory for mine management to conduct a risk assessment at the workplace, but is not prescriptive regarding the contents or format of the assessment, or the competence of the risk assessor. It also provides for inspections at mining operations by the Department of Mineral Resources, under the auspices of the Mine Health and Safety Council. In addition, the Act prescribes the mandatory establishment of health and safety committees at all mining operations. The Act does not provide for formal approval or the permitting or licensing of a mine from a health and safety perspective.

5.2.2.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Mineral Resources.

5.2.3 The National Environmental Management Act (Act 107 of 1998)

5.2.3.1 The aim of the Act

The Act provides for cooperative environmental governance by establishing principles for decision-making on matters affecting the environment, the establishment of institutions that will promote cooperative governance and the implementation of procedures for coordinating environmental functions exercised by various state departments and institutions. The focus is on environmental governance in its broadest sense.

The Act makes provision for detailed environmental management in the form of the EIA Regulations, reviewed in 2014. Activities that could have a detrimental impact on the environment, including human beings, are listed in detail in these regulations. The regulations determine that an environmental impact assessment needs to be performed for such activities, by a competent environmental assessment practitioner.

5.2.3.2 The scope and application of the Act

The Act is applicable to institutions, companies, industry and members of the public in South Africa, to prohibit the pollution of air, soil, surface water and groundwater, which can have detrimental biophysical and socio-economic consequences. The most important regulatory function of the Act lies in the enforcement of environmental impact assessments for specific listed human activities through the Environmental Impact Assessment (EIA) Regulations (2014). The regulations prescribe the contents, format and approval process for environmental impact assessment reports in much detail. Strict prescriptions are also provided for the qualifications of environmental impact assessment practitioners. As such the Act provides for the formal authorisation of any listed activity. The Act does not make a distinction between employees and members of the general public.

5.2.3.3 The state department responsible for the administration of the Act

The Act is administered by the National Department of Environmental Affairs in collaboration with the Departments of Environmental Affairs of the nine provinces.

5.2.4 The National Nuclear Regulator Act (Act 47 of 1999)

5.2.4.1 The aim of the Act

The aim of the Act is to provide for the establishment of a National Nuclear Regulator in order to regulate nuclear activities in South Africa. The purpose and functions of the NNR are described in the Act as well as the manner in which it is to be managed. Most importantly, it makes provision for safety standards and regulatory practices for the protection of persons, property and the environment against nuclear damage.

5.2.4.2 The scope and application of the Act

The Act is applicable to all nuclear facilities in particular and includes the safety of employees and members of the public. Employees and members of the general public are both considered in the Act and the Nuclear Regulations (2006). The regulations issued under the Act (Government Printer 2006) makes provision for risk assessments at nuclear facilities and the setting or norms for individual (employee) and societal (public) risk levels. As nuclear installations are regulated in accordance with international agreements (IAEA 2016) the NNR ensures that international best practices are applied in South Africa, including risk assesments. South Africa became a member of the IAEA in 1957 (NNR 2016). International best practices for nuclear installations are described in the latest publication of the OECD, NEA and IEA (OECD, NEA & IEA 2015), where reference is also made to the Fukushima nuclear disaster in Japan in 2011 (CNN 2011).

5.2.4.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Energy.

5.2.5 The National Road Traffic Act (Act 93 of 1996)

5.2.5.1 The aim of the Act

The Act provides for road traffic matters which apply uniformly throughout the Republic of South Africa. The prime aim of the Act is to ensure that roads are used safely and to place certain obligations on road users and the road infrastructure required to achieve this aim.

5.2.5.2 The scope and application of the Act

The Act is applicable to all road systems operated in South Africa, to ensure the safety of people utilising any form of road transportation, including vehicle drivers, passengers and cargo. It focuses on road users, which implies all members of the public.

The application of the Act is not restricted to workplaces, but includes all public roads. As such, it covers all members of the general public who make used of roads in South Africa, hence there is no prescription on health and safety committees. The Act also specifies requirements for the transportation of hazardous goods, such as liquid fuel, gas and toxic chemicals, through densely populated areas. An important provision in the Act is the policing of road traffic and the prosecution of traffic rule offenders.

5.2.5.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Transport.

5.2.6 The National Railway Safety Regulator Act (Act 16 of 2002)

5.2.6.1 The aim of the Act

The Act aims to provide for the establishment of a Railway Safety Regulator by prescribing its objectives and functions and for the manner in which it is to be managed. In addition, the Act makes provision for safety standards and regulatory practices for the protection of persons, property and the environment with regard to rail transportation.

5.2.6.2 The scope and application of the Act

The Act is applicable to all people utilising rail transportation on railroad systems in South Africa and has to ensure the safety of employees, passengers and cargo. A distinction is not made between employees and members of the public as both groups are protected equally under the Act. It allows the Regulator to authorise the use of infrastructure and equipment, carry out inspections and investigate incidents that could affect the safety of people (employees and the public). The Act makes, *inter alia*, provision for the handling and transportation of hazardous goods.

5.2.6.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Transport.

5.2.7 The Disaster Management Amendment Act (Act 16 of 2015)

5.2.7.1 The aim of the Act

This Act provides for an integrated and coordinated disaster management policy for South Africa that focuses on the prevention or minimisation of the risk of disaster. It also provides for emergency preparedness, mitigation of the severity of disasters, rapid and effective response to disasters and post-disaster recovery. National, provincial and municipal disaster management centres are established under the Act of 2002. However, in the Disaster Management Amendment Act (2015) the disaster management functions on national level have been devolved to provincial level.

5.2.7.2 The scope and application of the Act

The Act is applicable to all people in South Africa that can be affected by the devastating effects of a natural or human-caused (human-induced) disaster. The Amendment Act (2015) requires the implementation of disaster management plans at provincial and local government level and the establishment of provincial and local disaster management centres. The focus of the Act is on the health and safety of the general public and the protection of assets.

5.2.7.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Cooperative Governance and Traditional Affairs.

5.2.8 The Safety at Sports and Recreational Events Act (Act 2 of 2010)

5.2.8.1 The aim of the Act

This Act was introduced in South Africa in 2010 when the country hosted the Soccer World Cup tournament, in anticipation of the health and safety risks associated with large sports events. The Act provides for measures to safeguard the physical well-being and safety of people and property at sports, recreational, religious, cultural, exhibition, organisational or similar events held at stadiums, venues or along a route.

The similarity between this Act and the National Disaster Management Amendment Act (2015) is obvious. Both Acts focus on disaster management, although the Safety at Sports and Recreational Events Act takes a proactive approach to prevent disasters associated with large crowds of people.

5.2.8.2 The scope and application of the Act

The Act is applicable to all social events in indoor or outdoor venues where more than 2 000 people may gather. The Act purely deals with the safety of the general public and makes provision for extensive powers to be granted to the South African Police Service with regard to the inspection, planning and control of the events. It also prescribes the requirements for emergency response actions at public events.

5.2.8.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Cooperative Governance and Traditional Affairs.

5.2.9 The National Health Act (Act 61 of 2003)

5.2.9.1 The aim of the Act

The aim of this Act is to provide a framework for a structured, uniform health system in the Republic of South Africa, taking into account the obligations imposed by the Constitution and other laws on the national, provincial and local governments with regard to health services. The Act aims at healthcare for all people in the country and does not distinguish between employees and the general public.

5.2.9.2 The scope and application of the Act

The Act is applicable to all people, health institutions and health employees in South Africa on national, provincial and district (local) level. The focus is primarily on the provision of healthcare services to all inhabitants of the country and as such has an important bearing on the well-being of people. It allows for inspections at health institutions with regard to infrastructure and personnel.

It must be noted that the safety of people in terms of exposure to safety and health hazards is not addressed explicitly in the Act. The Act takes a treatment approach, after an illness or injury of whatever nature has struck, although much is done to educate citizens about illness prevention as a proactive strategy.

5.2.9.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Health.

5.2.10 The Fire Brigade Services Act (Act 99 of 1987)

5.2.10.1 The aim of the Act

The Act provides for the establishment, maintenance, employment, coordination and standardisation of fire brigade services on local government level in South Africa.

5.2.10.2 The scope and application of the Act

The Act is applicable to all institutions that have the responsibility of providing a fire-fighting and rescue service to the people of South Africa. It focuses on the provision of infrastructure and resources for the effective rendering of a fire brigade service on local and institutional level. It focuses on the health and safety of members of the public at large.

5.2.10.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Cooperative Governance and Traditional Affairs.

5.2.11 The Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)

5.2.11.1 The aim of the Act

The Act provides for compensation for the disablement of employees caused by occupational injuries or diseases sustained or contracted in the course of their employment duties, or for death resulting from such injuries or diseases.

The Act focuses entirely on employees and not on the general public, which has an important bearing on this study. The financial compensation of employees is an important step towards disaster recovery, both for affected employees and the owner of a major hazard installation. This aspect forms part of business continuity planning as discussed by Smith (2012).

5.2.11.2 The scope and application of the Act

The Act is applicable to employers and employees in all labour sectors of South Africa. It provides for the mandatory financial contribution of all employers to a national insurance fund to provide for the financial compensation of employees who sustained occupational injuries and diseases in the course of their duties. The Act does not apply to members of the general public. This is the only Act that regulates monetary compensation for accidents, albeit only for employees, and therefore plays an important role in disaster recovery. The obligation on owners of major hazard installations to compensate members of the public for injuries or illness sustained as a result of a disaster caused by the installation is not covered in South African legislation and depends on the outcome of litigation (Mail & Guardian 1997; Batterman et al. 1998; City Press 2011).

5.2.11.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Labour.

5.2.12 The Civil Aviation Act (Act 13 of 2009)

5.2.12.1 The aim of the Act

The Civil Aviation Act makes provision for the control and regulation of aviation within South Africa. This is done through the establishment of the South African Civil Aviation Authority, which has been authorised with safety and security supervisory functions. It also allows for the establishment of an independent Aviation Safety Investigation Board in compliance with the conditions of the Chicago Convention of the International Civil Aviation Organisation (ICAO 1944). In addition to other international conventions such as the Convention on Offences and Certain other Acts Committed on Board Aircraft, the Convention for the Suppression of Unlawful Seizure of Aircraft and the Convention for the Suppression of Unlawful Acts Against the Safety of Civil Aviation, the Act also provides for a National Aviation Security Programme and, most importantly, measures directed at controlling of the safety and security of aircraft, airports and property.

5.2.12.2 The scope and application of the Act

The Act is applicable to all aircraft systems and operators that can have an effect on the safety of people in South Africa, including military aircraft in peaceful use. The emphasis is on the safety of people utilising air transportation, including passengers and cargo. Such safety measures obviously apply to aircraft personnel as well as members of the public (passengers). The Act also provides for the provision of adequate infrastructure at airports and the implementation of the necessary protocols for the safe transportation of passengers and cargo. The focus of the Act is therefore on the prevention of accidents and the proper investigation of accidents with a view to designing preventative measures.

The significance of the Act was demonstrated with prominent publicity in April 2016, when airline carrier SA Express was grounded by the South African Civil Aviation Authority as a result of a series of non-compliances on the operator's safety monitoring systems (IOL, 2016). SA Express was stopped flying in order to prevent potential catastrophic safety incidents.

5.2.12.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Transport.

5.2.13 The South African Maritime Safety Authority Act (Act 5 of 1998)

5.2.13.1 The aim of the Act

In essence this Act aims to ensure the safety of life and property at sea and to prevent and rectify pollution from ships in the marine environment of South Africa.

5.2.13.2 The scope and application of the Act

The Act is applicable to all naval systems and operators present in South African sea waters, including military ships that are in peaceful use, to ensure the safety of people utilising naval transportation, including passengers and cargo. It focuses primarily on the establishment and functions of the Maritime Safety Authority, which has the right to inspect ships and marine equipment in South African sea waters.

5.2.13.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Transport.

5.2.14 The Petroleum Pipelines Act (Act 60 of 2003)

5.2.14.1 The aim of the Act

The aims of this Act are to:

- Promote competition in the building and operation of petroleum pipelines, loading facilities and storage facilities

- Promote the effective, sustainable and orderly development, operation and use of petroleum pipelines, loading facilities and storage facilities
- Ensure the safe, efficient, economic and environmentally responsible transport, loading and storage of petroleum products. This is the most important aim of the Act as far as this study is concerned, because it addresses the health and safety of employees at the facilities as well as members of the public.
- Promote equitable access to petroleum pipelines, loading facilities and storage facilities
- Facilitate investment in the petroleum pipeline industry
- Provide for the security of petroleum pipelines and related infrastructure
- Promote companies in the petroleum pipeline industry that are owned or controlled by historically disadvantaged South Africans, by means of licence conditions to enable them to become competitive
- Promote the development of competitive markets for petroleum products
- Promote access to affordable petroleum products
- Ensure an appropriate supply of petroleum to meet market requirements

5.2.14.2 The scope and application of the Act

While the Act has a strong focus on economic aspects such as market competition and development, equitable access to resources and investment in the petroleum industry, the health and safety of people (employees and members of the public) are also important.

The Petroleum Pipelines Act has an important bearing on this study. It includes the safe storage of liquid petroleum products and therefore refers to storage depots. The Buncefield depot fire is a case in point (HSE 2008; Mannan 2009). As part of the action research conducted for this study, several discussions were held with NERSA to develop a safety framework for the licensing of petroleum storage facilities. The work done emphasised that the biggest risk of storage depots is that of the overfilling of storage tanks fed by pipelines. The recommendations made by the Buncefield Major Incident Investigation Board (BMIIB 2008) to prevent tank overfilling, as was the case at the depot in Buncefield, are in the process of being implemented in South Africa.

5.2.14.3 The state department responsible for the administration of the Act

The Act is administered by the Department of Energy.

5.2.15 The Disaster Management Framework

5.2.15.1 The aim of the Framework

The national disaster management framework is the legal instrument specified by the Disaster Management Amendment Act (2015) to address such needs for consistency across multiple interest groups, by providing *“a coherent, transparent and inclusive policy on disaster management appropriate for the Republic as a whole”*.

5.2.15.2 The scope and application of the Act

The framework is applicable to all people in South Africa that can be affected by the devastating effects of a natural or human-caused (human-induced) disaster. The Amendment Act (2015) requires the implementation of disaster management plans at provincial and local government level and the establishment of provincial and local disaster management centres. The focus of the Act is on the health and safety of the general public and the protection of assets.

5.2.15.3 The state department responsible for the administration of the Act

The framework is administered by the Department of Cooperative Governance and Traditional Affairs.

5.3 A critical discussion of the legislation in South Africa

From the examination of the 14 pieces of health and safety legislation and the disaster management framework, the following pattern emerges:

5.3.1 All pieces of legislation aim at the protection of the health and safety of human beings, as employees at an enterprise or as members of the general public or both, against the harmful impacts that a disaster can have on them.

5.3.2 The scope and application of all legislation is focused on manmade systems or events that have the potential to harm people or damage assets. The Disaster Management Amendment Act (2015) also includes natural disasters.

5.3.3 A variety of independent state departments administer the legislation, as follows:

- Department of Labour.
- Department of Mineral Resources.
- Department of Environmental Affairs.
- Department of Energy.
- Department of Transport.
- Department of Cooperative Governance and Traditional Affairs.
- Department of Health.

5.3.4 The cluster of legislation has a common aim, namely the regulatory management of human-induced health and safety risks associated with equipment or installations or facilities that can have a detrimental effect on people, whether they are employees or members of the general public.

5.3.5 The pieces of legislation that were examined have the following in common:

- They are aimed at the proactive protection of the health and safety of people.
- Members of the general public are always the focus of the legislation.
- Employees are in some cases the focus of the legislation.
- Health and safety committees and employee consultation and involvement are essential legal prerequisites in workplaces.
- Risk assessments in hazardous environments are prescribed by some legislation, in varying degrees of detail.
- The competence of risk assessors is prescribed by only one Act.
- All legislation makes provision for inspections by the authorities to ensure that the requirements of the particular Act and Regulations are met.
- Emergency response planning is prescribed in some legislation.
- All legislation prescribes the proper investigation and recording of incidents that can affect the health and safety of people or the integrity of assets.
- All legislation makes provision for the necessary funding, resources and management structures of authoritative bodies.

5.3.6 The legislation cluster aims at the protection of the health and safety of people. As such it can be expected that there must be some common protocol for the prevention of incidents, the implementation of incident mitigation measures and the management of emergencies. However, this is not the case. Only some legislation requires risk assessments to be performed in hazardous environments. The content of the risk assessment is prescribed only by the MHI Regulations (2001) and the Nuclear Regulations (2006).

5.3.8 With the exception of the Fire Brigade Services Act (Act 99 of 1987) and the Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993) all the Acts are focused on disaster prevention.

5.3.9 There is a significant lack of uniform guidelines with regard to preventative measures when it comes to the health and safety of communities that can be affected by a particular installation or facility. This can be partly explained by the fact that five state departments administer the cluster of health and safety legislation.

5.3.10 None of the legislation makes mention of the vulnerability of communities that can be affected by a hazardous installation or activity. Community vulnerability in terms of coping capacity and resilience is not considered in any of the legislation pieces at all.

5.3.11 The objective of this research is to design an optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa. It is clear that, while there may be a need for such a model, the proposed model must allow for sufficient flexibility to accommodate the needs of the different state departments responsible for the administration of the legislation.

5.4 The regulatory management of major hazard installations in South Africa

Apart from the influences that major disasters had on legislation around the world, no meaningful information could be found in the literature on the development of legislatory models for the management of health and safety related to major human-induced hazards, especially in South Africa.

The major industrial disaster that occurred in Seveso, Italy, in 1978 shaped industrial safety regulation around the world (Homberg et al. 1979). In 2001 South Africa adopted the Major Hazard Installation Regulations under the Occupational Health and Safety Act (Act 85 of 1993). The Major Hazard Installation Regulations are based on the UK COMAH Regulations, which flowed from the Seveso II Directive of the European Union. The prime focus of the occupational health and safety legislation in South Africa is the safety and health of employees in organisations (the labour force) and not so much that of the general public. Figure 5.1 shows the interrelationship of competent authorities and health and safety legislation in South Africa.

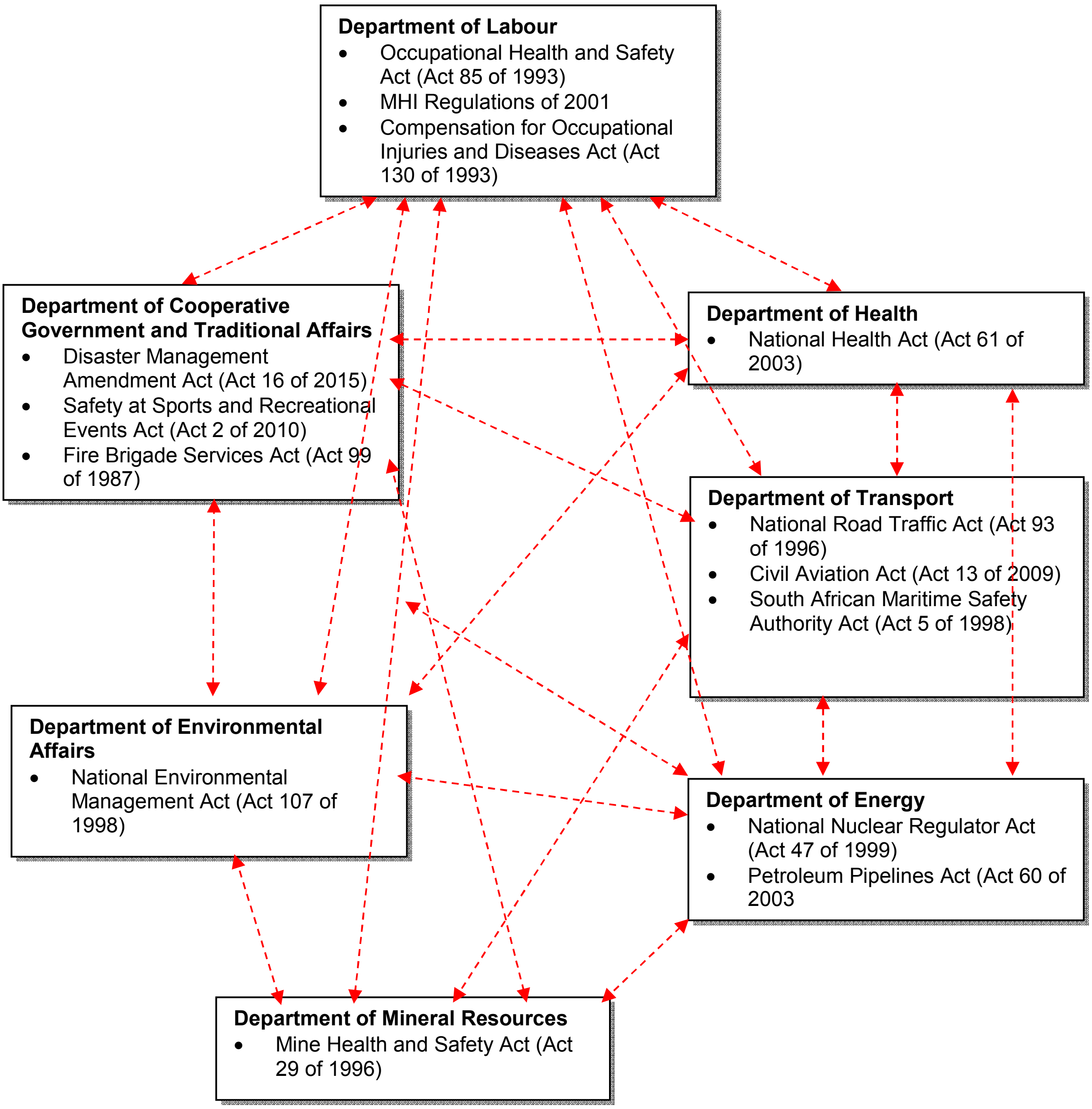

Figure 5.1 The interrelationship of competent authorities and health and safety legislation in South Africa

The interrelationship between the various competent authorities and the legislation aimed at the protection of the health and safety of persons in South Africa, as shown in Figure 5.1, emphasises the following:

- Legislation is fragmented. Core legislation, namely the protection of the health and safety of people, is contained in all 14 Acts that were examined, but is intermingled with other pieces of organisational legislation with different aims. What one would like to see is one piece of legislation that specifies quite clearly the requirements for the protection of the health and safety of people, including employees at major hazard installations and members of the public.

- The legislation for the protection of the health and safety of people is administered by at least seven different competent authorities that are autonomous and independent of one another. The standards applied for the safety of the public differ markedly, for example: The Department of Labour does not specify the detailed methodology of risk assessments that should be performed at major hazard installations. The Department of Mineral Resources only stipulates that a risk assessment must be performed at mines, without any specific methodology. It is left to the owner or operator of the major hazard installation and the mine to determine its own risk assessment methodology. Furthermore, some mines do not take the communities around their operation into consideration when the risk assessment is performed, for example where they have toxic gases such as sulphur dioxide (as reducing agent) and ammonia (as refrigerant) stored and used on smelter and mine sites, as well as contamination of drinking water with uranium.

- There is considerable overlapping in the decision-making processes of the competent authorities, for example: The installation of a bulk storage tank for liquid petroleum gas with a capacity of more than 80 cubic metres is classified as a listed activity in the EIA Regulations (2014) that requires an environmental impact assessment under the National Environmental Management Act (2007). At the same time, the installation requires a major hazard installation risk assessment under the Occupational Health and Safety Act (1993) and the Major Hazard Installation Regulations (2001). The environmental impact assessment report must be handed to the national or provincial Department of Environmental Affairs, while the major hazard installation risk assessment report must be submitted to the Department of Labour. It happens frequently that the Department of Environmental

Affairs sees it as its mandate to approve or not approve the major hazard installation risk assessment report, while in fact it remains the responsibility of the Department of Labour. The principle of cooperative governance needs to be applied in this particular case (CGTA 2009), i.e. the cooperation of all spheres of government. A culture needs to be developed among all government departments that encourages the coordination and elimination of duplication while synergies have to be explored for improved efficiency.

- Cross-functional decision-making takes place in government, which breeds inefficiencies. One government department considers it to be the responsibility of another to take a decision. Eventually, no decision is taken at all or the wrong decision is taken, because it falls outside of the scope of the decision-making department. Considerable time is lost in this process to the detriment of the industrial investor with adverse effects on local economic development and employment creation.

Regulatory conflict exists in South Africa, in that the boundaries between environmental legislation and safety legislation are not clearly defined, with the result that overlapping of authority occurs. In cases where environmental authorisation is required from the Department of Environmental Affairs for new hazardous installations, environmental assessment practitioners erroneously pull the major hazard installation risk assessment reports, compiled under the MHI Regulations for the Department of Labour, into the environmental impact assessment process. As a result, the Department of Environmental Affairs mistakenly gained a mandate to authorise risk assessment reports that fall under the Department of Labour. This causes the stipulations of the MHI Regulations to be violated, for example public consultation protocols.

Campbell (2013) concluded that if South Africa were to move to better regulation of major hazard installations, a number of ingredients would be needed:

- Good regulations, backed by clear, unambiguous guidance such as risk assessment.
- Focus on high-hazard industries.
- Competent, appropriately staffed organisations.
- A bigger, more competent Department of Labour.

- An integrated approach to land-use planning, driven by local planning authorities.

5.5 The regulatory management of major hazard installations in the rest of the world

5.5.1 United Kingdom

It is important to consider the work done in the UK regarding the development of regulations for major hazard installations. The history of health and safety regulation in the UK dates back to 1833, when the first factory inspectors were appointed under the Factories Act 1833 (UK HSE 2013). Inspectors were appointed to focus on injury and to control the working hours of child textile employees. In July 1974 the Health and Safety Commission was formed under the Health and Safety at Work Act 1974. Its responsibilities included the health and safety of people at work, protecting the public generally against health and safety risks, giving advice to local authorities on the enforcement of the Act and assisting persons with duties under the Act. The promotion of ongoing research and information provision also formed part of its responsibilities.

The Health and Safety Executive (HSE) was established in January 1975 with the responsibilities of executing the duties of the Health and Safety Commission and enforcing health and safety legislation in all workplaces except those regulated by local authorities.

In 2006 the Health and Safety Commission and the Health and Safety Executive merged to form one organisation called the Health and Safety Executive (HSE). The HSE is the national regulatory body responsible for promoting better health and safety at work in Great Britain. However, enforcement is shared with local authorities in accordance with the Health and Safety (Enforcing Authority) Regulations of 1998. Health and safety legislation in the country was shaped largely by evidence gathered from the occurrence of major disasters, such as the following (UK HSE 2013):

- Flixborough chemical plant explosion in 1974 (28 fatalities).
- Golborne Colliery disaster in 1979 (10 fatalities).
- Methane explosion in the Abbeystead water pump station in 1984 (16 fatalities).
- Putney domestic gas explosion in 1985 (8 fatalities).
- Fire at Bradford City Football Stadium in 1985 (56 fatalities).
- Fire at King’s Cross underground railway station in 1987 (31 fatalities).

- Clapham train collision in 1988 (35 fatalities).
- Fire and explosion on the Piper Alpha offshore oil platform in 1988 (167 fatalities).
- Hillsborough Football Stadium spectator crush in 1989 (96 fatalities).
- Southall East Junction train collision in 1997 (7 fatalities).
- Ladbroke Grove train collision in 1999 (31 fatalities).
- Morecambe Bay cockle-picker drowning in 2004 (23 fatalities).
- Explosion at the ICL plastics factory in Glasgow in 2004 (9 fatalities).
- Explosion and fire at the Buncefield fuel depot in 2005 (more than 50 injuries).

Kevin Allars (2006) of the UK Health and Safety Executive expressed concern about the level of major incidents at major hazard installations in the UK. He commented that the findings of the Buncefield fuel depot disaster inquiry suggested that up to 60 major hazard installations in the UK which operate under the Control of Major Accident Hazards (COMAH) Regulations, will have to widen their public consultation areas. The UK Health and Safety Executive (1982; 1996) places a strong emphasis on this approach of public consultation, similar to what the NEMA prescribes in South Africa.

The Health and Safety Commission undertook a comprehensive review of the UK health and safety legislation in 1992 to determine whether existing legislation was still relevant and necessary in its current form. The review also aimed to reduce the administrative burdens that legislation could place on small businesses and to examine the general approach of the Health and Safety Executive regarding enforcement of the legislation. It was found that much of the current legislation was considered too voluminous, complicated and fragmented. The review report recommended the removal of 100 sets of regulations and seven pieces of primary legislation as well as simplification of the 340 requirements for administrative paperwork. A Simplification Plan was consequently implemented by the Health and Safety Executive to reduce the legislatory burdens on industry.

A follow-up review of health and safety legislation was commissioned by the Minister for Employment of the Department of Work and Pensions in 2011. The review was undertaken by a committee under the chairmanship of Professor Ragnar Löfstedt (2011), Director of the King’s Centre for Risk Management at King’s College. The scope of the review was to consider the combination, simplification or reduction of around 200 statutory legislatory instruments owned and enforced by HSE.

The purpose of the review (referred to as the Löfstedt Review, Löfstedt 2011) was as follows:

- To consider opportunities for reducing the burden of health and safety legislation on UK businesses, while maintaining the progress made in improving health and safety performance in UK industry.
- To take into account the extent to which these regulations have led to positive health and safety outcomes.
- To take into account the extent to which these regulations have created significant economic costs for businesses of all sizes.
- To consider the scope for combining, simplifying or reducing the approximately 200 statutory instruments owned by the Health and Safety Executive (HSE) in the UK and primarily enforced by the HSE and local authorities. In addition, the review must consider associated Approved Codes of Practice, which provide advice on compliance with health and safety law. These Codes have special legal status.
- To take into account whether the requirements of European Union (EU) Directives are being unnecessarily enhanced ("gold-plated") when transported into UK regulation.
- To take into account evidence or examples where health and safety regulations have led to unreasonable outcomes, inappropriate litigation and compensation.

The review sought evidence from government bodies, employers' organisations, employee organisations, professional health and safety bodies and academics. It was conducted under the chairmanship of Professor Ragnar Löfstedt, Director of the King's Centre for Risk Management at King's College, London.

The Löfstedt Review of 2011 is of particular significance for this study, for the following reasons:

- The UK Government developed an awareness of and sensitivity for the uncontrolled complexity of health and safety legislation and the resultant difficulties to implement it.

- Health and safety legislation can create a burden for businesses, which can impede economic growth and employment creation. In particular, businesses may incur unnecessary costs for the implementation of compliance actions.
- The responsibility for the enforcement of health and safety legislation in a country needs to be defined clearly to prevent overlap, inconsistent interpretation of the regulations and confusion among industry leaders.
- External influencing, whether enforced or self-imposed, of a country's health and safety legislation (in the case of the UK – the EU Directives; in the case of South Africa – the UK) has the potential to distort local regulations and makes it irrelevant for local circumstances in that country.

The Löfstedt Report (2011) concluded as follows:

- That self-employed bodies whose activities pose no potential health and safety risk of harm to others should be exempted from such legislation
- That all Approved Codes of Practice be reviewed
- That the UK government works more closely with the European Union to ensure that health and safety legislation is risk-based and evidence-based
- That sector-specific legislation must be consolidated
- That the HSE should direct all local authority health and safety inspections and enforcement activities in order to be consistent and focused on high-risk workplaces
- That clarification must be obtained regarding the protocols of early settlements between parties in cases of civil action from employees and the public against employers
- That the regulatory provisions imposing strict liability on employers be reviewed and aligned with the principle of "reasonably practicable"

According to the Health and Safety Executive of the UK (2013) the legislatory regulation of health and safety at nuclear installations in the UK received renewed attention in 1957 following a major incident at the Windscale nuclear site. It led to the passing of the

Nuclear Installations Act in 1959, followed by the formation of the Nuclear Installations Inspectorate (NII) within the Ministry of Power. In 1975 the Health and Safety Commission established several advisory committees, including the Advisory Committee on the Safety of Nuclear Installations. In so doing, the regulatory management of nuclear installations was taken on board by the then Health and Safety Commission, today the Health and Safety Executive. Research into the safety of nuclear installations in the UK received substantial impetus with the establishment of the Nuclear Safety Research Management Unit in 1990, when the responsibility for nuclear safety research was transferred from the UK Department of Energy to the Health and Safety Commission.

5.5.2 European Union (EU) countries

The complexity and room for confusion created by major hazard installation risk assessment was the topic of a study by Ignatowski and Rosenthal (2001). For this purpose they developed a Chemical Accident Risk Assessment Thesaurus (CARAT) in the Organisation for Economic Cooperation and Development (OECD) by the Working Group on Chemical Accidents. It had been recognised that it was difficult to communicate among the member countries about the risk assessment of hazardous installations. They concluded that this difficulty was based largely on the fact that certain "terms of art" have different meanings in different countries and cultures. Furthermore, different people and organisations use different terms of art to address the same concept. This cultural complexity is a prominent feature of South African society and may contribute to the problem of major hazard installation legislation. The lack of consistency in the definitions of essential terms of art creates an impediment to understanding among all stakeholders of the approaches and methodologies used in major hazard installation risk assessment, which, in turn, creates uncertainty for the significance of the assessment results obtained.

Shaluf (2007) introduces the concept of technological disasters instead of major hazard installation disasters. This helps to emphasise the industrial, manmade nature of such disasters in order to manage them effectively. Reference is made to some major industrial disasters in the world, namely Seveso 1978; Flixborough 1974; Bhopal 1984; Piper Alpha 1988. Shaluf refers to the following definition of a major accident as used by the International Labour Organisation:

"A major accident is an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of an industrial activity,

leading to a serious danger to man, immediate or delayed, inside or outside the establishment and to the environment, and involving one or more dangerous substances."

It must be noted that there is no reference to the labour force per se, although the inside and outside of the facility establishment are included.

Operators of hazardous installations, in particular those with limited resources and time constraints, often find it difficult to collect the large number of different safety critical success factors of their plants in accordance with the approaches developed by member countries in the Organisation for Economic Cooperation and Development (OECD), as outlined by Mengolini and Debarberis (2008). They propose that organisations should focus on a culture of safety among employees (plant operators and managers) so that major disasters can be prevented. A typical example would be to involve employees in regular safety focus group discussions.

Bellamy et al. (2008) found that the application of human factors to safety in hazardous work situations is often poor. In practice it requires an understanding of human capabilities and fallibilities so as to recognise the relationship between work demands and human capacities when considering human and system performance. The aim should be to eliminate or reduce the chance of adverse human behaviour, which can lead to harm through accidents or chronic exposures and conditions detrimental to health. This particular aspect relates to the situation prevailing at some major hazard installations in third-world countries.

Major hazard installations are needed in every country to provide for its manufacturing, agriculture, transportation and energy needs. These installations store large quantities of hazardous substances and energy in one place, such as refineries, petrochemical plants, chemical production plants, storage of liquid petroleum gas and water treatment plants. Some modern technical installations are so complex and so closely meshed that accidents are inherent in their design. According to Perrow (1999) such systems could generate *"normal accidents".* He makes it clear that most high-risk systems have inherent characteristics that make accidents in them *"normal"* as a result of failure interaction and the way the system and its components are composed. He refers to the Three Mile Island nuclear reactor disaster in 1979 as a case in point. Shaluf (2008) comes to the conclusion that the impact of technological disasters is not limited to the installations only, but can extend to neighbouring surroundings. The establishment of disaster criteria is useful to set benchmarks for the definition of disaster incidents and to declare the need for international assistance.

Papazoglou et al. (2003) state that the European Union Directive 96/82/EC for the control of major accident hazards (the Seveso II Directive) requires that major hazard companies implement a major accident prevention policy and have auditable safety management systems. They propose an integrated safety management system that links technical and managerial models to give insight into the quality of management and its influence on the safety of a plant. The quality of management is particularly relevant when the safety of major hazard installations is considered.

Following major disasters in Europe during the seventies, industrial safety regulations were passed in the European Community in 1982, called the Seveso Directive by the Council of the European Communities (1996). It imposed harsher industrial safety regulations. The Seveso Directive was updated and is currently referred to as the Seveso II Directive under European Union Law or the Control of Major Accident Hazards (COMAH) Regulations in the United Kingdom.

Löfstedt (2011) found that much of the health and safety legislation that applies to businesses in the UK, implements EU directives. About 63 percent of new health and safety regulations introduced between 1997 and 2009 originated in the EU, while EU Directives accounted for 94 percent of the cost of UK health and safety regulation introduced between 1998 and 2009.

The UK Health and Safety Executive’s Hazardous Installations Directorate (2010; 2013) has implemented a system of specialist inspectors to inspect and assess major hazard sites under their COMAH regulations. Bellamy et al. (2008) explain how human factors, safety management systems and wider organisational issues fit together. This is particularly important for hazardous installations in countries where there can be a lack of such a wider focus for various reasons, one being the lack of skilled human resources.

The dilemma of comparability of assessed risks from diverse hazards is addressed by Rushton and Carter (2009) of the UK Health and Safety Executive, Hazardous Installations Directorate. They introduce a new concept of total risk of death as measure to assist decisions on land-use planning. The concept supports more direct comparison with other risks such as everyday work and transport risks. It illustrates the problem that regulating authorities have to evaluate and authorise major hazard installations.

Campbell (2013) formulated three criteria to compare the regulatory management frameworks of South Africa, the USA and the European Union:

- Identification of major hazard installations
- Control over major hazard installations
- Control of land development in the vicinity of major hazard installations

A comparison of the Major Hazard Installation Regulations for EU countries and South Africa, using the three criteria above, is given in Table 5.2.

Table 5.2 Comparison of Major Hazard Installation Regulations for EU countries and South Africa (Criteria from Campbell 2013)

Criterion 1: How are major hazard installations identified?	
EU countries	**South Africa**
• Legislation applies to establishments and installations where a dangerous substance is present in quantities above a certain specified threshold. • The nuclear industry is excluded from the legislation. • EU countries have a clear approach to assisting industry in identifying whether or not the relevant legislation applies to a particular establishment or installation.	• Definition of a major hazard installation is ambiguous. • Risk assessment is prescribed as decision-making instrument. However, the assessment outcome leaves room for varying interpretations. • Classification of major hazard installations is unclear, non-specific and interpreted differently by industry roleplayers and authorities. • There is no differentiation between various categories of hazardous installations. • Legislation can create barriers to trade due to cost impact. • The nuclear industry is excluded from the legislation and is covered under separate legislation.

Table 5.2 Comparison of Major Hazard Installation Regulations for EU countries and South Africa (Criteria from Campbell 2013) *(continued)*

<table>
<tr><th colspan="2">Criterion 2: How are major hazard installations controlled?</th></tr>
<tr><th>EU countries</th><th>South Africa</th></tr>
<tr><td>

- The quantity of dangerous substances dictates the control measures.
- Establishments and installations fall into two groups: lower-tier sites and top-tier sites.
- *Lower tier establishments*: Notify the regulator; prepare a major accident prevention policy; take measures to prevent major accidents; report accidents.
- *Top tier establishments*: As above, but with the additional requirement to submit a safety report.
- The regulatory approach is balanced, where low-hazard facilities are not burdened with disproportionate cost and administration; high-hazard facilities are regulated in proportion to their scale of risk.
- Legislation is reviewed often, such as the Löfstedt review in the UK in 2011.

</td><td>

- Notify the authorities, perform a risk assessment and develop an on-site emergency response plan.
- The requirements beyond risk assessment are limited to emergency response planning, incident reporting and risk assessment revision.
- The same emergency management measures are required across all industries, for all types of hazardous installation categories, which is onerous for small operators.

</td></tr>
<tr><th colspan="2">Criterion 3: How are developments in the vicinity of major hazard installations controlled?</th></tr>
<tr><th>EU countries</th><th>South Africa</th></tr>
<tr><td>

- Member states are responsible for implementing policies and procedures for land-use control of new establishments, modification of existing establishments and new developments around Seveso II high-risk establishments
- The requirements are met differently across different member states.
- The Seveso II land-use planning directives vary across Europe.
- The process is controlled by planning authorities who are advised by technical specialists such as the Health and Safety Executive in the UK. This gives a greater degree of assurance that major hazards are taken into consideration for land-use planning.
- Environmental impacts are not explicitly addressed.

</td><td>

- Local authorities have the responsibility to control developments around existing major hazard installations.
- The major hazard installation regulatory process is in some cases detached from the land-use planning process and therefore not adequately considered in development planning.
- The regulations are ambiguous and therefore poorly enforced.
- Environmental impacts as defined in environmental legislation are not addressed in the regulations.

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</table>

The Convention for the Protection of Human Rights and Fundamental Freedoms issued by the European Court of Human Rights (2010) states as follows in Article 2, Right to Life:

"1. Everyone's right to life shall be protected by law. No one shall be deprived of his life intentionally save in the execution of a sentence of a court following his conviction of a crime for which this penalty is provided by law.

2. Deprivation of life shall not be regarded as inflicted in contravention of this Article when it results from the use of force which is no more than absolutely necessary:

(a) in defence of any person from unlawful violence;

(b) in order to effect a lawful arrest or to prevent the escape of a person lawfully detained;

(c) in action lawfully taken for the purpose of quelling a riot or insurrection".

The Convention has important implications for the regulatory management of major hazard installations, not only in Europe, but also in other countries around the world including South Africa (Constitution, Act 108 of 1996) for the following reasons:

- Human life is protected by law. Governments are therefore under an obligation to protect the lives of the people within their borders. It can be argued that any technological installation that has the potential to cause fatalities, has to be governed by appropriate legislation (law) that is aimed to ensure that such installation is designed, built, operated and managed in such a manner that the lives of employees at the installation and members of the public around the installation are protected.

- Intentional deprivation of life is a very important condition contained in the Convention. If a country fails to implement appropriate regulatory measures for the safe operation of major hazard installations within its borders, it can be construed as intentional deprivation of life if an incident of catastrophic proportions occurs at that installation. Thus there is a serious obligation on any country where major hazard installations are present, to have the appropriate regulatory measures in place.

- Likewise, the owner or operator of a major hazard installation in a particular country has an obligation to obey all laws aimed at the protection of human life in that country, through the appropriate design, construction, operation and management of such an installation.

- The Convention does not stipulate requirements specifically for major hazard installations, because clearly it was written to apply to human life in societal context. From a major hazard installation regulatory perspective the Convention can be regarded as the “Constitution” from which their own regulatory measures need to be developed by governments.

5.5.3 United States of America (USA)

The United States Environmental Protection Agency (EPA) plays a crucial role in the setting and enforcement of safety standards in the USA. In its historic overview the USA Environmental Protection Agency (2013) reports that President Nixon decided in July 1970 to establish an autonomous regulatory body to oversee the enforcement of environmental policy. In a message to the House and Senate, he declared his intention to establish the US Environmental Protection Agency and declared that its mission would centre on:

- The establishment and enforcement of environmental protection standards consistent with national environmental goals

- The conduct of research on the adverse effects of pollution and on methods and equipment for controlling it

- The gathering of information on pollution and the use of this information in strengthening environmental protection programs and recommending policy changes

- Assisting others through grants, technical assistance and other means, to arrest pollution of the environment

- Assisting the Council on Environmental Quality in recommending to the President new policies for the protection of the environment

Campbell (2013) reported that the EPA analysed the chemical incidents between 1980 and 1990 and compared them with the Bhopal disaster in India in December 1984. The result was the amendment of the US Clean Air Act of 1990 to make provision for specific mandates to enable the US Occupational Safety and Health Administration (OSHA) and the US EPA to establish regulations for the protection of employees in the workplace, the public at large and the environment in general. OSHA fulfilled its mandate by promulgating the Process Safety Management Regulation in 1992, while EPA promulgated the Risk Management Programme Regulation in 1996. The Process Safety Management Regulation focused on on-site health and safety management, while the Risk Management Programme Regulation focused on off-site health and safety hazard management. Table 5.3 gives a comparison of the Major Hazard Installation Regulations in the USA and South Africa.

Table 5.3 Comparison of Major Hazard Installation Regulations for the USA and South Africa (Critical success factors from Campbell 2013)

Criterion 1: How are major hazard installations identified?	
USA	**South Africa**
• Process safety management and risk management planning are used as decision-making instruments. • Legislation is based on threshold quantities of dangerous substances and applies to processes or installations. • The USA has a clear approach to assisting industry in identifying whether or not the relevant legislation applies to them. • Nuclear risks are also administered by the EPA.	• Definition of a major hazard installation is ambiguous. • Risk assessment is prescribed as decision-making instrument. However, the assessment methodology leaves room for varying interpretations. • Classification of major hazard installations is unclear, non-specific and interpreted differently by industry roleplayers and authorities. • There is no differentiation between various categories of hazardous installations. • Legislation can create barriers to trade due to cost impact. • The nuclear industry is excluded from the legislation and is covered under separate legislation.

Table 5.3 Comparison of Major Hazard Installation Regulations for the USA and South Africa (Critical success factors from Campbell 2013) *(continued)*

Criterion 2: How are major hazard installations controlled?	
USA	**South Africa**
• A 14-step process safety management system is required for all hazard facilities. • Incorporates process hazard analysis.	• Notify the authorities, perform a risk assessment and develop an on-site emergency response plan. • The requirements beyond risk assessment are limited to emergency response planning, incident reporting and risk assessment revision. • The same emergency management measures are required across all industries, for all types of hazardous installation categories, which is onerous for small operators.
Criterion 3: How are developments in the vicinity of major hazard installations controlled?	
USA	**South Africa**
• The Environmental Protection Agency (EPA) requires a risk management plan. It is passed on to local and state regulators. • The focus is on response rather than the proactive management of development around these installations. • Regulations are weak in this regard. The focus is on prevention and recovery at site rather than separation through planning control.	• Local authorities have the responsibility to control developments around existing major hazard installations. • The major hazard installation regulatory process is in some cases detached from the land-use planning process and therefore not adequately considered in development planning. • The regulations are ambiguous and therefore poorly enforced. • Environmental impacts as defined in environmental legislation is not addressed in the regulations.

5.5.4 France

France provides a clear focus on land-use planning as an important consideration for the regulation of major hazard installations. Salvi and Gaston (2004) describe the hazardous establishment context in France as a very complex decision process based on several criteria which are difficult to evaluate. The only explicit criteria in France are those related to the consequences of accidents that are used to define the safety distances around hazardous establishments. In their code related to the control of hazardous establishments (Code de l’environnement, Livre V, Art L512, 1976) the licence to operate such a facility is subordinated to a sufficient distance between the establishment and people in the vicinity. In other words, the regulatory bodies cannot theoretically license new establishments that can potentially harm people in case of a major accident, although the requirement is easier to apply for new installations than existing ones. This idea appeared first in an imperial act in 1810, then in a new law published in 1917 on hazardous and insanitary plants, but it was clearly reinforced with the law no 76-633 in 1976 that became the *"Environment Code"* in France in 2000.

It must be noted that this legislation is considered to be environment-focused in its broadest sense rather than labour-force focused. It includes the general public and is administered by the French Ministry of the Environment.

5.5.5 Malaysia

Malaysia provides a good perspective with regard to the foundation on which its regulatory framework is based. Shaluf et al. (2003) investigated the causes of technological (major hazard installation) disasters in Malaysia, in a fireworks factory, a petrochemical plant, a refinery and another mutual major hazard installation. They concluded that there were seven main causes of the disasters, namely:

- Social errors related to operators and managers at the installations
- Technical errors such as design shortcomings and equipment failures
- Organisational errors related to wrong procedures and documentation. The authors particularly focused on the link between the social and technical side of the installations through policies, regulations, rules, manuals, training and emergency plans
- Operational errors caused by the human and technical interface
- Warning systems used to alert management of the facility that dangerous operational conditions are starting to arise
- Triggering events after which disaster is unavoidable, such as unsafe acts and conditions
- Defence errors such as lack of emergency response measures

5.6 Chapter conclusions

This chapter provided an overview and comparison of the regulatory frameworks pertaining to major hazard installations in EU countries, the USA, France, Malaysia and South Africa. The following main conclusions were drawn:

5.6.1 The life of all citizens must be protected by law. Major hazard installations have the potential to kill people. The word “intentionally” has an important meaning in this regard. One can argue that a disaster such as Bhopal, Buncefield or Somerset West (Chapter 3) was not intentionally caused, but, on the other hand, if the disaster had been caused by human negligence, poor operational procedures and inadequate equipment maintenance, a case can be made out that there was at least an element of intentionality. It is possible that such incidents can then be construed as a violation of the Convention of the European Court of Human Rights (2010).

5.6.2 European legislation is evidence-based and was derived primarily as a consequence of the Seveso disaster in Italy. The UK played a major role in the development of the legislation and the resultant risk assessment protocols.

5.6.3 The EPA in the USA considered several chemical incidents worldwide, including the Bhopal disaster in India, to gather a sound information base for the development of its legislation. The approach of the EPA was therefore also evidence-based.

5.6.4 A threshold quantity of hazardous materials is specified as trigger for an on-site risk assessment, in the case of EU and USA legislation. It does not exist for South Africa, which creates some ambiguity in the interpretation of the legislation.

5.6.5 France places great emphasis on the broad environmental impacts of hazardous installations. Legislation falls under the Ministry of the Environment.

5.6.6 Land-use planning around major hazard installations is a constant dilemma in all countries, especially with regard to new community developments near existing installations and new major hazard installations near existing communities. The EU has made substantial progress with guidelines to govern this controversy, with its Planning Advice for Developments near Hazardous Installations (PADHI) Guidelines (HSE 2011). In South Africa such guidelines are not legally prescribed or enforceable and the onus rests on the relevant local authority to use its discretion with regard to new developments. This is an onerous and unreasonable responsibility, because local authorities have to balance the health and safety risks of the hazardous installation with the need for housing and infrastructure development and resultant economic growth in its geographic region of jurisdiction.

5.6.7 The complexity of uniform legislation in EU countries remains a burden. While the Seveso Directive is used as agreed health and safety legislation, some countries still feel the need for autonomous governance, e.g. France.

5.6.8 The overarching legislation in the EU is prescribed by the European Court of Human Rights, which determines that everyone’s right to life shall be protected by law and no one shall be deprived of his/her life intentionally. It can be argued that a major hazard installation has the potential to kill people intentionally if it is not designed, operated and maintained against the highest health and safety standards and norms to yield risks that are as low as reasonably practicable.

5.6.9 While there are marked similarities between EU Countries and the USA, albeit with some apparent shortcomings with regard to land-use planning, current legislation in South Africa needs revision in order to bring it on par with those of developed countries.

5.6.10 In particular, South African legislation has the potential for improvement in the following aspects:

- The definition of a major hazard installation is ambiguous, with the result that the classification of major hazard installations is unclear, non-specific and interpreted differently by industry roleplayers, risk assessors and authorities.
- Risk assessment is prescribed as a decision-making instrument, but the assessment methodology leaves room for varying interpretations due to the lack of a uniform assessment standard.
- There is no differentiation between various categories of hazardous installations.
- The same emergency management measures are required across all industries, for all types of hazardous installation categories, which is onerous for small operators.

- Local authorities have the sole responsibility to control developments around existing major hazard installations, but there are no clear regulatory guidelines or measures that can be legally enforced to prevent the establishment of vulnerable developments near existing major hazard installations.

- Apart from risk assessment, the requirements for major hazard installation planning are limited to on-site emergency response planning, incident reporting and risk assessment revision, leading to the major hazard installation regulatory process to be detached from the land-use planning process and therefore not adequately considered in development planning.

- Vulnerability studies do not form part of major hazard installation planning at all and aspects such as community vulnerability, coping capacity and resilience related to the specific installation are not considered.

- There is a gap between the Major Hazard Installation Regulations and the Disaster Management Act.

- Environmental impacts as defined in environmental legislation overlaps with the Major Hazard Installation Regulations and create conflict between the relevant state departments with regard to enforcing mandates.
- In his review Löfstedt (2011) made a general conclusion that is appropriate to South Africa, namely that health and safety regulatory requirements are misunderstood and applied inappropriately or inconsistently. The recommendations that flowed from the review addressed streamlining of the body of regulation through consolidation, redirecting enforcement activities towards workplaces where the highest risk of injury or ill health exists and rebalancing the civil justice system through the clarification of early settlement protocols and a review of strict liability imposed on employers.

5.6.11 South Africa is faced with the following options:

- Use the latest regulations and guidelines from developed countries, such as the UK, to create a regulatory framework for the management of hazardous installations in industry in order to protect, firstly, the health and safety of members of the public and, secondly, employees in the industry.

- Integrate existing legislation that involves major hazard installations and disasters.
- Ensure that an economic regime is created and maintained in local industry that is conducive to fixed investment, profitability and employment creation.

Chapter 6

Research methodology

6.1 Introduction

This chapter describes the methodology that was used in this study to elicit and interpret data and obtain information for the research. The methodology included a variety of techniques:

- Quantitative information gathering at 373 major hazard installations
- Participative action research in the form of participation in working groups in the field of risk evaluation committees, risk standard formulation and the licensing of liquid petroleum fuel depots
- Personal qualitative discussions with various members of regulating authorities and industrial enterprises
- Attendance of four annual seminars organised by the South African National Accreditation System (SANAS)
- Attendance of three seminars organised by the South African Department of Labour
- Feedback received from presentations at three conferences, one local and two international
- A structured workshop held with members of regulating authorities, academics and major hazard installation operators
- Feedback received from one publication in a local journal
- Attendance of a block course in the field of disaster management
- Structured personal discussion with international experts in the field of health and safety regulation and business continuity
- Literature study

The research limitations are also outlined in this chapter in order to define the scope and exclusions of the study. The challenges encountered during the research are also explained. Research challenges refer to obstacles that were met in the course of data collection and information gathering and analysis that could hamper the study or make the findings unreliable or invalid. The solutions to these challenges are also pointed out.

6.2 Quantitative information gathering

During the period 2011 to 2015 quantitative health and safety risk assessments were conducted by the researcher under contract at 373 hazardous facilities in South Africa and Lesotho, as prescribed under the MHI Regulations of 2001. The owners or operators of these 373 hazardous facilities were selected as sample cluster for the gathering of quantitative information for this research. The respondents comprise enterprises in 26 industry sectors as summarised in Table 6.1.

Table 6.1 Summary of respondents for the gathering of quantitative data per industry

Industry	Number of respondents (%)	Size of organisation*		
		Small	Medium	Large
1. Steel	8 (2.1)	0	2	6
2. Petroleum refineries	1 (0.3)	0	0	1
3. Natural gas pipelines	4 (1.0)	0	2	2
4. Petrochemical plants	3 (0.8)	0	0	3
5. Liquefied petroleum gas storage and cylinder filling	168 (45.0)	168	0	0
6. Explosives	1 (0.3)	1	0	0
7. Automotive body works	3 (0.8)	0	3	0
8. Food and beverages	9 (2.4)	0	7	2
9. Petroleum recycling facilities	2 (0.6)	2	0	0
10. Public entertainment facilities	19 (5.1)	0	14	5
11. Compressed natural gas transport by sea and use in onshore power stations	1 (0.3)	1	0	0
12. Breweries	21 (5.6)	0	21	0
13. Water treatment plants	27 (7.2)	27	0	0
14. Airport fuel storage depots	5 (1.3)	5	0	0

Table 6.1 Summary of respondents for the gathering of quantitative data per industry *(continued)*

Industry	Number of respondents (%)	Size of organisation*		
		Small	Medium	Large
15. Synthetic fibres	4 (1.1)	1	3	0
16. Grain milling facilities	23 (6.5)	4	19	0
17. Bakeries	18 (4.8)	3	15	0
18. Crematoriums	5 (1.3)	5	0	0
19. Mining operations	6 (1.6)	2	4	0
20. Hospitals	6 (1.6)	6	0	0
21. Natural gas vehicle service stations	4 (1.1)	4	0	0
22. Chicken farms	21 (5.6)	21	0	0
23. Bitumen and tar plants	2 (0.6)	2	0	0
24. Installation of liquefied petroleum gas as energy source at shopping malls	2 (0.6)	2	0	0
25. Pharmaceuticals	4 (1.1)	4	0	0
26. Residential complexes that utilise liquefied petroleum gas as energy source	6 (1.6)	6	0	0
Total	**373 (100.0)**	**264 (70.8)**	**90 (24.1)**	**19 (5.1)**

* Size of organisation is defined by the number of employees:
Small: 50 or fewer employees
Medium: Between 51 and 1 000 employees
Large: 1 001 employees or more

The total number of major hazard installations in South Africa on 30 March 2016 was reported by the Department of Labour to be 574. The respondent sample in this study therefore comprises 65% of the total major hazard installation population in the country.

In performing the quantitative risk assessments there was personal interaction with the management of the installations as well as health and safety officials appointed at middle to lower levels in the different organisations. This methodology gave the researcher insight into the way major hazard installations are operated in South Africa, from a regulatory perspective but also from an owner/operator perspective.

Prior to discussions with respondents, a list of key health and safety critical success factors was compiled. Mengolini and Debarberis (2008) argue that a limitation of resources makes it difficult for operators of hazardous installations to compare themselves against a set of health and safety key performance areas, or critical success factors, in accordance with the approaches developed by member countries in the Organisation for Economic Cooperation and Development (OECD). Rüter and Vikström (2009*)* built on the concept by identifying key processes by means of key performance areas for medical practitioners who are responsible for coordination and command at disaster incidents. They consider the concept of medical critical success factors as vital to the successful management of a disaster. The concept is relevant to and important for this study – where the health and safety of people are concerned, clear critical success factors should be identified in a pre-disaster scenario.

Ford Runge and Gonzalez-Valero (2011) developed key performance areas for sustainable agricultural development. They believe that any such performance area should be able to balance judgement with procedure. They also emphasise the importance of simplicity in the development of critical success factors – a case of less is more.

A surgeon at the Harvard Medical School, A. Gawande (2010), set out the concept of simplicity that was later expanded by Ford Runge and Gonzalez-Valero (2011). He maintains that the official standards for safe surgical care, compiled by the WHO, which were well researched and written, overwhelm medical employees with too many complex, inflated requirements and protocols, with the result that they have little effect. Gawande (2010) recommends the use of simple checklists in lieu of bulky standards. The checklist of key performance areas, equally applicable to the concept of critical success factors, should comply with three minimum criteria:

- Simplicity.
- Measurability.
- Communicability.

As far as suitable legislation for the regulatory management of health and safety at hazardous facilities is concerned, a set of 21 critical success factors was identified through a study of the literature, quantitative discussions with industry roleplayers, international experts and representatives of competent authorities in South Africa. The purpose of the indicators is to provide a checklist (Gawande 2010) of essential elements for the formulation of regulatory management measures as protection mechanism for the health and safety of people where hazardous facilities are concerned. In other words, the health and safety critical success factors are a reflection of the comprehensiveness and thus the ability of the legislation that is being formulated to protect the health and safety of people against technological disasters. The indicators are therefore an indication of the performance of the legislation per se, not the person or organisation that must abide by it. It is important to note that each critical success factor is not a goal in itself, but a demarcation of an area where detail actions must be developed by the owners or operators of hazardous facilities. The important point is that future legislation must address the issues described by the critical success factors. The critical success factors are shown in Table 6.2.

Table 6.2 Critical success factors for the regulatory management of health and safety at hazardous facilities in South Africa

No	Health and safety critical success factor for legislation
1	Health and safety risk assessment with emergency response plan
2	Protection of the health and safety of employees and communities
3	Frequent communication with employees and communities
4	People vulnerability
5	Employee and community coping capacity
6	Employee and community resilience
7	Sustainable development and living
8	Leadership in legislation formulation
9	Non-overlapping, non-repetitive and optimised health and safety legislation
10	Health and safety impacts on employees and communities
11	Relationship with community neighbours
12	Clear understanding of the MHI Regulations
13	Clear understanding of the overarching OHS Act
14	Clear differentiation between the roles of the Department of Labour and the Department of Environmental Affairs
15	Clear understanding and acceptance of the MHI classification criteria
16	Clear understanding of the role of the local emergency services
17	Competence of the local emergency services
18	Historical record of major incidents or near misses at the hazardous facility premises
19	Historical record of major incidents or near misses at all hazardous facilities in South Africa
20	Commitment to the implementation of risk mitigation measures
21	Proper land-use planning near hazardous installations

With the above critical success factors in mind, a set of questions was developed for discussion with respondents. The questions are listed in Annexure 1.
The 21 critical success factors listed above can be condensed into nine strategic areas with regard to disaster science:

- Communities and employees as external and internal receptor groups respectively in case of a disaster.
- Vulnerability, coping capacity and resilience of communities and employees alike.
- Emergency response planning, including mitigatory preparedness.
- Role of the local emergency services, keeping in mind that they may be exposed to interlinked, overlapping and duplicated legislation.
- Sustainable development of businesses that own or operate hazardous facilities as well as local receptor communities.
- Leadership in legislation formulation against the background of the use of HSE legislation in South Africa.
- Knowledge and understanding of the regulatory dispensation, including interlinked and duplicating legislation.
- Land-use planning as a first step in disaster prevention, for new hazardous facilities near existing communities, or for new habitable developments around existing hazardous facilities.
- Recordkeeping with regard to past major incidents.

The following question arises: Is there a relation between the critical success factors identified in Table 6.2 and the three hypotheses formulated in Chapter 1? The answer is yes, there is indeed a relation. Throughout the research it was essential to keep the following research design sequence in mind, including the formulated hypotheses:

- Problem statement.
- Research questions.
- Hypotheses.
- Study objectives.

Six of the critical success factors that were identified during the research have a direct relation with the three hypotheses that cover vulnerability, overlapping legislation and land-use planning, as shown in Table 6.3 below.

Table 6.3 Relation between critical success factors and hypotheses

Critical success factor		Hypothesis relation
The owner or operator of the hazardous installation is familiar with and understands the term "community or people health and safety vulnerability".	→	**Hypothesis 1** Existing South African legislation for the management of hazardous installations does not address the health and safety vulnerability, coping capacity and resilience of communities near or around such installations with regard to fires, explosions and the release of toxic gases.
The owner or operator of the hazardous installation is familiar with and understands the term "community coping capacity" with regard to a disaster.	→	
The owner or operator of the hazardous installation is familiar with and understands the term "community health and safety resilience" with regard to a disaster.	→	
The legislation relevant to hazardous installation operations is overlapping. There are some definite common elements, but it is contained in different Acts that are administered by different state departments, each with its own political agendas and motivational forces. This is confusing and inefficient legislation.	→	**Hypothesis 2** Health and safety legislation in South Africa is fragmented and scattered among various independent state departments, which results in inefficient enforcing of the legislation for the management of hazardous installations.
The owner or operator of the hazardous installation finds it difficult to differentiate between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning his/her hazardous installation.	→	
The owner or operator of the hazardous installation has a knowledge and understanding of the need for proper land-use planning near hazardous installations.	→	**Hypothesis 3** The effective planning of land-use is a critical component of the overall management of hazardous installations, but does not receive the required attention under existing South African legislation.

6.3 Action research

Action research is one of several different forms of action investigation, which is a generic term for a repetitive process in which one improves practice by systematically oscillating between taking actions in the field of practice and enquiring into it (Tripp 2005).

The process follows a cycle that comprises the following steps in an attempt to enhance a particular way of doing things by constantly changing the practice or work function:

- Planning.
- Implementation (taking action).
- Monitoring (description).
- Evaluation.

The action research process is characterised by repetitive active information gathering (inquiry) and interpretation, which eventually yields continuous learning about the particular practice.

Action research is distinguished from other kinds of action inquiry, by defining it as a series of recognised research techniques to initiate changes to the way of doing things and to monitor the effect that these changes have on the practice in the action inquiry cycle. Tripp (2005) is of the opinion that the term “action inquiry” as a superior process has become preferable to “action research”. Action inquiry should therefore be seen as incorporating action research, to prevent the latter term from becoming so widely and loosely applied that it becomes meaningless.

Action research is considered by Tripp (2005) as difficult to define, firstly because it is such a natural process, which is sometimes difficult to be recognised as a formal research process; and secondly because it has evolved differently over the years for different applications.

The most workable definition of action research is given by Brown and Dowling (2001) as “a term which is applied to projects in which practitioners seek to effect transformations in their own practices”. This definition can be enhanced by including reference to continuous improvement. It is proposed that the definition of action research should read as follows: “Action research is a process whereby the practitioner seeks to transform his/her practices through continuous analysis and improvement." This definition makes it clear that action research is not academically aimed at solving a particular research problem, but rather describes a conventional work improvement process while gathering useful information and experience to make a constructive contribution to the field.

Adelman (1993) points out that Kurt Lewin is often referred to as the originator of action research, from work that the latter did with his students in 1930. Their work was classified into four types of action research.

- Type 1: Diagnostic action research. This research is designed to produce a required action plan. The researcher intervenes in an already existing work process to identify and analyse the problem and recommend solutions, corrective actions or mitigation measures. There is, however, one distinct proviso: the recommendations must be feasible, effective and acceptable to all affected people.
- Type 2: Participant action research. In this type of research it is assumed that other people must be involved in the research process from the beginning. These participants have to support the identification of the research or practice problem and accept the need for the final proposed solution. In that way, they can create buy-in to support the corrective action plan. A typical example of this type of research is the formation of dedicated work groups with upfront role clarification to achieve a clearly defined goal.
- Type 3: Empirical action research. Empirical action research entails the process of record keeping and accumulation of collective experience in day-to-day work. It is a continuous process where one work group is succeeded by another. One shortcoming of this procedure is that conclusions are drawn from the experience of a single group over a particular time period. Other successive groups may come to different conclusions, not necessarily wrong, but possibly completely in contrast with previous work. One reason for this dissonance is the variations caused by different members in the group, with different personality traits, goal orientation, cultural background and intelligence. However, empirical action research has proved useful in many applications such as clinical medicine.
- Type 4: Experimental action research. Of all the varieties of action research, the experimental type has the best potential for the advancement of scientific knowledge. This technique calls for a well-defined study under closely controlled

conditions where variables are identified upfront and manipulated in a controlled and recorded manner. This form of action research allows the relative effectiveness of various techniques or work processes to be compared. Under favourable conditions it can be used to test specific hypotheses. It is considered to be the most difficult form of action research to carry out.

In this study, participant action research was applied as follows:

- The major hazard installation work group meetings of three local authorities were attended at 14 meetings: eThekwini Municipality, Ekurhuleni Metropolitan Municipality and City of Tshwane. The mandate of these work groups was to evaluate the quantitative risk assessments for new major hazard installations against the requirements of the MHI Regulations (2001). A total of 11 meetings was attended. During the work group sessions consideration was given to contemporary issues such as the impact of major incidents on communities surrounding the major hazard installations, land-use planning near the installation, measures to mitigate the health and safety risks of the installation and ways in which local authorities can improve their regulatory responsibilities.

- Five meetings were attended as a member of a work group that compiled a new national standard for quantitative risk assessments on major hazard installations. The mandate of the work group was to consider international best practice in the formulation of a new, uniform set of standards, regulated by the South African Bureau of Standards. This work had become necessary in order to ensure that quantitative risk assessments on major hazard installations were standardised against international norms so that different accredited risk assessors could achieve similar assessment results on the same or a similar installation.

- A collaborative project with NERSA is in progress for the formulation of technical licence requirements for petroleum storage facilities. The proposed requirements take into consideration the recommendations of the Buncefield Major Incident Investigation Board (BMIIB 2008) for the prevention of storage tank overfilling.

6.4 Personal interviews with local roleplayers

Gubrium and Holstein (2001) argue that qualitative interviewing is based on conversation with the researcher asking questions and listening, and respondents answering. Respondents should be appreciated as opinion-makers and not mere conveyors of information. The purpose of qualitative interviewing is to tap into the experience of the respondent, elicit opinions and obtain interpretations. The aim is not to uncover facts or laws. The process can be considered as a conventional conversation. It is important to note that the perspectives of the respondent may shift from one standpoint to another, based on personal experience and preferences, and have to be analysed carefully by the researcher. With regard to interviews with employees at a major hazard installation, two perspectives were to be expected: that of the respondent's role as employee and that of the respondent as an individual and ordinary member of society. Although the qualitative interview can be approached from a dualistic conversation between the researcher and the respondent, it requires careful planning with regard to interview content, formulation and structuring of questions and interpretation of the respondent's answers, which may oscillate between their role as employee and as individualistic human being. The latter role may be in conflict with the employee role.

The recommendations by Crawford (1997) were followed in the preparation of structured interviews with respondents for research purposes:

- Decide on the information required. The information need should be guided by the research problem and should be focused on the overall objective of the research, in this case the development of an optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa. Although international perspectives on the research objective are extremely important, local contextualization remains of paramount importance.
- Define the target respondents. The respondents were carefully selected to represent authorities in the field of regulatory management of health and safety risks and disaster reduction. Both local and international respondents were selected.
- Choose the method(s) of reaching your target respondents. Personal interviews and group discussions are considered by Crawford (1997) to be of greater value, because they are much more extensively used than other forms of communication methods. He states a general rule, namely that the more sensitive or personal the information, the more personal the form of data collection should be. In this

research the problem was not so much the sensitivity of the information as its complexity. Hence specific attention was given to personal explanation of the subject matter to respondents.

- Decide on the question that must be discussed with respondents. The criterion was always: Is this question really needed? Every question was evaluated in terms of its contribution to the achievement of the research objectives as they are specified in the research proposal. Questions were formulated in such a way that they would be of direct use in testing the hypotheses established during the research design.

- Develop the question wording. The cultural differences of the respondents, their limited exposure to the management of major hazard installations in some cases and their knowledge of health and safety risks were taken into consideration in the formulation of questions. The personal interview technique made it easy to formulate questions, because the respondent could be guided throughout the interview process to facilitate clarification and understanding of the subject matter.

- Put questions into a meaningful order and format. In order to ensure that respondents remained focused on the research problem questions were arranged to follow a natural sequence. This could be easily achieved in the verbal interviewing process. It was necessary to change the order of the questions from one respondent to the next.

- Check the length of the question list. Although no questionnaire was used in the research, it remained important to keep the interview to a limited timeframe. Respondents were busy with their daily work and a balance had to be maintained between the length of the interview and the quality of the information gathered. A list of 21 questions was developed that covered the information requirements of the research problems and objectives.

- Pre-test the question list. Questionnaires were not used, but the list of aspects was tested during the first number of interviews. It could easily be adjusted in terms of comprehension, question length and the attention span of the respondent.

- Develop the final survey form.

A set of questions was developed as listed in Annexure 1. These questions were designed to cover the objectives of the study, to test the three hypotheses and to provide information that would contribute to the formulation of a new regulatory model. Personal interviews, on a qualitative basis, were conducted with prominent roleplayers in the field of major hazard installation regulation. The following respondent organisations were included:

- The South African National Accreditation System (SANAS), which is responsible for the accreditation of approved inspection authorities for the execution of quantitative health and safety risk assessments on major hazard installations. Respondents include four system auditors and four technical auditors.
- Approved inspection authorities (risk assessors) for major hazard installation risk assessments. Eight respondents were selected for interviews according to their experience in the South African industry.
- The emergency services departments of local authorities. Eleven senior officials in these departments, who are members of their major hazard installation task teams, were interviewed.
- National and provincial officials from the Department of Labour. Ten respondents were involved.
- Three officials from the Disaster Management Departments at local and provincial level.
- Two insurance companies that are involved in risk cover for major hazard installations. Three respondents were interviewed.
- Departments of Environmental Affairs at national and provincial level. Five respondents were interviewed, based on their involvement in the evaluation of MHI risk assessments for new investment projects as part of a mandatory environmental impact assessment process.

6.5 Personal discussions with international experts

Qualitative discussions were held with persons who are considered internationally as authorities in the field of health and safety regulation. The following institutions were involved:

- The Institute of Business Continuity Management in London, UK. One respondent was interviewed.
- The Health and Safety Executive, London. One respondent was interviewed.

The main points of the structured discussion with the two respondents above are contained in Annexure 2.

6.6 Attendance of annual seminars organised by SANAS

SANAS is the accreditation body in South Africa, on behalf of the Department of Labour, with the responsibility to ensure that health and safety risk assessors (or approved inspection authorities) comply with the requirements of the ISO-17020 (2012) standard. SANAS annually facilitates seminars with all approved inspection authorities to discuss the latest trends in the industry, locally and internationally. Four such seminars were attended.

6.7 Attendance of three annual seminars organised by the Department of Labour

The responsibility for the administration of the South African Occupational Health and Safety Act (Act 85 of 1993) and the Major Hazard Installation Regulations (2001) rests with the Department of Labour. Approved inspection authorities for major hazard installation risk assessments perform their duties under supervision of the Department, which also facilitates annual seminars with all approved inspection authorities and SANAS to discuss matters that affect the industry. Three such seminars were attended.

6.8 Feedback received from three conference presentations

The preliminary results of the research were presented at three conferences in 2014, as follows:

- The Disaster Management Institute of South Africa, Durban.
- The Southern Africa Society for Disaster Reduction, Windhoek.
- The International Society for Integrated Disaster Risk Management, Canada.

Feedback was obtained from audiences at these conferences, which guided this study.

6.9 Facilitation of a structured workshop with members of regulating authorities, academics and operators of major hazard installations

NOAA (2010) states that a common misconception is that good workshop results will occur simply by getting all the experts together in the same room. However, assembling the right group of people is only the first step. A facilitator has to be appointed to structure, guide and support the discussion process by keeping the group on track towards the intended objectives. NOAA (2010) lists the following functions of a workshop facilitator:

- Helps the group to define the purpose of the workshop and list the required objectives to be achieved.
- Designs discussion and problem-solving processes for the group to meet its objectives.
- Guides group discussions to keep participants focused on the workshop objectives and to stay on track. This can be done by asking key questions and continuously reminding the group of its stated goal.
- Ensures that group assumptions are stated and tested and that all participants get ample opportunity to participate in discussions. No member of the team may feel side-lined or ignored. Every contribution to the workshop objectives counts.
- Maintains a neutral role and has no vested interest in the conclusions of the workshop.
- Records key points of the discussions and consensus decisions taken by the group.
- Helps the group to plan for the implementation of the consensus workshop decisions.

Steinert and Ouellet (2016) argue that the needs of adults as members of a workshop group must be considered, because they have peculiar characteristic behaviour that must to be taken into consideration to make a success of the workshop, including the following:

- Adults have a variety of motivations for attending the workshop.
- They come to the workshop learning situations with clearly defined expectations about particular workshop learning outcomes.

- They present their individual ideas with different learning styles.
- Much of adult learning is relearning rather than new learning.
- Adult learning involves changes in attitudes as well as skills and knowledge.
- Most adults prefer to learn and participate through experience.
- Incentives for adult learning usually come from within the individual.

Lakey (2010) maintains that learners in a workshop environment pursue their own agendas, no matter what the facilitator does. This aspect is in agreement with what Steinert and Ouellet (2016) report.

A structured workshop was facilitated with members of industry, operators of major hazard installations, academics in the field of disaster risk reduction and management and competent authorities at national, provincial and local government level. A record of the workshop discussion and resolutions are contained in Annexure 3.

6.10 Feedback from publication in a local journal

Preliminary results of this research were published in *Jamba Journal of Disaster Risk Studies*, AOSIS Publications. Valuable criticism and recommendations on the article were obtained from local and international experts at two independent universities.

6.11 Course in disaster management

A block course on vulnerability and disaster risk reduction was attended in Port Elizabeth in 2014. The course was presented by leading academics in the field of disaster research and management from the University of the Free State and the United Nations University. The course material covered the following subjects:

- Introduction to disaster management, disaster risk reduction, terminology and complexity of definitions.
- Basic principles, theoretical basis and conceptual frameworks of vulnerability, indicators and indices.
- Disasters and trends.
- Vulnerability concepts and models.

- Selecting a vulnerability assessment framework; discussion of pros and cons of selected frameworks.
- Building an understanding about vulnerability in regard to particular hazard.
- Environmental vulnerability and ecosystem services.
- Building an understanding about vulnerability in regard to particular hazard.
- Vulnerability models: SUST model.
- Vulnerability models: MOVE conceptual framework.
- Discussion of several case studies.
- Introduction to economic vulnerability and risk assessment indicators.
- Visit to the Nelson Mandela Metro Municipality Provincial Disaster Management Centre.
- Visit to the Provincial Disaster Management Centre at the South African Weather Services in Nelson Mandela Bay.
- Research methodologies for disaster management risk assessments, indices and resilience building.
- Introduction to geospatial technologies.
- Space-based solutions and international mechanisms in support of disaster risk management.
- Geospatial technologies in support of disaster risk management and prevention: examples throughout the disaster management cycle.
- Examples from the Coastal Systems Research Group Natural Resources and the Environment, South Africa.
- Introduction to GPS devices.
- Field excursion.

6.12 Literature study

A literature study was undertaken based on the following:

- Information obtained during structured discussions with operators of major hazard installations in South Africa.

- Feedback received from academics on a publication by the author in *Jamba Journal of Disaster Risk Studies.*
- The outcome of a structured workshop with operators of major hazard installations, industry decision-makers and academics in the field of disaster risk reduction.
- Advice from various experts from over the world in the field of disaster risk reduction, obtained during presentation feedback and interaction at three conferences in 2014:
    - The Disaster Management Institute of South Africa, Durban.
    - The Southern Africa Society for Disaster Reduction, Windhoek.
    - The International Society for Integrated Disaster Risk Management, Canada.

In the literature survey, the following theories and models were identified as relevant to this study:

- Systems theory (Cilliers 1998; Mullins 2005; Weirich 2008; Chikere and Nwoka 2015; Skoko 2013; Chun et al. 2008; Coetzee and Van Niekerk 2012).
- Regulation and control theory (Majone 1994; Gunningham 2014 Hood et al. 001; Levi-Faur 2010; Stiglitz 2012).
- Sustainability theory (Barry 1997; Sen 1999; Jenkins 2009; Pei-Ing et al. 2014).
- Vulnerability theory (Turner II A et al. 2003; Hugo et al. 2000; Birkmann 2005; Renaud 2006; Wisner 2002; Scmidt-Thorné; EC 2011; Komaljot 2014).
- Disaster theory (Wisner et al. 2004; Sabharwal 2014; Birkmann 2006; Awal 2015).
- Theory on natural-technological (Natech) disasters (Arelklano et al. 2003; Steinberg and Cruz 2004; Greiving 2006; EEA 2010; Krausmann et al. 2011).
- Business continuity theory (Smith 2012a; Maroney 2010; Brainard 2008).
- Theory of critical success factors (Gates 2010; Parmenter 2016; Alexandrova & Ivanova 2013; Wronka 2013).

6.13 Research limitations

The research was limited in certain areas of investigation. These areas are listed as follows:

6.13.1 Limitation on disaster type

The research focuses on technological disasters caused by hazardous facilities that can have a negative impact on the health and safety of people. Natural disasters are excluded from the study, except for their role as a trigger of technological disasters to create Natech disasters.

6.13.2 Limitation on hazards and risks

The study focuses on health and safety hazards and risks to people, both employees at hazardous facilities and communities near or around such facilities. The field of study falls within occupational and public health and safety, specifically with regard to human-induced risks associated with major hazard installations that could lead to accidents of catastrophic proportions. The term “risk” in this study refers to health and safety risks while others such as financial, security, political or economic risks are excluded.

The study focuses on the health and safety requirements of human populations and is therefore aimed at the social requirements of people. It does not consider the ecological needs of flora and fauna species, although reference is made in the study to broad-based environmental legislation.

6.13.3 Limitation on model outcome

The aim of the study is to develop a model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa. It is not attempted to design a new technical risk assessment model for human-induced safety hazards associated with such facilities. The study does not focus on risk assessment protocols or methodologies, but on the regulation of health and safety risks.

6.13.4 Geographic limitation

The study focuses solely on South African legislation regarding major hazard installations (MHI Regulations 2001) and the development of a new regulatory management model for the country. However, it is quite possible that the outcome of the study could be applied to other developed and undeveloped countries around the world. The reason for this preliminary conclusion is that technological disasters are the same in all countries and mitigation measures to protect society are quite similar.

6.14 Research challenges

Eleven research challenges were encountered in this study. They are listed below together with the actions taken to overcome them.

6.14.1 Knowledge of the MHI Regulations

Some owners and operators of major hazard installations have limited or even no knowledge about the MHI Regulations. They are consequently unaware of their responsibilities with regard to the protection of the health and safety of communities near or adjacent to their installation, although they know that they have to protect their employees against injury or illness. These respondents have a better knowledge of the OHS Act than the MHI Regulations, although the latter forms part of the Act. The reason for this anomaly was not investigated, but one possible reason may be that the owners and operators of major hazard installation facilities deal with the OHS Act on a daily basis through independent audits under the OHS 18001 international health and safety compliance system (ISO 2007), interaction with health and safety committees and the handling of day-to-day small injuries in the workplace.

Many South African companies currently trade in global markets and are therefore subject to international trading standards. One such standard is the OHS 18001 standard on occupational health and safety, which is set as a prerequisite for market entry especially by European countries.

In general, it was difficult to elicit information from some respondents in this study for the above reason.

How this challenge was overcome

Respondents that showed an obvious lack of knowledge of the MHI Regulations, were tutored on the requirements of the regulations and their responsibilities under them.

6.14.2 Knowledge of disaster legislation

Some owners and operators of major hazard installations and competent authorities at local, provincial and national level have limited or even no knowledge of disaster legislation in South Africa. They generally felt that the Disaster Management Act (2002) is not applicable to them and they failed to see the interaction between the MHI Regulations and the Act. For example, the Department of Labour considered the Act as the sole responsibility of the Department of Cooperative Governance and Traditional Affairs (COGTA). The amendment of the Act (2002) to Act 16 (2015) contributed to the misunderstanding and confusion.

How this challenge was overcome

Respondents were first tutored as far as possible so that they could interpret questions about the Disaster Management Act correctly and with the required insight.

6.14.3 Role of local authorities

Some local authorities have limited knowledge of the MHI Regulations. They see it as their responsibility to focus on the Fire Brigade Services Act (Act 99 of 1987) and the relevant local municipal bylaws for the execution of their duties. The MHI Regulations are regarded by most local authorities as the responsibility of the Department of Labour.

How this challenge was overcome

It was pointed out to local authorities that Section 9 of the MHI Regulations requires local authorities to exercise specific duties with regard to the locality of major hazard installations near certain facilities such as other, adjacent major hazard installations or airports. The duty of the local authority specifically refers here to land-use development, an aspect that is not well defined in the MHI Regulations.

6.14.4 Information disclosure

Owners or operators of major hazard installations were generally hesitant to disclose information about previous incidents at their sites, because they were scared that it could prejudice their legal position under the MHI Regulations. Many of these respondents failed to notify the Department of Labour of the existence of the major hazard installation on their premises, about near misses at the installation or about modifications that they made to existing major hazard installations. These constitute criminal offences.

How this challenge was overcome

It was explained to such respondents that complete confidentially and non-disclosure of respondents' identities are prerequisites for major hazard installation risk assessments and that no information would be disclosed to any third party that could disadvantage the legal position of the respondent.

6.14.5 Link between natural and technological disasters

Technological disasters caused by major hazard installations in South Africa are not linked to natural disasters and are not covered under local legislation. The concept is also unknown to most respondents who own or operate major hazard installations, as well as the competent authorities at all three government levels. One possible reason for this is that South Africa is not prone to natural disasters such as earthquakes, floods, hurricanes or volcanic activity in regions where major hazard installations are located.

How this challenge was overcome

It was necessary to obtain guidance from literature studies and discussions with experts on Natech disasters.

6.14.6 Vulnerability concepts

Terms such as community vulnerability, coping capacity, resilience and business continuity are unknown to most respondents from industry and competent authorities. Owners and operators of major hazard installations are only concerned about what is written in the legislation and leave it to the competent authorities to address these terms.

How this challenge was overcome

Guidance was obtained from literature studies and discussions with experts on vulnerability and business continuity.

6.14.7 Author's knowledge of vulnerability theory and related concepts

The author had to expand his knowledge of the theories on disaster risk reduction, vulnerability and coping capacity, as well as resilience and disaster recovery measures.

How this challenge was overcome

The researcher attended a block course on vulnerability and disaster risk reduction in 2014 in Port Elizabeth, presented by the University of the Free State and the United Nations University.

6.14.8 Overlapping legislation

Local respondents were confused about the overlapping of legislation that aims at the protection of the health and safety of people. Although the various pieces of legislation, administered by different authorities, have the same objective – each within its own sphere of operations – there was a definite lack of responsibility acceptance for administration of the legislation. At an operational level, it has serious consequences in the sense that owners and operators of major hazard installations are not encouraged to see the bigger picture of community vulnerability. As a result, the MHI Regulations are not seen in the serious light that they deserve. The implication for this study was that many owners and operators of major hazard installations, especially at mines and airports, did not grasp the importance of the MHI Regulations.

How this challenge was overcome

A structured workshop was organised and facilitated with the theme "A critical evaluation of commonalities and exclusions between the MHI Regulations and the Disaster Management Act in South Africa".

6.14.9 Availability of disaster statistics

There are no formal, verified statistics available in South Africa on the number and nature of historical technological disasters. Unlike in Europe and the USA, such statistics are simply not available locally. It had an influence on this research for two reasons: Firstly, the extent of technological hazards in South Africa could not be assessed properly. Secondly, information for a South African case study is limited.

How this challenge was overcome

Technological disasters in Europe, India and Japan were used to describe the potential severity of similar incidents in South Africa. As far as a South African case study is concerned, information was obtained from an article published by Batterman et al. (1998) in Michigan, USA, on a sulphur fire at Somerset West, South Africa, in 1995.

6.14.10 Revision of MHI Regulations

The South African Department of Labour is currently steering a process for the revision of the Major Hazard Installation Regulations of 2001. Very little is known about the potential outcome of the process, which started in 2011, and it would therefore be inappropriate and actually misleading to consider the possible outcome of the legal amendment process. The challenge for this study was to make a decision on whether the research must be delayed until the new regulations were promulgated, or whether it had to continue.

How this challenge was overcome

It was decided not to wait for the new MHI regulations, but to continue with the research. The outcome of the regulatory model has to be independent from any changes in existing legislation.

6.14.11 Availability of major hazard installation statistics

Accurate statistics of the number of registered major hazard installations in South Africa could not be obtained from the Department of Labour.

How this challenge was overcome

The researcher made a best estimate of the number of registered major hazard installations in South Africa.

6.14.12 Ethical considerations

The researcher was well aware that interview respondents could feel hesitant to disclose information to the researcher, because such disclosure could implicate compromise their employers and their careers. On the other hand, respondents were aware that information disclosure was mandatory. The qualitative interviews conducted in this research were done within the following framework:

- Interviews formed part of the mandatory MHI risk assessments performed at existing clients in accordance with the MHI Regulations (2001) under the OHS Act (Act 85 of 1993).
- The researcher performed the risk assessments and conducted the interviews as risk assessor that is accredited by SANAS in terms of the International Standard ISO/IEC-17020 (2012) and registered by the Department of Labour as an AIA.

The above framework demands confidentiality of all mandatory information disclosed by respondents to the researcher, which was explained as such to all respondents. It was further explained to respondents that some of the disclosed information would be used for broad-based research purposes and that no reference would be made to any person, company, institution or department in the processing and disclosure of the information. None of the respondents objected to information disclosure.

6.15 Chapter conclusions

In this section the conclusions that were reached on the research methodology are presented.

6.15.1 Limitations of the study

The study has the following limitations:

- Disaster type.
- Hazards and risks.
- The expectation of what the model must achieve.
- Geographic limitation.

6.15.2 Research challenges

Eleven challenges were encountered in the course of the study and actions were taken by the author to overcome them. The challenges relate to the following aspects:

- Limited knowledge in the industry about the South African MHI regulations (2001).
- Limited knowledge in the industry about the South African disaster legislation. Local authorities have limited knowledge of the South African MHI Regulations.
- Reluctance of industry role players to disclose information about previous safety incidents at their sites.
- Legislation does not exist with regard to Natech disasters.
- Limited knowledge in the industry about community vulnerability, resilience, coping capacity and business continuity planning.
- The researcher had limited knowledge of disaster reduction and community vulnerability.
- Confusion caused by the overlapping of legislation for the protection of the health and safety of people.
- Absence of local statistics on the number and nature of historical technological disasters.
- Limited knowledge about the current revision of the MHI Regulations (2001).

6.15.3 Research techniques

Ten techniques were applied in the research methodology, as shown schematically in Figure 6.1.

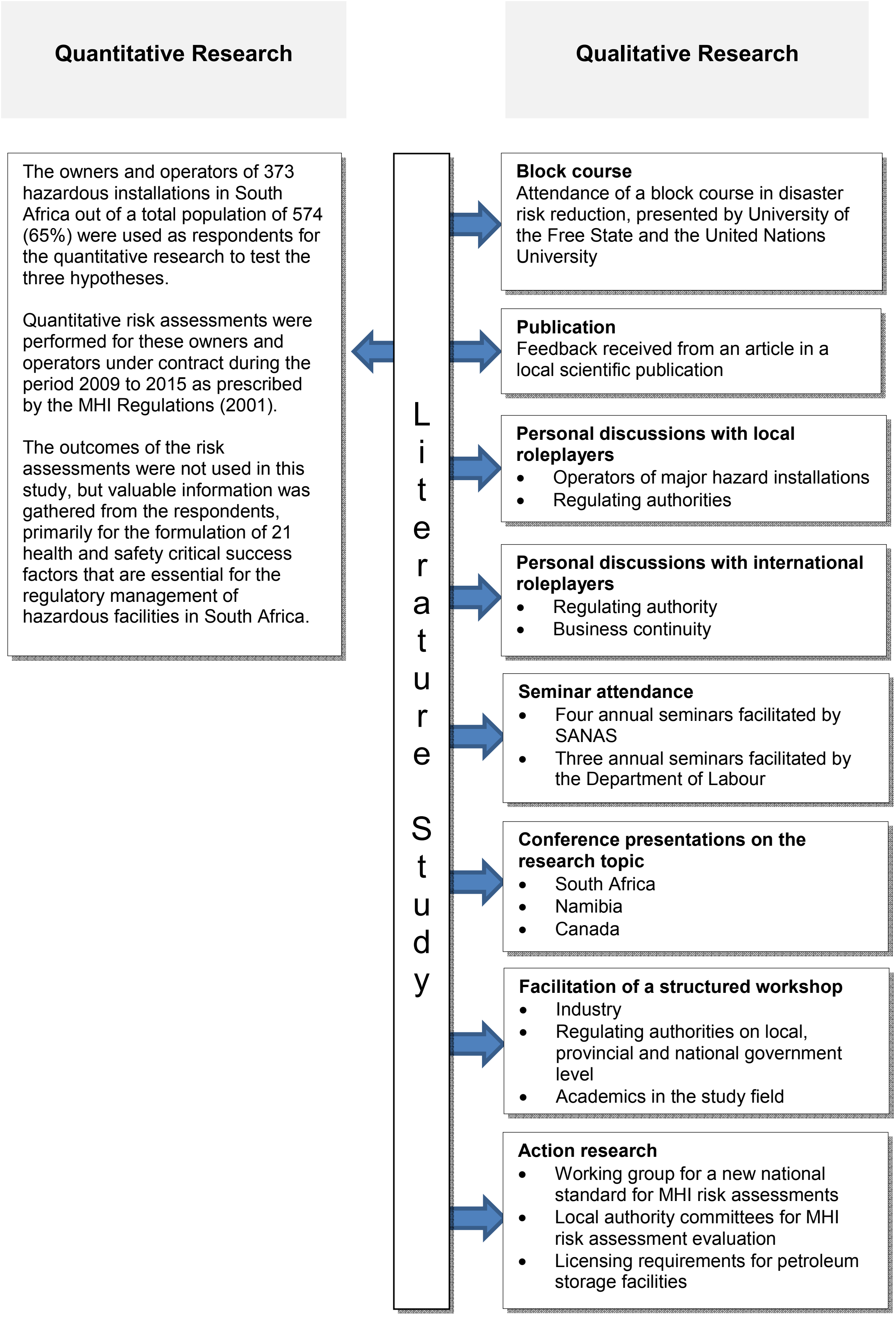

Figure 6.1 Schematic representation of the research methodology (Source: Author)

Chapter 7

Research results and findings

7.1 Introduction

This chapter presents the results of the data collection and research that were performed on a sample of industry respondents. The owners or operators of 373 major hazard installations, where quantitative health and safety risk assessments were conducted by the researcher under contract from 2011 to 2015, were selected as sample cluster for the gathering of quantitative information for this research. The respondents comprise enterprises in 26 industry sectors (refer to Table 6.1 above). These enterprises comprise 65% of the total number of major hazard installations in South Africa, as confirmed by the Department of Labour.

The selection of the 373 enterprises (65% of the industry total) was based on quantitative health and safety risk assessments that the researcher conducted under contract at the major hazard installations on these sites under the MHI Regulations (2001).

7.2 Identification and formulation of critical success factors

The starting point of the research was to identify the critical success factors that would be required to enable the effective formulation of legislation to manage hazardous installations in South Africa. The critical success factors crystallized from the following research steps:

7.2.1 Literature research

The literature was studied on the following eight theories:

- Systems theory.
- Regulation and control theory.
- Sustainability theory.
- Vulnerability theory.

- Disaster theory.
- Theory on natural-technological disasters.
- Business continuity theory.
- Critical success factor theory.

7.2.2 Qualitative interviews

Discussions were held with the following respondent groups:

- Local competent authorities. Refer to Annexure 1 for a list of the questions put to respondents.
- Local owners and operators of hazardous facilities. Refer to Annexure 1 for a list of the questions put to respondents.
- Local and international industry experts. Refer to Annexure 2 for a record of the discussions.

7.2.3 Facilitation of a structured workshop

A structured workshop was facilitated with participants from government on national, provincial and local level, industry owners and operators of major hazard installations, disaster managers and academic experts. The record of the workshop is contained in Annexure 3.

7.2.4 Critical success factors

The research yielded the following 21 critical success factors:

- Emergency response.
- Community protection during emergencies.
- Communication with affected communities.
- Vulnerability of people.
- Coping capacity of people.
- Resilience of people.
- Sustainable development.
- Legislation origin.
- Rationalised legislation.

- Community impact.
- Knowledge of affected communities.
- Implications of legislation.
- Knowledge of relevant legislation.
- Role clarification among competent authorities.
- Facility classification criteria.
- Role of emergency services.
- Competence of emergency services.
- Data disclosure.
- Statistical database.
- Disaster mitigation measures.
- Land-use planning.

7.3 Quantitative results from industry

The results of the quantitative research are contained in Table 7.1. A more detailed quantitative analysis of the research data in terms of small, medium and large hazardous facility enterprises is presented in Annexure 4.

Table 7.1 Summary of the quantitative research results from 373 responding hazardous installation owners/operators

No	Critical success factor	Yes	No	Don't know	Total	% Yes
1.	There is an on-site health and safety emergency response plan at the hazardous installation site.	252	121	0	373	67.6
2.	If there is an on-site emergency response plan, it specifically describes how the health and safety of communities around the hazardous installation will be protected.	13	243	0	252	3.6
3.	The owner or operator of the hazardous installation makes a deliberate effort to liaise frequently with neighbouring communities with regard to the health and safety risks imposed upon them as a result of the existence of the installation.	32	341	0	373	8.6

Table 7.1 Summary of the quantitative research results from 373 responding hazardous installation owners/operators *(continued)*

No	Critical success factor	Yes	No	Don't know	Total	% Yes
4.	The owner or operator of the hazardous installation is familiar with and understands the term *"community or people health and safety vulnerability"*. ***Linked to Hypothesis 1***	3	359	11	373	0.8
5.	The owner or operator of the hazardous installation is familiar with and understands the term *"community coping capacity"* with regard to a disaster. ***Linked to Hypothesis 1***	2	358	13	373	0.5
6.	The owner or operator of the hazardous installation is familiar with and understands the term *"community health and safety resilience"* with regard to a disaster. ***Linked to Hypothesis 1***	11	341	21	373	2.9
7.	The owner or operator of the hazardous installation is familiar with and understands the term *"sustainable development and living".*	14	357	2	373	3.8
8.	The existing major hazard installation legislation is not South Africa specific, but based on foreign legislation and guidelines. South Africa is therefore considered to be a follower, not a leader.	356	0	17	373	95.4
9.	The legislation relevant to hazardous installation operations is overlapping. There are some definite common elements, but legislation is contained in different Acts that are administered by different state departments, each with its own political agendas and motivational forces. This is confusing and inefficient legislation. ***Linked to Hypothesis 2***	366	7	0	373	98.1
10.	The owner or operator of the hazardous installation fully understands the health and safety impacts that their hazardous installation could have on neighbouring communities.	18	355	0	373	4.8

Table 7.1 Summary of the quantitative research results from 373 responding hazardous installation owners/operators *(continued)*

No	Critical success factor	Yes	No	Don't know	Total	% Yes
11.	The owner or operator of the hazardous installation knows exactly who their business and community neighbours are.	67	306	0	373	18.0
12.	The owner or operator of the hazardous installation knows exactly what the implications are of being classified as a major hazard installation under the MHI Regulations.	17	350	6	373	4.6
13.	The owner or operator of the hazardous installation knows clearly how the MHI Regulations fit into the overall OHS Act.	298	75	0	373	79.9
14.	The owner or operator of the hazardous installation finds it difficult to differentiate between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning their hazardous installation. ***Linked to Hypothesis 2.***	319	54	0	373	85.5
15.	The owner or operator of the hazardous installation understands and accepts the criteria used to classify an installation as a major hazard installation under the MHI regulations.	14	325	4	373	3.8
16.	The owner or operator of the hazardous installation knows exactly what the role is of the local emergency services in the prevention of and response to a major incident.	128	245	0	373	37.3
17.	The owner or operator of the hazardous installation believes that local emergency services are generally incompetent and has little knowledge of the MHI Regulations.	362	5	9	373	97.1

Table 7.1 Summary of the quantitative research results from 373 responding hazardous installation owners/operators *(continued)*

No	Critical success factor	Yes	No	Don't know	Total	% Yes
18.	The owner or operator of the hazardous installation is willing to disclose historical major incidents or near misses that occurred on the premises.	12	361	0	373	3.2
19.	The owner or operator of the hazardous installation can provide historical statistics of major incidents that occurred in South Africa.	21	352	0	373	5.6
20.	The owner or operator of the hazardous installation is committed to implementing the recommended risk mitigation measures as identified in the risk assessment study, in line with the ALARP principle.	370	3	0	373	99.2
21.	The owner or operator of the hazardous installation has a knowledge and understanding of the need for proper land-use planning near hazardous installations. ***Linked to Hypothesis 3.***	7	365	1	373	1.9

7.4 Analysis and discussion of the research results

In this section the quantitative research results are presented and analysed in more detail, particularly to identify explanations for responses. Throughout the discussion of the critical success factors, respondents made valuable contributions to the enhancement of health and safety and the implications, interpretation and effectiveness of legislation in this regard. One has to bear in mind, however, that responses were given against the prevailing socio-political and economic climate in South Africa, which was not perceived as positive by many respondents.

The results are discussed and supplemented with qualitative information obtained from respondents during discussions.

7.4.1 Critical success factor 1

There is an on-site health and safety emergency response plan at the hazardous installation site.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	179	62	11	252
Yes, %	68 *Note 1*	69 *Note 1*	58 *Note 1*	67.6 *Note 2*

Notes to the quantitative results:

1 The percentage is expressed for the respondent group (small, medium or large enterprises) and not for the total sample. For example n=179 respondents from small enterprises answered YES from a total small enterprise respondent group of 264 (see Annexure 4) which is 68%.

2 The percentage is expressed for the total sample, N=373. For example 252 respondents from all enterprise groups answered YES, which is 67.6%.

Discussion of the results

The development and implementation of an on-site emergency response plan is a priority at only 67.6% of the hazardous installations investigated. There is an alarming misconception that emergency response actions are solely the responsibility of the local authority emergency services. On the other hand, discussions with local authority officials confirmed their understanding and acceptance that the management of an emergency at a major hazard installation is first and foremost the responsibility of the owner or operator as first responder. The vital importance of first-responding emergency actions on site was explained to the owners or operators of the hazardous installation, but where follow-up surveys were done after a few months, the problem still persisted. There was a general lack of concern for or understanding of the impacts that the hazardous facility could have on neighbouring communities.

In addition to the absence of the on-site emergency response plans, plans were completely outdated and of little value. In such cases it was decided that no plan was available on site. For example, the names and designations of operating employees changed and the particulars of new incumbents were not listed in the plan. In some cases building expansions had taken place on the site, which necessitated a relocation of the emergency assembly point, but the matter was not attended to.

The availability of an updated on-site emergency response plan at major hazard facilities is the focus of inspections by the Department of Labour, but the installations can obviously not be inspected every day. It is a requirement of the MHI Regulations (2001) that all sites where a major hazard facility exists must have an on-site emergency response plan that must be evaluated as part of the risk assessment by an accredited risk assessor. It was found that emergency response plans were available at large enterprises, but outdated and therefore of little or no use. This was despite the fact that large enterprises have dedicated health and safety officers and that their operations are subjected to annual external audits under the ISO-18000 international health and safety standards (ISO 2007).

Small enterprises were in the majority to answer affirmative (179 respondents). The quality of their emergency response plans could be questionable, but they showed a high level of conformance in this regard. The reason was found to be that these respondents (who comprised mostly entrepreneurs) did not want to run the risk of not complying with the law. Their business, which they started from the ground, are too valuable to them.

Of the 11 affirmative respondents in large enterprises:

- 7 had implemented the OHS-18000 international health and safety standard.
- 9 export their products to global markets.
- 8 are listed on a stock exchange.
- 8 reported to have good quality health and safety officers.
- 6 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 62 affirmative respondents in medium enterprises:

- 34 had implemented the OHS-18000 standard.
- 48 export their products to global markets.
- 41 reported to have good quality health and safety officers.

- 38 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.
- All 62 attributed their conformance to this critical success factor to dedicated health and safety officers who are properly trained for their tasks.

Of the 179 affirmative respondents in small enterprises:

- 146 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.

Companies listed on the South African JSE or on a foreign stock exchange (8 of the 11 respondents) are accountable to a large shareholder base and do business on a global scale. Where updated plans were available on site at medium and large enterprises, it was the result of diligent health and safety officers who were properly trained for their job.

Of the 8 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 28 non-affirmative respondents in medium enterprises:

- 23 reported low employee morale.
- 16 considered the health and safety legislation as a financial and administrative burden.

Of the 85 non-affirmative respondents in small enterprises:

- 81 considered the health and safety legislation as a financial and administrative burden.
- 85 had a stronger focus on profit-making than on health and safety protection.

7.4.2 Critical success factor 2
If there is an on-site ER plan, it specifically describes how the health and safety of communities around the hazardous installation will be protected.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	9	3	1	13
Yes, %	3	3	5	3.6

Discussion of the results

There was a marginal difference in response from small, medium and large enterprises. Emergency response plans focus primarily on the protection of employees and not so much on the protection of the public against a major incident at the installation. Most of the respondents (96.4%) did not consider the surrounding community as a priority target group that should be protected against a major incident at the hazardous installation. Community protection is considered by large enterprises to be the task of the local emergency services. The protection of communities was more of a priority at small and medium enterprises, due to a fear that disturbed communities may cause the business to be closed down.

This finding is endorsed by the findings for critical success factors 4, 5 and 6 where it was noted that community vulnerability, coping capacity and resilience were not considered important enough.

Of the 18 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 87 non-affirmative respondents in medium enterprises:

- 54 reported low employee morale.
- 65 considered the health and safety legislation as a financial and administrative burden.

Of the 255 non-affirmative respondents in small enterprises:

- 244 considered the health and safety legislation as a financial and administrative burden.
- 239 had a stronger focus on profit-making than on health and safety protection.

7.4.3 Critical success factor 3

The owner or operator of the hazardous installation makes a deliberate effort to liaise frequently with neighbouring communities with regard to the health and safety risks imposed upon them as a result of the existence of the installation.

<u>Quantitative results</u>

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	23	7	2	32
Yes, %	9	8	11	8.6

<u>Discussion of the results</u>

This aspect is not considered important by 91.4% of the owners or operators of hazardous installations and it does not receive continuous attention, especially in the case of informal settlements. In general, regular communication with neighbouring businesses is not done effectively, the contact details were outdated and there was not a specific person tasked with the responsibility of community communication. Effective and continuous communication with neighbouring communities depends largely on the diligence of the employee member responsible for health, safety, the environment and risk at the hazardous installation. Where the respondent company has a dedicated public affairs function, communication with receptor communities with regard to their health and safety was considered to be the responsibility of the plant manager. As was found for critical success factor 2, small enterprises were more inclined to maintain close relations with neighbouring communities out of fear that upset communities may disrupt or close down the business operations.

Of the 7 affirmative respondents in medium enterprises:

- 2 had implemented the OHS-18000 standard.
- 4 export their products to global markets.
- 7 reported to have good quality health and safety officers.

- 2 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.
- 4 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.

Of the 17 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 83 non-affirmative respondents in medium enterprises:

- 33 reported low employee morale.
- 12 considered the health and safety legislation as a financial and administrative burden.

Of the 241 non-affirmative respondents in small enterprises:

- 221 considered the health and safety legislation as a financial and administrative burden.
- 98 had a stronger focus on profit-making than on health and safety protection.

7.4.4 Critical success factor 4

The owner or operator of the hazardous installation is familiar with and understands the term *"community or people vulnerability".*

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	1	1	1	3
Yes, %	0.4	1	5	0.8

Discussion of the results

It is alarming to note that such a high proportion (99.2%) of the respondents do not have a basic understanding of the term, which has become common in disaster terminology for many years. There is a broad understanding of the impacts that the hazardous installation can have on people, but driving factors that influence community vulnerability are not considered, such as poverty, accessibility for emergency responders, population density, average age, level of education and health condition. The main reason for this finding was that it is not contained in the MHI Regulations (2001) or the OHS Act (1993).

During a discussion with a senior representative of the HSE in the UK, it was confirmed that the vulnerability of communities around hazardous installations is not taken into consideration in the UK and the rest of EU countries, a point that is most significant for this study.

Of the 18 non-affirmative respondents in large enterprises:

- 6 were government institutions.

Of the 89 non-affirmative respondents in medium enterprises:

- 78 reported low employee morale.
- 71 considered the health and safety legislation as a financial and administrative burden.

Of the 263 non-affirmative respondents in small enterprises:

- 257 considered the health and safety legislation as a financial and administrative burden.
- 260 had a stronger focus on profit-making than on health and safety protection.

7.4.5 Critical success factor 5

The owner or operator of the hazardous installation is familiar with and understands the term *"community coping capacity"* with regard to a disaster.

<u>Quantitative results</u>

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	1	0	1	2
Yes, %	0.4	0	5	0.5

Discussion of the results

Again, 99.5% of respondents do not understand the term. Similar to vulnerability, the capacity of neighbouring communities to cope with a disaster caused by the hazardous installation is unclear, unknown and receives no attention in on-site emergency response plans.

The one affirmative respondent among large enterprises has heard of the term from his international controlling company based in Europe, where disaster management is probably more common than in South Africa, due to the prevalence of natural events such as earthquakes, high winds, tsunamis and flash floods.

There was an insignificant difference in response from small, medium and large enterprises.

Of the 18 non-affirmative respondents in large enterprises:

- 5 were government institutions.

Of the 90 non-affirmative respondents in medium enterprises:

- 76 reported low employee morale.
- 88 considered the health and safety legislation as a financial and administrative burden.

Of the 263 non-affirmative respondents in small enterprises:

- 206 considered the health and safety legislation as a financial and administrative burden.
- 239 had a stronger focus on profit-making than on health and safety protection.

7.4.6 Critical success factor 6

The owner or operator of the hazardous installation is familiar with and understands the term *"community resilience"* with regard to a disaster.

<u>Quantitative results</u>

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	8	3	0	11
Yes, %	3	3	0	2.9

<u>Discussion of the results</u>

Community disaster resilience goes hand in hand with vulnerability and coping capacity and is not well understood either. Not one of the on-site emergency response plans that were examined made reference to this aspect.

Small enterprises appeared to be more concerned about the potential impacts of their major hazard installations on communities, because the latter has collective power to disrupt or even close down the business. These small enterprises comprised operations for the storage of liquefied petroleum gas, the filling of liquefied petroleum gas cylinders and the purification of waste oil and solvents.

Of the 8 affirmative respondents in small enterprises:

- 8 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 3 reported to have a good quality health and safety officer.

Of the 19 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 87 non-affirmative respondents in medium enterprises:

- 76 reported low employee morale.
- 59 considered the health and safety legislation as a financial and administrative burden.

Of the 256 non-affirmative respondents in small enterprises:

- 226 considered the health and safety legislation as a financial and administrative burden.
- 239 had a stronger focus on profit-making than on health and safety protection.

7.4.7 Critical success factor 7

The owner or operator of the hazardous installation is familiar with and understands the term *“sustainable development and living”.*

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	10	3	1	14
Yes, %	4	3	5	3.8

Discussion of the results

Small enterprises showed a higher level of understanding and appreciation of the term sustainability, because the owners or operators comprised entrepreneurs who developed their businesses from the ground, who are sensitive to long-term profit making and who are the major provider of income for their families. Of the 10 respondents who answered in the affirmative, six were family businesses.

The term is included in most of the respondents’ environmental policies *(“protect the environment for the sake of our children”)*, but it is generally considered to be an environmental issue to prevent pollution of the air, soil and water. As far as the health and safety impacts – especially instantaneous disasters – of the hazardous installation on existing and future communities are concerned, there is not a clear understanding of their relation with sustainable development.

Land-use planning is of particular importance here. It is of the utmost importance that the owners or operators of hazardous installations stay in touch with the local authority with regard to new community developments around their premises, to plan in advance for sustainable settlement. A serious concern, of course, is the rapid and almost uncontrollable spreading of informal settlements, complicated by political agendas.
Of the 18 non-affirmative respondents in large enterprises:

- 4 were government institutions.

Of the 87 non-affirmative respondents in medium enterprises:

- 18 reported low employee morale.
- 77 considered the health and safety legislation as a financial and administrative burden.

Of the 254 non-affirmative respondents in small enterprises:

- 247 considered the health and safety legislation as a financial and administrative burden.
- 248 had a stronger focus on profit-making than on health and safety protection.

7.4.8 Critical success factor 8

The existing major hazard installation legislation is not South Africa specific, but based on foreign legislation and guidelines. South Africa is therefore considered to be a follower, not a leader.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	252	86	18	356
Yes, %	96	96	95	95.4

Discussion of the results

Respondents from small enterprises were the majority to answer in the affirmative (252 respondents). It was found that they were more sensitive to government performance than was the case with medium and large enterprises.

The South African MHI Regulations (2001) are largely based on the UK COMAH Regulations, which flowed from the Seveso II Directive of the EU. South Africa is still not at the point where own legislation is developed locally, taking into consideration the distinctive circumstances that prevail in the country, such as disadvantaged communities, poverty, community vulnerability, level of education and lack of infrastructure. This need was also pointed out during a workshop with government officials, industry leaders and academics.

The main reason for the high affirmative response rate is the political situation in South Africa. Respondents believed that the existing government does not have sufficient competence to be able to drive new legislation. This observation is critically important, since effective legislation formulation and implementation is a direct function of the abilities of government officials.

Of the 18 affirmative respondents in large enterprises:

- 15 had implemented the OHS-18000 international health and safety standard.
- 16 export their products to global markets.
- 6 are listed on a stock exchange.
- All 18 reported to have good quality health and safety officers.
- 16 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 86 affirmative respondents in medium enterprises:

- 29 had implemented the OHS-18000 standard.
- 31 export their products to global markets.
- 63 reported to have good quality health and safety officers.
- 77 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 4 non-affirmative respondents in medium enterprises:

- 0 reported low employee morale.
- 1 considered the health and safety legislation as a financial and administrative burden.

Of the 12 non-affirmative respondents in small enterprises:

- 11 considered the health and safety legislation as a financial and administrative burden.

- 9 had a stronger focus on profit-making than on health and safety protection.

7.4.9 Critical success factor 9

The legislation relevant to hazardous installation operations is overlapping. There are some definite common elements, but legislation is contained in different Acts that are administered by different state departments, each with its own political agendas and motivational forces.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	259	89	18	366
Yes, %	98	99	95	98.1

Discussion of the results

The majority of respondents (98.1%) agreed on this aspect. It was also raised as a concern during a workshop with government officials, industry leaders and academics. Similar to what Löfstedt (2011) found in the UK, there is a need to consolidate and streamline health and safety legislation in South Africa. There may still be different state departments that govern the legislation in their respective spheres of jurisdiction, but the core essentials of the legislation should not be as different as they are now. It was specifically reported that environmental legislation (EIA Regulations 2014) and health and safety legislation (MHI Regulations 2001) do not correspond, especially with regard to administration by the competent authorities: environment legislation is administered by the national department and the various provincial departments of environmental affairs, while health and safety legislation is administered by the national and various provincial divisions of the Department of Labour.

The main reason for the finding that legislation is duplicated, overlapping and confusing as presented by respondents, is the perception that the current government creates legislation in order to employ more officials.
Small enterprises were in the majority to answer in the affirmative (259 respondents). These respondents comprises entrepreneurs who regarded health and safety legislation as an onerous burden on small businesses.

Of the 18 affirmative respondents in large enterprises:

- 18 had implemented the OHS-18000 international health and safety standard.
- 4 export their products to global markets.
- 4 are listed on a stock exchange.
- All 18 reported to have good quality health and safety officers.
- 12 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 89 affirmative respondents in medium enterprises:

- 19 had implemented the OHS-18000 standard.
- 24 export their products to global markets.
- 77 reported to have good quality health and safety officers.
- 86 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 5 non-affirmative respondents in small enterprises:

- 4 considered the health and safety legislation as a financial and administrative burden.
- 1 had a stronger focus on profit-making than on health and safety protection.

7.4.10 Critical success factor 10

The owner or operator of the hazardous installation fully understands the health and safety impacts that their hazardous installation could have on neighbouring communities.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	13	4	1	18
Yes, %	5	4	5	4.8

Discussion of the results

Respondents were either ignorant about this aspect or did not consider it important enough in the operation of their hazardous installation. Their focus is mainly on the health and safety of employees. This aspect correlates well with responses obtained for critical success factors 2 to 7. Community protection is considered to be the responsibility of the local emergency services.

Small enterprises were in the majority to answer in the affirmative (13 respondents, entrepreneurs). The reason was found to lie in a fear that affected communities may close down business operations if their health and safety is not respected and protected.

Of the 13 affirmative respondents in small enterprises:

- 13 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 1 reported to have a good quality health and safety officer.

Of the 18 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 86 non-affirmative respondents in medium enterprises:

- 34 reported low employee morale.
- 19 considered the health and safety legislation as a financial and administrative burden.

Of the 251 non-affirmative respondents in small enterprises:

- 235 considered the health and safety legislation as a financial and administrative burden.
- 222 had a stronger focus on profit-making than on health and safety protection.

7.4.11 Critical success factor 11

The owner or operator of the hazardous installation knows exactly who their business and community neighbours are.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	48	17	2	67
Yes, %	18	19	11	18.0

Discussion of the results

A high proportion of respondents (82%) are unclear on this aspect. There is a general belief that each business must make provision for its own health and safety protection measures, primarily focused on own employees, with the assistance of the local emergency services. Communities around the installation are neglected. The rapid, seemingly uncontrolled, development of informal, poor settlements near the installation was given as one reason for their approach.

Small and medium enterprises know their neighbours better than large enterprises. Two reasons were given for this finding:

- Small and medium enterprises usually rent their factory space where their hazardous facility is based, from a common landlord and the enterprises are organised, formally and informally, in ratepayers associations where they get to know their neighbouring businesses quite well.
- Small and medium enterprises do not have access to support services on the same level as large corporates, such as legal, maintenance, liaison with authorities and negotiating power. They therefore *“stick together for survival”.*

Of the 17 affirmative respondents in medium enterprises:

- 11 had implemented the OHS-18000 standard.
- 6 export their products to global markets.
- 17 reported to have good quality health and safety officers.
- 14 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 48 affirmative respondents in small enterprises:

- 43 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 36 reported to have a good quality health and safety officer.
- 48 are directly involved in the day-to-day management of health and safety matters on site.

Of the 17 non-affirmative respondents in large enterprises:

- 5 were government institutions.

Of the 73 non-affirmative respondents in medium enterprises:

- 24 reported low employee morale.
- 38 considered the health and safety legislation as a financial and administrative burden.

Of the 216 non-affirmative respondents in small enterprises:

- 256 considered the health and safety legislation as a financial and administrative burden.
- 198 had a stronger focus on profit-making than on health and safety protection.

7.4.12 Critical success factor 12

The owner or operator of the hazardous installation knows exactly what the implications are of being classified as a major hazard installation under the MHI Regulations.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	12	4	1	17
Yes, %	5	4	5	4.6

Discussion of the results

Small businesses were in the majority (12 respondents) to confirm the statement.

The majority of respondents (95.4%) were unsure of the implications of being classified as a major hazard installation under the MHI Regulations (2001). They do not like the idea, thinking that it will place an additional burden on the business, either through intensified management attention, interrogation by the authorities or extra cost. There was a misconception that the term *“major hazard installation”* could deter customers and employees and provoke the animosity of surrounding communities. They did not understand the importance of continuous structured communication with the competent authorities and community leaders.

It was found that the situation is further aggravated by the fact that some local authorities are not knowledgeable about the MHI Regulations (2001) and the OHS Act (1993). As a result, owners and operators of hazardous installations were reluctant to accept that the classification of their installations as major hazard installations will enforce closer liaison with local authorities on them. From a local authority perspective, it became apparent that the classification of a hazardous installation as a major hazard installation is perceived to create a higher job risk for emergency responders and local municipalities, where poor service delivery has become the talk of the town in South Africa. A strong political driving force was therefore identified behind the responses.

Of the 12 affirmative respondents in small enterprises:

- 12 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 12 reported to have a good quality health and safety officer.
- 12 are directly involved in the day-to-day management of health and safety matters on site.

Of the 18 non-affirmative respondents in large enterprises:

- 6 were government institutions.

Of the 86 non-affirmative respondents in medium enterprises:

- 57 reported low employee morale.
- 44 considered the health and safety legislation as a financial and administrative burden.

Of the 252 non-affirmative respondents in small enterprises:

- 237 considered the health and safety legislation as a financial and administrative burden.
- 226 had a stronger focus on profit-making than on health and safety protection.

7.4.13 Critical success factor 13

The owner or operator of the hazardous installation knows clearly how the MHI Regulations fit into the overall OHS Act (Act 85 of 1993).

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	211	72	15	298
Yes, %	80	80	79	79.9

Discussion of the results

Only 20% of the cumulative respondents were unsure of this aspect, especially of the fact that the MHI Regulations (2001) should not be read in isolation, but in context with the OHS Act (1993). The uncertainty stemmed from a lack of understanding that the OHS Act (1993) is primarily applicable to the health and safety of employees in the workplace, while the aim of the MHI Regulations (2001) is to focus on the public at large, even though it is not stated clearly enough in the legislation. It was found that respondents were more willing and able to discuss the requirements of the OHS Act (1993) than the MHI Regulations (2001).

This critical success factor emphasised the fact that the MHI Regulations (2001) are seen by respondents as *"foreign"* and therefore unimportant in the South African context. It correlates well with CSF 8 where 95.,4% of the respondents believe that South Africa is a legislation follower and not a leader, at least as far as health and safety legislation is concerned.

This finding is also endorsed by what was found in the UK Löfstedt Review (2011), namely that safety legislation needs to be untangled, streamlined and made less onerous on owners and operators of hazardous facilities.

Small businesses were again in the majority (211 respondents) to confirm the statement. They claimed that health and safety as well as environmental legislation are a burden on their business and too complex to assimilate or to understand. Legislation should be made less complex for small enterprises.

Of the 15 affirmative respondents in large enterprises:

- 11 had implemented the OHS-18000 international health and safety standard.
- 5 export their products to global markets.
- 2 are listed on a stock exchange.
- 14 reported to have good quality health and safety officers.
- 13 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 72 affirmative respondents in medium enterprises:

- 41 had implemented the OHS-18000 standard.
- 34 export their products to global markets.
- 70 reported to have good quality health and safety officers.
- 59 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 211 affirmative respondents in small enterprises:

- 193 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 202 reported to have a good quality health and safety officer.
- 211 are directly involved in the day-to-day management of health and safety matters on site.

Of the 4 non-affirmative respondents in large enterprises:

- 4 were government institutions.

Of the 18 non-affirmative respondents in medium enterprises:

- 17 reported low employee morale.
- 12 considered the health and safety legislation as a financial and administrative burden.

Of the 53 non-affirmative respondents in small enterprises:

- 25 considered the health and safety legislation as a financial and administrative burden.
- 39 had a stronger focus on profit-making than on health and safety protection.

7.4.14 Critical success factor 14

The owner or operator of the hazardous installation finds it difficult to differentiate between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning their hazardous installation.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	225	77	17	319
Yes, %	85	86	90	85.5

Discussion of the results

There was a marked difference between small and medium enterprises on the one hand and large enterprises on the other. Small businesses were again in the majority (225 respondents) to confirm the statement. The reason was that they preferred a *"one-stop shop"* as far as the regulation of their businesses are concerned.

The majority of respondents (85.5%) had difficulties to differentiate between the two governmental departments. The National Environmental Management Act (Act 107 of 1998) and the Environmental Impact Assessment (EIA) Regulations (2014) prescribe clear requirements for the establishment of new hazardous facilities, and are governed by the Department of Environmental Affairs. An EIA is usually required, above a certain volume threshold, for such facilities to enable the department to issue an environmental authorisation. These facilities also trigger the MHI Regulations (2001) as governed by the Department of Labour, which necessitate a comprehensive health and safety risk assessment. It happens frequently that the Department of Environmental Affairs erroneously considers it to be its mandate to have jurisdiction over the MHI risk assessment and therefore oversteps its boundaries of jurisdiction. It violates the principle of cooperative governance, leads to confusing interpretation and execution of legislation and create delayed regulatory approvals.

The main reason why large enterprises were in agreement with the statement is because they operate on a large scale with high volumes of hazardous materials on site compared with small and medium enterprises. Hence they are obliged to obtain environmental authorisation under the EIA Regulations (2014), together with classification of their facilities as major hazard installations under the MHI Regulations (2001).

Of the 17 affirmative respondents in large enterprises:

- 12 had implemented the OHS-18000 international health and safety standard.
- 3 export their products to global markets.
- 4 are listed on a stock exchange.
- 11 reported to have good quality health and safety officers.
- 17 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 77 affirmative respondents in medium enterprises:

- 36 had implemented the OHS-18000 standard.
- 37 export their products to global markets.
- 72 reported to have good quality health and safety officers.
- 69 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 225 affirmative respondents in small enterprises:

- 198 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 218 reported to have a good quality health and safety officer.

- 222 are directly involved in the day-to-day management of health and safety matters on site.

Of the 2 non-affirmative respondents in large enterprises:

- 2 were government institutions.

Of the 13 non-affirmative respondents in medium enterprises:

- 9 reported low employee morale.
- 9 considered the health and safety legislation as a financial and administrative burden.

Of the 39 non-affirmative respondents in small enterprises:

- 26 considered the health and safety legislation as a financial and administrative burden.
- 30 had a stronger focus on profit-making than on health and safety protection.

7.4.15 Critical success factor 15

The owner or operator of the hazardous installation understands and accepts the criteria used to classify an installation as a major hazard installation under the MHI regulations.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	10	3	1	14
Yes, %	4	3	5	3.8

Discussion of the results

Only 3.8% of the respondents understood the main criterion that is used by risk assessors to classify a hazardous installation as an MHI: if the effects of a major incident at the installation can reach beyond the boundaries of the installation premises, then the surrounding public could be affected and the installation is classified as an MHI. This criterion is provided as an explanatory guideline by the Department of Labour and is not explicitly contained in the MHI Regulations of 2001. Even this guideline creates uncertainty, because there may be no human population near the installation, even if a large volume of hazardous material is stored on site. In many cases and despite the use of sophisticated mathematical modelling computer software to determine safety distances around hazardous installations, the risk assessor has to use his/her professional judgement, which naturally leads to differences of opinion. Local authorities are placed in the middle of this confusion, because they have the final say on whether a new major hazard installation can be allowed in its area of jurisdiction and they experience a lack of clear legislative guidelines. As a result the local authority is reluctant to take a decision.

This critical success factor emphasises the importance of unambiguous and clear legislation that spells out the requirements placed on owners and operators of hazardous facilities.

Small enterprises were in the majority to answer in the affirmative (10 respondents). They were found to be more cooperative with regulating authorities for the sake of business continuation: *"Just tell me what I must do, so that I can carry on with my business".*

Of the 10 affirmative respondents in small enterprises:

- 10 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 10 reported to have a good quality health and safety officer.
- 10 are directly involved in the day-to-day management of health and safety matters on site.

Of the 18 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 87 non-affirmative respondents in medium enterprises:

- 64 reported low employee morale.
- 61 considered the health and safety legislation as a financial and administrative burden.

Of the 254 non-affirmative respondents in small enterprises:

- 223 considered the health and safety legislation as a financial and administrative burden.
- 191 had a stronger focus on profit-making than on health and safety protection.

7.4.16 Critical success factor 16

The owner or operator of the hazardous installation knows exactly what the role is of the local emergency services in the prevention of and response to a major incident.

<u>Quantitative results</u>

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	90	34	4	128
Yes, %	34	38	21	34.3

<u>Discussion of the results</u>

Most respondents (65.7%) disagree with the statement. In rural areas there are no local emergency services available and if there are, they are considered to be incompetent to render an effective service. Several reasons were given for this, namely a shortage of staff, untrained employees and lack of equipment. As a result of this poor service delivery, many owners or operators of hazardous installations do not trust the local emergency services.

There was a marked difference between small and medium enterprises on the one hand and large enterprises on the other. A total of 79% of large enterprises disagree with the statement, compared with 66% and 62% for small and medium enterprises respectively. Small enterprises were in the majority with 90 respondents answering in the affirmative. There were three reasons for this finding:

- Small and medium enterprises are more dependent on help from local emergency services in case of a technological disaster, than large corporates who own and operate their own rescue services on site.
- Poor service delivery on local level is a hot topic in South Africa. Municipalities are therefore not trusted and is considered incompetent when it comes to the rendering of emergency services.

- Municipal structures are highly politicised with nepotism at the order of the day. It leads to further distrust in the competence of job incumbents and the overall ability of the local emergency services to render an effective service. Nine respondents (2.4%) refer to ethnic differences between business owners and municipal officials as a hampering factor.

Of the 4 affirmative respondents in large enterprises:

- 0 had implemented the OHS-18000 international health and safety standard.
- 1 export their products to global markets.
- 0 are listed on a stock exchange.
- 4 reported to have good quality health and safety officers.
- 4 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 34 affirmative respondents in medium enterprises:

- 17 had implemented the OHS-18000 standard.
- 16 export their products to global markets.
- 19 reported to have good quality health and safety officers.
- 33 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 90 affirmative respondents in small enterprises:

- 90 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 88 reported to have a good quality health and safety officer.
- 90 are directly involved in the day-to-day management of health and safety matters on site.

Of the 15 non-affirmative respondents in large enterprises:

- 5 were government institutions.

Of the 56 non-affirmative respondents in medium enterprises:

- 28 reported low employee morale.
- 39 considered the health and safety legislation as a financial and administrative burden.

Of the 174 non-affirmative respondents in small enterprises:

- 163 considered the health and safety legislation as a financial and administrative burden.
- 169 had a stronger focus on profit-making than on health and safety protection.

7.4.17 Critical success factor 17

The owner or operator of the hazardous installation believes that local emergency services are generally incompetent and have little knowledge of the MHI Regulations.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	257	88	17	362
Yes, %	97	98	90	97.1

Discussion of the results

The response on this critical success factor correlates with the response to critical success factor 15. Most respondents (99%) have no or little trust in the ability of their local emergency services to deal with disasters caused by the hazardous installation. This is especially true for district and rural municipalities. In the case of some of the large metropolitan municipalities, the level of service delivery is good, but there is a risk averse approach in the sense that new hazardous installations should be avoided. Such an approach clearly has a detrimental effect on fixed capital investment, economic growth and employment creation.

Large enterprises have a notable lower affirmative response compared with small and medium enterprises. The reason for this was that large enterprises are given priority by the local emergency services, for three reasons:

- Large enterprises have more *“legal enforcement muscle”*.

- Large enterprises have higher quantities of hazardous materials on site for storage or processing, which increases the risk of fire, explosion and toxic gas release. Local emergency services understand that this increased risk places a higher responsibility on them in terms of service delivery and political performance.
- Large enterprises have the resources to appoint dedicated personnel as safety, health and environmental officers, whose function it is to liaise closely with the various competent authorities, including local emergency services.

Small enterprises had the most respondents (257) to agree with the statement, stemming from a general distrust in the ability of local municipalities to provide good services, especially to small businesses.

Of the 17 affirmative respondents in large enterprises:

- 9 had implemented the OHS-18000 international health and safety standard.
- 4 export their products to global markets.
- 2 are listed on a stock exchange.
- 13 reported to have good quality health and safety officers.
- 17 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 88 affirmative respondents in medium enterprises:

- 45 had implemented the OHS-18000 standard.
- 14 export their products to global markets.
- 58 reported to have good quality health and safety officers.
- 80 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 257 affirmative respondents in small enterprises:

- 224 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 239 reported to have a good quality health and safety officer.

- 244 are directly involved in the day-to-day management of health and safety matters on site.

Of the 2 non-affirmative respondents in large enterprises:

- 2 were government institutions.

Of the 2 non-affirmative respondents in medium enterprises:

- 2 reported low employee morale.
- 2 considered the health and safety legislation as a financial and administrative burden.

Of the 7 non-affirmative respondents in small enterprises:

- 5 considered the health and safety legislation as a financial and administrative burden.
- 4 had a stronger focus on profit-making than on health and safety protection.

7.4.18 Critical success factor 18

The owner or operator of the hazardous installation is willing to disclose historical major incidents or near misses that occurred on the premises.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	9	3	0	12
Yes, %	3	3	0	3.2

Discussion of the results

Most of the respondents (96.8%) were unwilling to disclose particulars about past major incidents at their hazardous installations. The reasons for this were that such data was not kept in a reliable format, but that they also fear legal prosecution. The MHI Regulations (2001) require all near misses (unsafe incidents) at a major hazard installation to be treated in a serious manner, so much so that it triggers a re-assessment of the health and safety risks at the installation. Respondents were therefore fully aware of the need to properly document health and safety incidents, even if it had a minor effect.

All large enterprise respondents (100%) indicated that they were not willing to disclose information on historical health and safety incidents, because they are under strict instruction from their overseas controlling companies, or – in the case of South African companies - they operate under strict market reporting rules laid down by the JSE Stock Exchange. Small and medium enterprises are not bound by such strict information disclosure rules. Small enterprises were in the majority to affirm the statement (9 respondents). They do not want to be seen as obstructive to the legal system and were willing to disclose date on their health and safety performance as long as it would not jeopardise their income generating operations.

All respondents understood that the recording of information on disasters and near misses at major hazard installations forms a critical part of the overall disaster management process in any country. It enables the construction of a database from which incident trends can be derived.

Of the 3 affirmative respondents in medium enterprises:

- 0 had implemented the OHS-18000 standard.
- 0 export their products to global markets.
- 2 reported to have good quality health and safety officers.
- 3 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 9 affirmative respondents in small enterprises:

- 9 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 8 reported to have a good quality health and safety officer.
- 9 are directly involved in the day-to-day management of health and safety matters on site.

Of the 19 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 87 non-affirmative respondents in medium enterprises:

- 77 reported low employee morale.
- 80 considered the health and safety legislation as a financial and administrative burden.

Of the 225 non-affirmative respondents in small enterprises:

- 197 considered the health and safety legislation as a financial and administrative burden.
- 204 had a stronger focus on profit-making than on health and safety protection.

7.4.19 Critical success factor 19

The owner or operator of the hazardous installation can provide historical statistics of major incidents that occurred in South Africa.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	15	5	1	21
Yes, %	6	6	5	5.6

Discussion of the results

Only 5.6% of all respondents were willing to disclose historical statistics of major incidents that occurred in South Africa. All respondents were not knowledgeable about major incidents that occurred in the past in South Africa, the main reason being that the Department of Labour does not disclose such information to the industry, mainly due to the legal prejudice that it may create for the case investigations. Such investigations may take years to complete. It is a shortcoming, since information about the cause and prevention of major incidents can be used constructively by all owners or operators of major hazard facilities to prevent disasters, as was found under critical success factor 18.

There was a surprisingly high number of small enterprise respondents who confirmed the statement (15 respondents) compared with 5 and 1 respondent for medium and large enterprises respectively. The reason was that these entrepreneurs made a bigger effort to stay abreast of developments in their industry, because their livelihood directly depends on it. Furthermore, they do not want to be seen as obstructive to any request related to their business.

In 2012 the Department of Labour has started to collate information on major hazard installations in South Africa in order to construct a reliable database of such installations. It will enable the department to keep these installations on their radar screen for regular inspections and advice and it emphasises the importance of recordkeeping as a vital part of disaster management, especially from a prevention point of view. In discussions with respondents it came out that this initiative of the Department was welcomed, as it was in their interest to ensure that their installations are designed, constructed and operated in a safe and reliable manner.

Incident statistics on major hazard installations are kept meticulously in Europe (HSE 2007; 2009; 2011) and USA (Lees 2005).

Of the 5 affirmative respondents in medium enterprises:

- 1 had implemented the OHS-18000 standard.
- 0 export their products to global markets.
- 5 reported to have good quality health and safety officers.
- 5 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 15 affirmative respondents in small enterprises:

- 11 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 11 reported to have a good quality health and safety officer.
- 15 are directly involved in the day-to-day management of health and safety matters on site.

Of the 18 non-affirmative respondents in large enterprises:

- 7 were government institutions.

Of the 85 non-affirmative respondents in medium enterprises:

- 78 reported low employee morale.
- 82 considered the health and safety legislation as a financial and administrative burden.

Of the 249 non-affirmative respondents in small enterprises:

- 167 considered the health and safety legislation as a financial and administrative burden.
- 233 had a stronger focus on profit-making than on health and safety protection.

7.4.20 Critical success factor 20

The owner or operator of the hazardous installation is committed to implementing the recommended risk mitigation measures as identified in the risk assessment study, in line with the ALARP principle.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	262	89	19	370
Yes, %	99	99	100	99.2

Discussion of the results

The majority of respondents (99%) were committed to this requirement and agreed to it, despite the fact that there were many cases where the mitigation measures had substantial financial implications for the owner or operator of the major hazard installation. Once again, as outlined by the response to critical success factor 10, the understanding of the respondents was that the mitigation measures were primarily necessary for the protection of the health and safety of employees, not so much the surrounding communities.

Respondents were unanimous in their views that the health and safety of people should be regarded as top priority to enable business to continue in a sustainable way. Small and medium enterprises were naturally concerned about the cost implications. Large enterprises considered the cost of legal compliance in health and safety management as *"the cost of staying in business".* Of course, these enterprises have a strong financial capital base and can more easily afford such cost than small and medium enterprises. They nevertheless have shareholders to report to and manage their health and safety budget with care.

As has been elicited at critical success factor 3, effective implementation of mitigation measures and emergency preparedness was found to be dependent on the role of the health and safety officer appointed in the enterprise. Large enterprises have dedicated personnel in this field, while it is not necessarily the case in small and medium enterprises.

Small enterprises were again in the majority (262 respondents) to confirm the statement. The reason was that they would walk the extra mile to ensure that they stay in business.

Of the 19 affirmative respondents in large enterprises:

- 9 had implemented the OHS-18000 international health and safety standard.
- 8 export their products to global markets.
- 2 are listed on a stock exchange.
- 17 reported to have good quality health and safety officers.
- 19 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 89 affirmative respondents in medium enterprises:

- 35 had implemented the OHS-18000 standard.
- 29 export their products to global markets.
- 80 reported to have good quality health and safety officers.
- 78 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 262 affirmative respondents in small enterprises:

- 261 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 246 reported to have a good quality health and safety officer.
- 262 are directly involved in the day-to-day management of health and safety matters on site.

Of the 2 non-affirmative respondents in small enterprises:

- 2 considered the health and safety legislation as a financial and administrative burden.
- 2 had a stronger focus on profit-making than on health and safety protection.

7.4.21 Critical success factor 21

The owner or operator of the hazardous installation has a knowledge and understanding of the need for proper land-use planning near hazardous installations.

Quantitative results

	Small enterprises	Medium enterprises	Large enterprises	Total Yes
Yes, n	5	2	0	7
Yes, %	2	2	0	1.9

Discussion of the results

There was an insignificant difference in response from small, medium and large enterprises on this critical success factor.

The affirmative response by only 1.9% of the respondents in the total sample was not surprising. Land-use planning around major hazard installations is not on their agendas as part of their profit-making and is a matter that is left to the town planners and emergency services of local authorities. It certainly remains the latter's legal responsibility in terms of Section 9 of the MHI Regulations (2001), but the owners or operators of hazardous installations should never divorce themselves from it.

Where a new hazardous installation is planned near an existing community, or where a new community development project is planned near an existing hazardous installation, the implications are the same: If a major incident occurs at the installation, the community is at risk and it remains the responsibility if the owner or operator to prevent it.

The MHI Regulations (2001) enables local authorities to approve or disapprove major hazard installations near inhabitant areas. Since 2011 large municipalities such as City of Tshwane, eThekwini Metropolitan Municipality and Ekurhuleni Metropolitan Municipality have implemented MHI technical task teams to evaluate applications for new major hazard installations. The task teams includes municipal disaster management representatives. However, the town planning divisions of the municipalities have not yet fully bought into the disaster prevention planning process.

Of the 2 affirmative respondents in medium enterprises:

- 0 had implemented the OHS-18000 standard.
- 1 export their products to global markets.
- 2 reported to have good quality health and safety officers.
- 2 reported that the top management of the enterprise is actively involved in health and safety matters on a day-to-day basis.

Of the 5 affirmative respondents in small enterprises:

- 5 were entrepreneurs who build up the business from the ground and who will go to great lengths to protect their livelihood.
- 5 reported to have a good quality health and safety officer.
- 5 are directly involved in the day-to-day management of health and safety matters on site.

Of the 19 non-affirmative respondents in large enterprises:

- 5 were government institutions.

Of the 88 non-affirmative respondents in medium enterprises:

- 67 reported low employee morale.
- 81 considered the health and safety legislation as a financial and administrative burden.

Of the 259 non-affirmative respondents in small enterprises:

- 238 considered the health and safety legislation as a financial and administrative burden.
- 248 had a stronger focus on profit-making than on health and safety protection.

7.5 Testing of the hypotheses

The one-sample Z-test for the comparison of proportions was applied to the quantitative research results in order to determine whether the difference in YES and NO response groups was significant (Conover 2000). The three hypotheses (Chapter 1) were tested by using this statistical technique and the results are summarised in Table 7.2.

Table 7.2 Testing of the three hypotheses

Hypothesis and attributes	Description and statistical variables
Hypothesis 1	Existing South African legislation for the management of hazardous installations does not address the vulnerability, coping capacity and resilience of communities near or around such installations.
Linked to critical success factor	4 (Table 7.1)
Observed proportion of the population that agree with critical success factor 4 statement (Yes)	p = 0.0080 (3 of 373)
Linked to critical success factor	5 (Table 7.1)
Observed proportion of the population that agree with critical success factor 5 statement (Yes)	p = 0.0054 (2 of 373)
Linked to critical success factor	6 (Table 7.1)
Observed proportion of the population that agree with critical success factor 6 statement (Yes)	p = 0.0295 (11 of 373)
Null hypothesis (H_0)	There is no significant difference between the proportion of respondents that agree and those that disagree with the statement.

Table 7.2 Testing of the three hypotheses *(continued)*

Hypothesis and attributes	Description and statistical variables
Alternative hypothesis (H_1)	There is a significant difference between the proportion of respondents that agree and those that disagree with the statement.
Null hypothesis value	$p_0 = 0.5$
Level of confidence	95%
Type of test	Two-tailed
Value of α	0.05
Sample size	$n = 373$
Test statistic (z)	$z = (p - p_0)/\{ [p(1-p_0)]/n \}^{1/2}$ $z_1 = -18.99$ for critical success factor 4 $z_2 = -19.11$ for critical success factor 5 $z_3 = -18.19$ for critical success factor 6
Critical value for α = 0.5	1.96
Decision rule	If z is larger than 1.96 or less than -1.96, then the null hypothesis is rejected
Conclusion for critical success factor 4	$z = -18.99 < -1.96$ The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.9920) disagree that the owner or operator of the hazardous installation is familiar with and understands the term "community or people health and safety vulnerability". Therefore Hypothesis 1 is valid.

Table 7.2 Testing of the three hypotheses *(continued)*

Hypothesis and attributes	Description and statistical variables
Conclusion for critical success factor 5	z = -19.11 < -1.96 The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.9946) disagree that the owner or operator of the hazardous installation is familiar with and understands the term "community coping capacity". Therefore Hypothesis 1 is valid.
Conclusion for critical success factor 6	z = -18.19 < -1.96 The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.9705) disagree that the owner or operator of the hazardous installation is familiar with and understands the term "community health and safety resilience". Therefore Hypothesis 1 is valid.
Hypothesis 2	Health and safety legislation in South Africa is fragmented and scattered among various independent state departments, which results in inefficient enforcing of the legislation for the management of hazardous installations.
Linked to critical success factor	9 (Table 7.1)
Null hypothesis (H_0)	There is no significant difference between the proportion of respondents who agree and those who disagree with the statement.
Alternative hypothesis (H_1)	There is a significant difference between the proportion of respondents who agree and those who disagree with the statement.
Observed proportion of the population who agree with critical success factor 4 statement (Yes)	*p* = 0.9812 (366 of 373)
Test statistic (z)	z = 18.57
Linked to critical success factor	14 (Table 7.1)

Table 7.2 Testing of the three hypotheses *(continued)*

Hypothesis and attributes	Description and statistical variables
Observed proportion of the population who agree with critical success factor 4 statement (Yes)	*p* = 0.9552 (319 of 373)
Test statistic (z)	z = 17.58
Conclusion for critical success factor 9	Z = 18.57 > 1.96 The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.9812) agree that the legislation relevant to hazardous installation operations is overlapping; that there are some definite common elements, but the legislation is contained in different Acts that are administered by different state departments, each with its own political agendas and motivational forces; the result is confusing and inefficient legislation. Therefore Hypothesis 2 is valid.
Conclusion for critical success factor 14	z = 17.58 > 1.96 The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.8552) agree that the owner or operator of the hazardous installation finds it difficult to distinguish between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning their hazardous installation. Therefore Hypothesis 2 is valid.
Hypothesis 3	The effective planning of land-use is a critical component of the overall management of hazardous installations, but does not receive the required attention under existing South African legislation.
Null hypothesis (H0)	There is no significant difference between the proportion of respondents who agree and those who disagree with the statement.

Table 7.2 Testing of the three hypotheses *(continued)*

Hypothesis and attributes	Description and statistical variables
Alternative hypothesis (H1)	There is a significant difference between the proportion of respondents who agree and those who disagree with the statement.
Linked to critical success factor	21 (Table 7.1)
Observed proportion of the population that agree with critical success factor 4 statement (Yes)	p = 0.0188 (7 of 373)
Test statistic (z)	z = -19.29
Conclusion for critical success factor 21	z = -19.29 < -1.96 The null hypothesis is rejected. There is a statistically significant difference between the proportion of respondents who agree and those who disagree with the statement. The larger proportion (0.9786) disagree that the owner or operator of the hazardous installation has a knowledge and understanding of the need for proper land-use planning near hazardous installations. Therefore Hypothesis 3 is valid.

7.6 Chapter conclusions

7.6.1 Hypotheses testing

An attempt was made to identify possible relationships between the identified critical success factors and the three hypotheses, because it would confirm the mutually inclusive interdependence between the critical success factors and the hypotheses. Furthermore, it would further confirm the validity of the hypotheses to supplement the statistical testing – it would create a serious anomaly if none of the hypotheses could be linked to at least some of the critical success factors. It was found that there is indeed a link between the critical success factors and the hypotheses and linkages has already been shown in Table 7.2. By testing for the comparison of proportions on the relevant critical success factors, an inference could be made regarding the validity of the three hypotheses that flowed from the research problem. In all three cases, the hypotheses were confirmed to be valid.

7.6.2 Qualitative findings

Explanations were sought as to why some owners or operators of major hazard installations have a better understanding of the critical success factors and implemented them more effectively than others. The research results indicated that specific attributes were prevalent among enterprises that conformed to the critical success factors.

7.6.2.1 Attributes of enterprises that conformed with the critical success factors

- The majority of these enterprises consisted of companies that are listed on a stock exchange, either the JSE in South Africa or in the country where the mother company is registered. These companies are under strict supervision of their public shareholders, who want to ensure that the company complies with local and international legislation and that their investment is therefore safe. Legal compliance is a serious managerial focus for company boards and it filters through to the lowest levels of the workforce through various enforcement measures such as incentives or firm disciplinary action.

- Many of the conforming companies trade globally and are therefore subject to international operating requirements. These requirements include the ISO-14001 and OHS-18000 international standards for environmental and health and safety management respectively. Companies that are accredited under these standards are audited annually by independent auditors and compliance with the South African OHS Act and MHI Regulations is very prominent in these audit protocols.

- Conformance with the critical success factors is a function of the knowledge, skills, experience and attitude of the employees who are tasked with the responsibility of health and safety supervision and management. Without exception, conforming companies appointed good quality employees to fulfil this responsibility in terms of training, experience and dedication. In all medium and large enterprises a health and safety committee was in force, with close communication to top management.

- Management involvement at board level in health and safety matters was a prominent attribute in all conforming enterprises. This is important for various reasons, such as employee motivation, sound corporate governance and the allocation of budgets to facilitate the implementation of health and safety risk mitigation measures for major hazard installations.

- Successful enterprises did not view compliance with the MHI Regulations as a burden, financially or administratively. They rather welcome it as an essential aid to their day-to-day safe management of the major hazard installation. Inspectors from the Department of Labour and the local authority are therefore welcomed on site and the management of those companies make a serious effort to maintain good relations with the authorities, which filters down to the lowest level of operating employees in all companies.

7.6.2.2 Attributes of enterprises that did not conform to the critical success factors

- Government enterprises at provincial and local level were generally non-conforming. These include hospitals where flammable gas installations exist for boiler fuel, water treatment plants where toxic chlorine gas is used as disinfectant and municipalities that manage new community developments near major hazard installations inappropriately. The non-conformance manifested in the absence of suitable on-site emergency response plans, the appointment of incompetent employees for the management of the health and safety associated with major hazard installations and a general lack of knowledge of the MHI Regulations and the OHS Act. To a large extent, health and safety risk mitigation measures were either non-existent or poorly implemented. A lack of financial resources was usually given as the reason.

- Low employee morale was found to be a strong contributing factor to non-conformance. There are of course many reasons for it, but the most notable ones were lack of training, lack of sufficient human resources and budget constraints.

- Many small enterprises, such as distributors of liquid petroleum gas and chemical producers, considered the MHI Regulations as a burden, both financially and administratively. Expenditure on an accredited major hazard installation risk assessor and the implementation of risk mitigation measures were seen as financial barriers to trade. On the administrative side, liaison with the authorities at national, provincial and local government level was highlighted as operational obstacles, primarily due to a lack of decision-making capacity and time delays.

It was noted that small enterprises generally had a stronger focus on profit-making than on the safety of their major hazard installation operations. This aspect featured especially strong among young entrepreneurs. They would much rather appoint an independent consultant to take care of the health and safety of their operations than spend managerial time on managing it themselves.

7.6.2.3 General conclusions

- Without exception, the authorities on all three governance levels took a rational yet firm stance on cases of noncompliance. It was found that they understood the need for support of industrial development as a prime prerequisite for employment and wealth creation, but that it has to take place in a responsible manner, in full compliance with local health and safety legislation.

- The political climate in South Africa strongly influenced the responses from respondents. Owners and operators of major hazard installations has varying degrees of distrust in the competence of government officials, especially in the emergency services on local government level.

- Small enterprises comprised entrepreneurs who built their businesses from the ground and would do anything to protect its wellbeing. The owners and operators of these major hazard installations are serious about their legal compliance and their relationship with surrounding communities, because they regard it as *"assurance"* that they would stay in long-term business. They would conform to the critical success factors, but only just and follow an approach of *"do as little as possible, at a low cost, just to comply"*.

- The complexity and overlapping of health and safety legislation and environmental legislation is a concern for all respondents, some more than other. This finding was particularly notable among small and medium enterprises who included many entrepreneurs and had minimum resources at their disposal such as financial capital, legal back-up and human resources.

Chapter 8

The development of a regulatory management model for human-induced health and safety risks associated with hazardous facilities in South Africa

8.1 Introduction

This chapter is the culmination of the research that was done in this study, namely the presentation of a new South African model for the regulatory management of hazardous technological facilities. The model is explained in the text and presented in schematic format.

The model is based on specific topics that were studied in the literature and three technological disaster case studies as well as the collection of data from various respondents, as outlined in Chapter 6, Research Methodology.

8.2 The aim of the model

The main objective of this study is to develop an optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa.

8.3 Features of the model

The model serves as a guiding framework for the development of health and safety legislation in South Africa and has several distinct features:

8.3.1 A systems approach is followed for the design of the model. It is fundamentally built on previous work done by Levett (1998), Jenkins (2009) and Pei-Ing et al. (2014) as contained in the alternative model for sustainable development, Figure 2.10.

8.3.2 It follows an approach of optimisation to make it as effective and practicably applicable as possible. The model takes into consideration the aim of the legislation, namely to protect the health and safety of people, including employees working at the hazardous facility and the communities around it. It is also very important that a "gold-plated" approach should be avoided. Legislation that is not carefully thought through can place such a burden on society that it becomes either impracticable or the cause of deliberate violation with a flood of cases to test it in a court of law.

8.3.3 The model is primarily based on South African socio-economic conditions. It takes existing legislation for major hazard installations in South Africa into consideration and improves on it. However, the model could have potential for application in other countries of the world as well.

8.3.4 The model focuses on the health and safety risks that hazardous facilities pose to people. It does not make provision for other risks such as financial, trade or broad-based economic risks.

8.3.5 The model focuses on risks that are human-induced. Firstly, it implies risks that are directly caused by human activity in the form of a disaster trigger, and secondly it implies that the risk originated from the human construction or operation of a hazardous installation. The purpose of this prescription is to make a clear distinction between technological and natural risks.

8.3.6 The model is specifically developed for hazardous facilities that could threaten the health and safety of people. It includes natural hazards such as earthquakes, tsunamis, wild fires, flash floods, hurricanes and volcanic activity only as far as these disasters can act as triggers for technological disasters.

8.4 Components of the regulatory management model

From the 21 critical success factors identified in Chapter 6 it is deduced that the model must at least contain the following nine essential components or subsystems:

8.4.1 Land-use planning

Proper land-use planning forms a critical action step in disaster prevention. It comprises three different elements:

- Planning for new infrastructure and residential developments near existing major hazard installations.
- Planning for new infrastructure and residential developments near new major hazard installations.
- Planning for new major hazard installations near existing infrastructure and residential developments.

8.4.2 Hazard identification and risk assessment

The hazards that people may be exposed to as a result of the facility need to be identified and characterised, and a quantitative risk assessment has to be performed on each hazard. The hazards include three elements (Lees 2005):

- Fires.
- Explosions.
- Atmospheric release of toxic gases.

The model must make provision for external hazards to the hazardous facility that are caused by natural destructive phenomena such as earthquakes, flash floods and wild fires (Natech triggers). Such natural disasters have the potential to trigger a technological disaster at the hazardous facility. Natural disasters are relevant to the model only as far as hazardous facilities, and not communities, are concerned.

8.4.3 Disaster prevention

The prevention of a technological disaster has to be the ultimate goal of all health and safety regulatory arrangements by governments. Measures to prevent a technological disaster from occurring at hazardous facilities include the following operational controls:

- Use of safe and reliable state-of-the-art technology in the design and operation of the facility.
- Proper land-use planning as the overall mitigation measure. This element is considered to be of such importance that it was elevated to one of the independent model components.
- Correct selection of employees to operate and manage the hazardous facility.

- Training of employees and management to ensure that health and safety at the facility remains a high priority at all times.
- Proper maintenance of plant and equipment.
- Regular internal auditing of the operations to identify potential shortcomings in the health and safety system of the facility.
- Allocation of sufficient funds (budget) for the safe and reliable operation of the facility.
- Dedicated and continuous management attention to the safety of the facility, to prevent illness, injury and death.
- Full compliance at all times with all regulatory requirements at national, provincial and local level. This includes maintenance of sound relations with all competent authorities.

8.4.4 Vulnerability

This component refers to employees (internal focus), the organisation itself (internal focus) and members of receptor communities (external focus). Vulnerability must be integrated with the following elements:

- Exposure to health and safety hazards.
- Coping capacity.
- Resilience.

8.4.5 Sustainability

It refers to both the communities near or around the hazardous facility and the organisation itself that houses the hazardous installation. Once again, there is an internal (endogenous) as well as an external (exogenous) perspective. In addition to the long-term survival of the organisation, sustainable living for employees is also critically important, as a priority. Their health and safety as well as their livelihood need to be protected.

8.4.6 Disaster response

The main aim of disaster response is to develop a proper emergency reaction plan. The following elements are important:

- The emergency reaction plan must be formulated specifically for the hazards that the facility pose to people and assets.
- The plan must be compiled in collaboration with competent authorities at national, provincial and local government level.
- The plan must be compiled in consultation with receptor community structures.
- The plan must be tested during mock emergencies at frequent intervals, in collaboration with competent authorities at national, provincial and local government level.
- Adequate financial and human resources must be allocated to execute the disaster response actions.

8.4.7 Disaster recovery and rehabilitation

There are two critical aspects of this component:

- Community recovery and rehabilitation. The receptor community has to be assisted in a planned manner to return to its normal state. This may take a long time and include remedial actions such as:

    - Medical treatment for victims.
    - Financial assistance for the families of victims.
    - Restoration of structures.
    - Repair of existing infrastructure or installation of new infrastructure.
    - Trauma counselling for affected people.
    - Third party insurance cover.

- Facility recovery and rehabilitation. Recovery and rehabilitation of the hazardous facility is considered to be an iterative process with a low frequency determined by the number of disaster incidents per year. The process is illustrated in Figure 8.1.

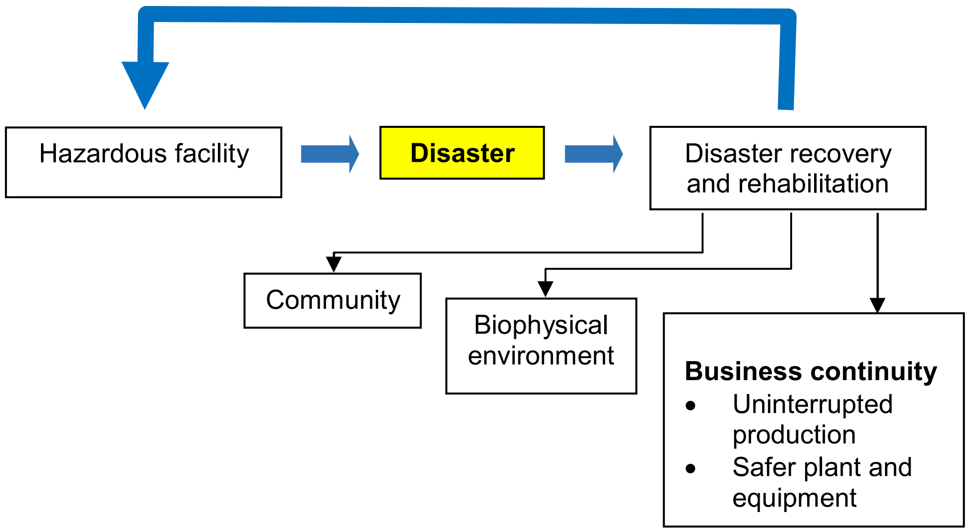

Figure 8.1 Facility recovery and rehabilitation as part of the disaster recovery cycle (Source: Author)

According to Lees (2005) the aim with the management of any hazardous facility is always to ensure that cyclical repetitions in the above process occur with an incident frequency (f_i) as low as possible, i.e.

$$f_i \longrightarrow 0$$

Recovery and rehabilitation of the hazardous facility can be achieved as follows:

- Insurance pay-out for immediate damage.
- Insurance pay-out for consequential damage (loss of business income).
- Rebuilding of the plant.
- Improvement measures such as safer or more robust technology.
- Interim arrangements with clients to ensure uninterrupted supply of product and after-sales service.
- Rehabilitation of the environment in case of spillages of hazardous materials, including fire-fighting liquids, which can create pollution of the soil, surface water and underground water.
- Business continuity planning. A disaster at a hazardous facility can have very serious impacts on employees and the surrounding communities in terms of

injuries, illness and fatalities. However, the disaster can at the same time also have devastating effects on the organisation itself in terms of business interruption or even closure. The model must therefore also incorporate business continuity and sustainability measures as part of the overall regulatory process. The role of short-term insurance must also be taken into consideration.

8.4.8 Communication

Planning for comprehensive, effective communication should form part of the disaster prevention and management process. It comprises the following elements:

- Communication with receptor communities.
- Communication with employees.
- Communication with news journalists.
- Communication among emergency management team members.
- Communication among relevant government departments.

8.4.9 Rationalisation and optimisation of existing legislation

The research results indicated that South African health and safety legislation is overlapping, duplicated and spread among various competent authorities. It leads to confusion and ineffective legal administration and the model must therefore make provision for optimisation of the legislation.

8.5 Construction of the regulatory management model

In order to comply with the 21 health and safety critical success factors as well as the above nine components, the model was constructed around three domains, namely environment, community and the hazardous facility. The next step was to create a transition from the health and safety critical success factors identified by the 373 respondent owners and operators of hazardous facilities in South Africa, to a regulatory management framework. It was necessary to establish a link with the above three domains and their components in order to ensure that, firstly, the critical success factors are appropriately captured in the health and safety regulatory framework and that, secondly, each critical success factor gives direction to a system component, which forms part of a regulatory domain. The linking process is shown in Annexure 5.

Linking of the three domains is shown in Figure 8.2.

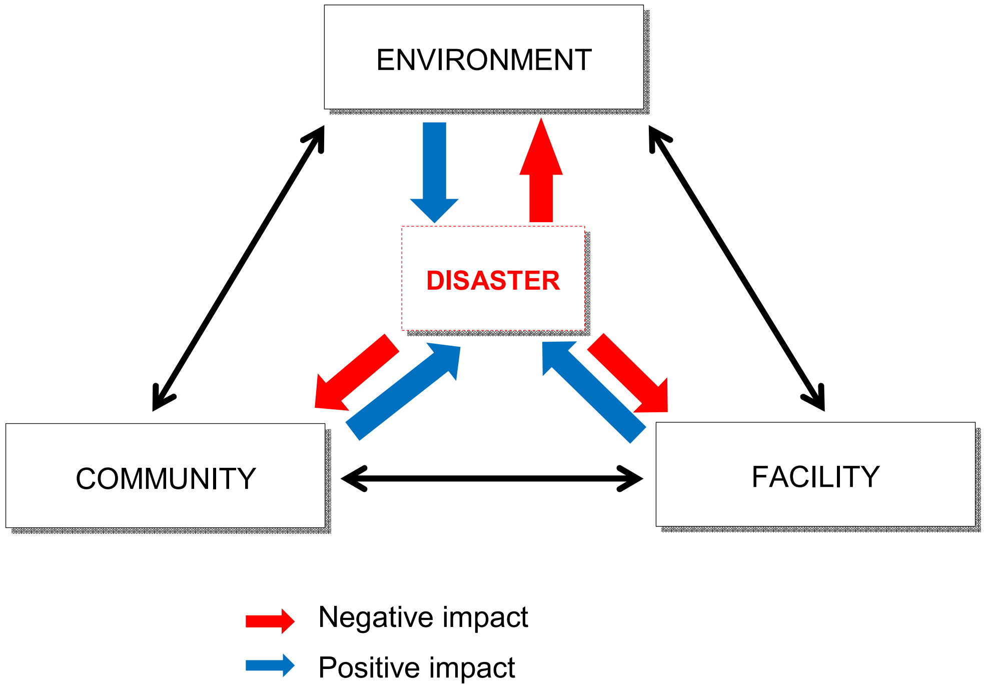

Figure 8.2 Three main domains of the regulatory management model for health and safety associated with hazardous facilities (Source: Author)

8.6 Features of the model

The model comprises three system domains, namely:

- The hazardous facility itself, which includes both existing and future facilities, with eight subsystems:
    - Employees.
    - Assets.
    - Hazard and risk identification and norm setting.
    - Economic sustainability and business continuity.
    - Emergency preparedness and disaster response actions.
    - Disaster recovery and rehabilitation.
    - Communication.
    - Operational controls.

- The exposed community or social group within which the hazardous facility is located, or which is contained inside the hazardous facility, e.g. employees or clients. The community grouping comprises three subsystems:

  - Vulnerability of people, including hazard exposure, coping capacity and resilience.
  - Social sustainability.
  - Land-use planning.

- The broader environment, which include the following six subsystems:
  - Socio-economic.
  - Political. This subsystem refers to the regulation formulation process and the integration, consolidation and rationalisation of existing Acts and Regulations.
  - Biophysical.
  - Economic.
  - Legal.
  - Technological.

8.7 Summary of the model development process

The sequence of the model development process is shown schematically in Figure 8.3.

The 21 critical success factors that were identified in the research, were used as the starting point to develop the model. These success factors are considered to be essential for the effective formulation of legislation for the regulatory management of hazardous facilities in South Africa. From the critical success factors, three regulatory domains were identified. The domains represent the broad framework within health and safety legislation should be created. Finally, various subsystems have been identified within the three regulatory domains.

Identification of health and safety critical success factors required for effective legislation

- Quantitative research
- Qualitative research
- Literature research
- Action research

↓

Regulatory domains

- Hazardous facility
- Community
- Environment

↓

Regulatory domain subsystems

Hazardous facility
- Employees
- Assets
- Hazard and risk identification
- Economic sustainability and business continuity
- Emergency preparedness and disaster response actions
- Disaster recovery and rehabilitation
- Communication
- Operational controls

Community
- Vulnerability of people, including hazard exposure, coping capacity and resilience
- Social sustainability
- Land-use planning

Environment
- Socio-economic
- Political: Integration, consolidation and rationalisation of existing Acts and Regulations
- Biophysical
- Economic
- Legal
- Technological

↓

Regulatory management model

Figure 8.3 Sequence of development of the regulatory management model (Source: Author)

8.8 Chapter conclusions

The following conclusions are drawn from this chapter:

8.8.1 The model primarily makes provision for health and safety hazards to which people are exposed and must include employees at the hazardous facility, the business entity that owns or operates the facility and community members around it. The model therefore has an endogenous (internal) as well as an exogenous (external) focus on the vulnerability of people, although the protection measures for the two societal groups will be different (refer to Figure 2.16). Other risks such as financial risks or market-related risks do not form part of the model.

8.8.2 The concept of business recovery is included in the model as a critical component. It is not sufficient to focus on the safety features of a hazardous facility or the vulnerability of surrounding social groupings – the vulnerability of the facility itself has to be taken into account. By its very nature, a hazardous facility has all the potential to be self-destructive. This can happen as a result of one or more of the following major incidents:

- A fire, which will result in the complete reconstruction or replacement of the hazardous facility.
- An explosion, which will also result in the complete reconstruction or replacement of the hazardous facility.
- The release of toxic gases, which will necessitate the complete decommissioning of the facility.

8.8.3 A dynamic systems approach was followed, which treats the various components of the model as open and interactive with constant feedback and change.

8.8.4 The model distinguishes between existing and future hazardous technological facilities in relation to land-use development through the inclusion of a land-use planning subsystem, which has to consider new hazardous facilities near existing inhabited areas as well as new population developments near exiting hazardous facilities.

8.8.5 The model allows for legislatory audits by competent authorities. All concepts are therefore perceptible and workable for both the management and the employees of the hazardous facility and the general receptor community near or around the facility.

8.8.6 The model integrates and consolidates all existing Acts and Regulations that are aimed at the protection of the health and safety of people.

8.8.7 The model has to be validated against the following criteria which are analysed in this study:

- The three case studies, Bhopal, Somerset West and Buncefield (Chapter 4).
- The array of health and safety legislation that is currently in force in South Africa (Chapter 5).
- The disaster management framework of South Africa (Chapter 5).

8.8.8 From the linkages between health and safety critical success factors, their connection with the regulatory domains and the subsystems of the domains, a regulatory management model has been compiled. The model is illustrated in Figure 8.4.

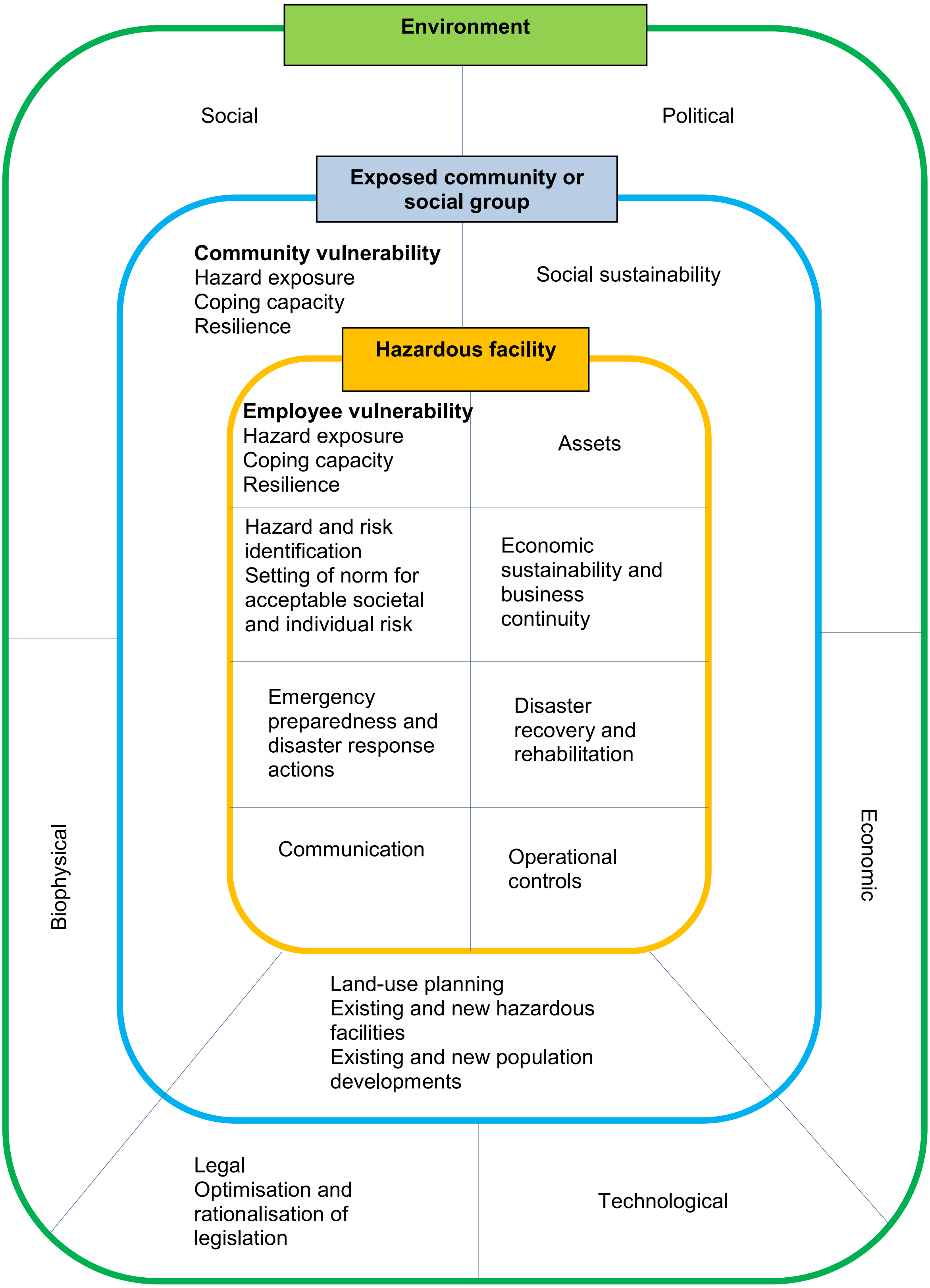

Figure 8.4 Schematic representation of the regulatory management model (Source: Author)

8.8.9 Consideration was given to the practical implementation of the theoretical model. It is illustrated in Figure 8.5, the model implementation framework. The theoretical model must be read in conjunction with its implementation framework.

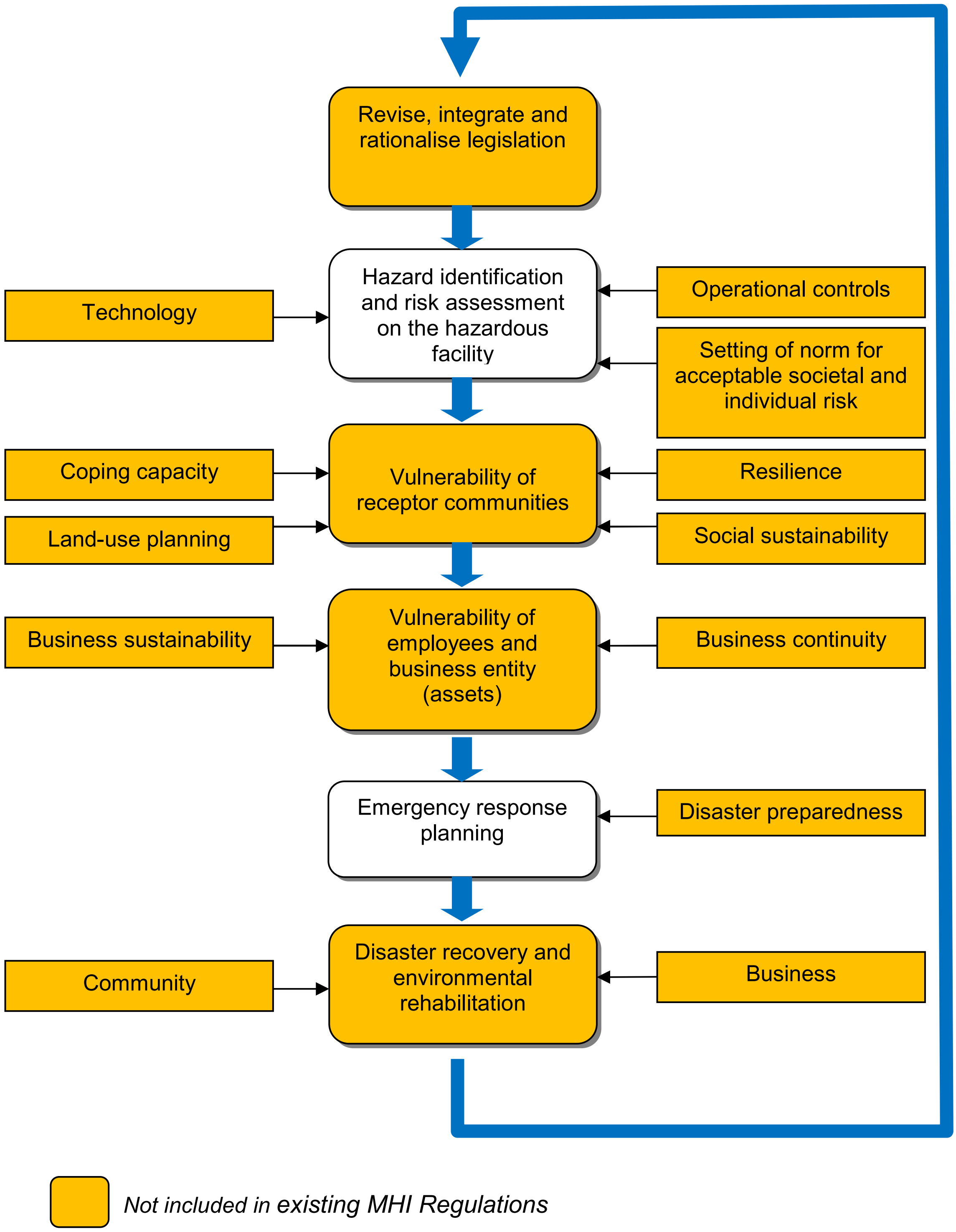

Figure 8.5. Implementation framework of the model (Source: Author)

Chapter 9

Validation of the model for human-induced health and safety risks associated with hazardous facilities

9.1 Introduction

This chapter explores the validity of the regulatory model, firstly, against three case studies:

9.1.1 The Bhopal disaster in India in 1984, when a large quantity of toxic methyl isocyanate was released from the Union Carbide plant

9.1.2 The Somerset West sulphur fire in South Africa, when large quantity of toxic sulphur dioxide was released from the AECI plant

9.1.3 The Buncefield liquid petroleum fuel depot in England, when a petrol vapour cloud explosion and ensuing fire were caused by the overfilling of a storage tank

The causes of the three disasters are listed against the ability of the regulatory management model to act as a first-stage disaster preventative measure. Evidence is provided of gaps in the existing South African health and safety related legislation and how the model is able to draw attention to the filling of these gaps. The model is then validated against existing health and safety focused Acts and Regulations of South Africa, as discussed in Chapter 5. Finally, typical application of the model to human-induced health and safety regulations is described.

9.2 Root causes of the Bhopal disaster

Taking into consideration the conflicting outcome of the Bhopal disaster investigations as reported by Kalelkar (1988) of Arthur D. Little Engineering Consultants, Dharmendra et al. (2014) and Peterson (2009), it is concluded that the root causes of the disaster were as follows:

- Sabotage.
- Lack of safe plant operating procedures.
- Poor plant maintenance.

- Lack of funds.
- Poor land-use planning.
- Reluctance by the government to impose strict enough regulatory measures on the plant.
- Lack of community vulnerability assessment.

9.3 Root causes of the Somerset West disaster

The root causes of the disaster were summarised in the Desai Commission report (1997) and elaborated on by Batterman et al. (1998):

- Lack of community vulnerability assessment, considering poverty factors and improper sheltering places.
- Ineffective community evacuation measures.
- Poor or inadequate on-site emergency response planning.
- Lack of proper hazard identification and risk assessment.
- Poor fire-fighting infrastructure.
- Poor communication with communities prior to and during the disaster.
- Poor communication among the various rescue operation teams.
- Lack of community consultation prior to the disaster on emergency planning matters.
- Lack of training of emergency response personnel.
- Lack of follow-up medical care for disaster victims.
- Inadequate legislation to protect the health and safety of people.

9.4 Root causes of the Buncefield disaster

The Buncefield Major Incident Investigation Board (HSE 2011) report the following root causes of the petroleum depot disaster:

- The vulnerability of the depot facilities was not assessed prior to the disaster.
- The vulnerability of the surrounding community was not assessed prior to the disaster.
- Inefficient tank level monitoring systems.
- Lack of operational information to depot operating personnel.
- Ineffective health and safety audits at the depot.

- Emotional pressure put on depot operating personnel.
- Health and safety requirements at the depot were neglected.
- Hazard identification and risk assessment was insufficient.

9.5 Validation of the model against the root causes of the Bhopal, Somerset West and Buncefield disasters

The ability of the regulatory management model to act as preventative instrument for the prevention of the root causes of the three disasters is evaluated in Table 9.1.

Table 9.1 Evaluation of the ability of the regulatory management model to prevent disasters

Root causes of disaster	Model domain	Domain component or subsystem that addresses the root cause
Bhopal • Sabotage • Lack of safe plant-operating procedures • Poor plant maintenance • Lack of funds • Poor land-use planning • Reluctance by government to impose strict enough regulatory measures on the plant • Lack of community vulnerability assessment	Hazardous facility	• Employees: security, training, protection of health and safety • Asset maintenance • Financial resources (budget): economic sustainability, business continuity • Operational controls
	Community	• Land-use planning • Vulnerability assessment
	Environment	• Legislation • Technology

Table 9.1 Evaluation of the ability of the regulatory management model to prevent disasters *(continued)*

Root causes of disaster	Model domain	Domain component or subsystem that addresses the root cause
Somerset West • Lack of community vulnerability assessment, considering poverty factors and improper sheltering places • Ineffective community evacuation measures • Poor or inadequate on-site emergency response planning • Lack of proper hazard identification and risk assessment • Poor fire-fighting infrastructure • Poor communication with communities prior to and during the disaster • Poor communication among the various rescue operation teams • Lack of community consultation prior to the disaster on emergency planning matters • Lack of training of emergency response personnel • Lack of follow-up medical care for disaster victims • Inadequate legislation	Hazardous facility	• Emergency preparedness and disaster response • Disaster recovery • Hazard identification and risk assessment • Operational controls
	Community	• Vulnerability assessment • Communication • Pre-disaster consultation • Disaster recovery
	Environment	• Legislation

Table 9.1 Evaluation of the ability of the regulatory management model to prevent disasters *(continued)*

Root causes of disaster	Model domain	Domain component or subsystem that addresses the root cause
Buncefield • The vulnerability of the depot facilities was not assessed prior to the disaster • The vulnerability of the surrounding community was not assessed prior to the disaster • Inefficient tank level monitoring systems • Lack of operational information to depot operating personnel • Ineffective health and safety audits at the depot • Emotional pressure put on depot operating personnel • Health and safety requirements at the depot were neglected • Hazard identification and risk assessment were insufficient	Hazardous facility	• Vulnerability of the facility • Vulnerability of the business • Operational controls • Hazard identification and risk assessment
	Community	• Vulnerability of community • Business continuity at risk due to possible fuel shortages
	Environment	• Biophysical impact due to air, water and soil pollution

9.6 Evaluation of existing South African health and safety legislation against the critical success factors identified

Table 9.2 presents an evaluation of the 14 existing pieces of health and safety related legislation as well as the disaster management framework, against the 21 critical success factors identified in Chapter 6. There is evidence of gaps in the existing legislation. The table also shows how these gaps are filled when the regulatory management model is applied.

Table 9.2 Evaluation of existing health and safety legislation against the critical success factors (see Table 6.2)

	Critical success factor																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Occupational Health and Safety Act (Act 85 of 1993) and the Major Hazard Installation Regulations of 2001																					
2. Mine Health and Safety Act (Act 29 of 1996)																					
3. National Environmental Management Act (Act 107 of 1998)																					
4. National Nuclear Regulator Act (Act 47 of 1999)																					
5. National Road Traffic Act (Act 93 of 1996)																					
6. National Railway Safety Regulator Act (Act 16 of 2002)																					
7. Disaster Management Act (Act 57 of 2002)																					
8. Safety at Sports and Recreational Events Act (Act 2 of 2010)																					
9. National Health Act (Act 61 of 2003)																					
10. Fire Brigade Services Act (Act 99 of 1987)																					
11. Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)																					
12. Civil Aviation Act (Act 13 of 2009)																					
13. South African Maritime Safety Authority Act (Act 5 of 1998)																					
14. Petroleum Pipelines Act (Act 60 of 2003)																					

Key to the table:

1 Risk and emergency response (ER) plan	8 Fundamentally locally developed legislation	15 Norm used to classify as an MHI
2 ER plan focused on communities	9 Legislation not overlapping with others	16 Role of local emergency services
3 Communication with communities	10 Community health and safety impacts	17 Competence of local emergency services
4 Community disaster vulnerability	11 Business and community neighbours	18 Disclosure of historical incident data
5 Community disaster coping capacity	12 Implications of being a hazardous facility	19 Historical incident data base available
6 Community disaster resilience	13 Relation of MHI Regulations to OHS Act	20 Implementation of mitigation measures
7 Sustainable development and living	14 Different roles for DOL and DEA	21 Proper land-use planning

(green)	Critical success factor is contained in the existing legislation
(yellow)	Critical success factors that are not contained in the existing legislation, but are addressed by the model
(grey)	Vulnerability, coping capacity and resilience are not specifically named in the Nuclear Regulator Act (Act 47 of 1999), but are addressed in the Nuclear regulations (2006) in the form of a specific norm for societal risk. Addressed by the model.

9.7 Validation of the model against existing South African health and safety legislation and the disaster management framework

The model is validated against the 14 South African Acts and Regulations as well as the Disaster Management Framework (Government Printer 2005) listed in Chapter 5, the primary aim of which is the protection of the health and safety of people in workplaces and in society in general. The health and safety focus of each Act or Regulation has been identified and then compared with the capability of the model to address that specific legislatory focus by highlighting the domain component of the model that is relevant to the legislatory focus. The results of the validation are shown in Table 9.3.

Table 9.3 Validation of the regulatory management model against the existing health and safety legislation in South Africa

Legislation	Health and safety focus	Model reference
1. Occupational Health and Safety Act (Act 85 of 1993) and the Major Hazard Installation Regulations of 2001	Any workplace	**Domain** • Hazardous facility • Community • Environment
2. Mine Health and Safety Act (Act 29 of 1996)	Mine equipment Mine machinery Underground operations Ore refining plant	**Domain** • Hazardous facility • Community • Environment
3. National Environmental Management Act (Act 107 of 1998)	Biophysical environment Socio-economic environment	**Domain** • Hazardous facility • Community • Environment
4. National Nuclear Regulator Act (Act 47 of 1999)	Nuclear reactors	**Domain** • Hazardous facility • Community • Environment
5. National Road Traffic Act (Act 93 of 1996)	Road vehicles Transportation of hazardous materials	**Domain** • Hazardous facility • Community • Environment
6. National Railway Safety Regulator Act (Act 16 of 2002)	Trains Transportation of hazardous materials	**Domain** • Hazardous facility • Community • Environment

Table 9.3 Validation of the regulatory management model against the existing health and safety legislation in South Africa *(continued)*

Legislation	Health and safety focus	Model reference
7. Disaster Management Act (Act 57 of 2002)	Natural disasters Technological disasters	**Domain** • Community • Environment
8. Safety at Sports and Recreational Events Act (Act 2 of 2010)	Events where more than 2 000 people attend	**Domain** • Hazardous facility • Community • Environment
9. National Health Act (Act 61 of 2003)	All citizens of South Africa Communities	**Domain** • Community • Environment
10. Fire Brigade Services Act (Act 99 of 1987)	Rescue services infrastructure and resources	**Domain** • Community • Environment
11. Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)	Any workplace	**Domain** • Hazardous facility • Community • Environment
12. Civil Aviation Act (Act 13 of 2009)	Aircraft Airports	**Domain** • Hazardous facility • Community • Environment
13. South African Maritime Safety Authority Act (Act 5 of 1998)	Ships Seaports	**Domain** • Hazardous facility • Community • Environment
14. Petroleum Pipelines Act (Act 60 of 2003)	Liquid petroleum fuel storage depots Liquid petroleum fuel pipelines Gas pipelines	**Domain** • Hazardous facility • Community • Environment

Table 9.3 Validation of the regulatory management model against the existing health and safety legislation in South Africa *(continued)*

Legislation	Health and safety focus	Model reference
15. Disaster Management Framework (Government Printer 2005)	Natural disasters Technological disasters	• **Domain** • Community • Environment
	Key performance areas	**Domain/subsystem**
	Establish integrated institutional capacity within the national sphere	• Environment/political
	Establish a uniform approach to assessing and monitoring disaster risks	• Hazardous facility/ operational controls
	Ensure all disaster risk management stakeholders develop and implement integrated disaster risk management plans and risk reduction programmes	• Hazardous facility/ operational controls
	Ensure effective and appropriate disaster response and recovery	• Hazardous facility/ disaster recovery and rehabilitation
	Enablers	**Domain/subsystem**
	Comprehensive information management and communication system	• Hazardous facility/communication
	Promote a culture of risk avoidance among stakeholders	• Hazardous facility/hazard and risk identification/norms for acceptable risk/emergency preparedness/operational controls
	Establish mechanisms for the funding of disaster risk management	• Hazardous facility/assets

9.8 Typical application of the model

The question arises: How do we go from theory to practice, in other words how can the model be applied in reality to ensure that hazardous facilities are regulated in the most efficient way? The model can only have value if it can be applied in the form of specific actions. This process is illustrated in Annexure 6, where some typical action steps are shown, following from the three model domains, namely environment, social and facility. The model assists in this process by providing focused thinking on those elements of regulation that would optimise the regulatory management of a specific hazardous facility.

9.9 Chapter conclusions

9.9.1 This chapter shows that the model can be applied successfully in the following areas of technological disaster management:

- Prevention of the root causes of disasters, as proved through case studies of the Bhopal, Somerset West and Buncefield human-induced technological disasters.
- Improvement of the effectiveness of South African legislation that focuses on health and safety management. Existing legislation was evaluated against the 21 critical success factors that were identified in this study and certain salient shortcomings were pointed out. In particular, the model provides focus areas that will ensure that gaps in the existing legislation are covered.

9.9.2 A typical way in which the model can be applied to enhance the effectiveness of regulation for hazardous facilities, was explored in this chapter. The model provides a collective, comprehensive view of vital elements that should be contained in health and safety legislation.

Chapter 10

Conclusions, recommendations and further research

10.1 Introduction

This chapter provides the conclusions drawn from the study. The research results are evaluated against the following criteria:

- The research problem.
- Research questions.
- The objectives of the study.
- The three hypotheses.
- Validation of the model against three case studies.
- Validation of the model against existing health and safety legislation in South Africa.
- The ability of the model to address shortcomings in the existing health and safety legislation in South Africa.
- The contribution that this study can make to knowledge about technological disaster risk reduction.

10.2 Conclusions

The study leads to the following conclusions:

10.2.1 The research problem

The research problem was addressed. The regulatory management model provides the following regulatory improvements:

- By applying the proposed regulatory management model, South Africa will be in a position to take the lead in the world. Instead of following guidelines from the UK HSE and EU, South Africa can take the lead in the formulation of integrated health and safety legislation.

- The concepts of vulnerability and sustainability were addressed. Both concepts were integrated into the proposed model and made applicable to communities and hazardous facilities as disaster prevention and mitigation measures.

- The fragmented legislation in South Africa was addressed in the model through an integrating approach.

- The important issue of land-use planning near or around major hazard installations was addressed as a first step in the prevention of a technological disaster.

10.2.2 Research questions

The research questions were answered by the research, through the integration of the following aspects into the proposed regulatory management model:

- The health and safety vulnerability, coping capacity and resilience of communities.

- The vulnerability of the business enterprise that owns or operates the hazardous facility and its operational continuity.

- Defragmentation or rationalisation of current health and safety legislation into one piece of legislation under one competent authority to ensure that hazardous installations are managed in the most effective manner, taking the health and safety vulnerability of communities and the business owner or operator into consideration.

- Land-use planning, which is lacking in the existing MHI Regulations (2001), is incorporated to ensure that the health and safety vulnerability of communities is minimised.

10.2.3 The objectives of the study

The objectives and sub-objectives of the research have been met:

- An optimised model was developed for the regulatory management of human-induced health and safety risks associated with hazardous facilities in South Africa.

- The model is based on the following eight theories:

    - Systems theory.

- Regulation and control theory.
- Sustainability theory.
- Vulnerability theory.
- Theory on natural-technological disasters.
- Disaster theory.
- Business continuity theory.
- Critical success factor theory.

- The study provides a regulatory solution for the absence of community vulnerability assessment, the fragmentation of health and safety legislation and the lack of guidelines for land-use near or around hazardous installations in existing South African legislation. The outcome of the study is a regulatory model that can firstly be applied in South Africa, but also in other countries of the world.

- Existing health and safety legislation in South Africa was expanded with an exogenous assessment of the vulnerability, coping capacity and resilience of communities as well as the business enterprise that owns or operates the hazardous facility that could all be affected by a major incident at the facility. The vulnerability and business continuity requirements of hazardous facilities itself were also addressed.

- Singular responsibility for the enforcement and administration of the legislation, to avoid confusion and to enhance effective governance, is achieved.

- The uncertainty in the existing legislation regarding land-use near or around hazardous facilities is removed and provision is made for land-use spatial development as a first step in community protection.

- The impact of natural disasters on hazardous technological facilities is addressed.

- The proposed model has been tested against international and local historical human-induced disasters and found to comply with the objective of this study.

10.2.4 The three hypotheses

The research provides evidence that the three hypotheses are valid:

- Existing South African legislation for the management of hazardous installations does not address the health and safety vulnerability, coping capacity and resilience of communities near or around such installations with regard to fires, explosions and the release of toxic gases.
- Health and safety legislation in South Africa is fragmented and scattered among various independent state departments, which results in inefficient enforcing of the legislation for the management of hazardous installations.
- The effective planning of land-use is a critical component of the overall management of hazardous installations, but does not receive the required attention under existing South African legislation.

10.2.5 Validation of the model against three case studies

The model has been validated against three critical case studies from South Africa (the Somerset West sulphur fire), India (the Bhopal toxic gas release) and England (the Buncefield petroleum depot explosion and fire).

10.2.6 Validation of the model against existing health and safety legislation in South Africa

The model has been validated against 14 local Acts and Regulations relevant to the governance of the health and safety of people, as well as the disaster management framework of South Africa.

10.2.7 The ability of the model to address shortcomings in the existing health and safety legislation in South Africa

Existing South African health and safety legislation as well as the disaster management framework have been evaluated against 21 critical success factors developed in this study. Salient shortcomings in the legislation were highlighted in this manner. Evidence has been provided that the regulatory management model has the capability to address these shortcomings by filling the gaps where the critical success factors demand it.

10.2.8 The contribution that this study can make to knowledge about technological disaster risk reduction

The development of a new optimised model for the regulatory management of human-induced health and safety risks associated with hazardous facilities opens the door for a new regulation-formulation dispensation in South Africa and other countries of the world.

The model can make three distinct impacts on health and safety regulation:

- The model is based on a systems approach, with three open and interactive domains: environment, community and hazardous facility.

- It introduces the concept of disaster vulnerability, not only for employees at the hazardous facility and communities around the facility, but also for the organisation that houses the hazardous facility.

- The model introduces the concept of the social and economic sustainability of communities around the hazardous facility and the organisation itself. As far as the sustainability of the organisation is concerned, the concept of business continuity is introduced as part of the legislatory process.

The research and the model developed made seven important contributions in the field of disaster management with regard to human-induced technological disasters:

- It introduces the concept of community vulnerability as a vital component of the health and safety regulatory domain for hazardous facilities. The existing practice in South Africa and the European Union is to follow an endogenous approach whereby the health and safety risks of a facility are assessed. The approach is inward-focused. This research proposes an additional exogenous, outward-focused approach, whereby the vulnerability of the surrounding community is assessed, together with their disaster resilience and coping capacity. The disaster consequences that a major incident at a hazardous facility can have for a community, as well as the risk mitigation measures that are required, are therefore expanded considerably in an attempt to make hazardous facilities safer.

- Current health and safety legislation applicable to hazardous facilities in South Africa does not address the important concept of disaster recovery. The current focus is entirely on disaster prevention and mitigation. The regulatory management model addresses this concept. Restoration of the operation of the facility, in a safer and more reliable form, is of critical importance to the productive business entity as well as affected communities.

- It is vital for the business entity that owns or operates a hazardous facility to resume its business activities as soon as possible after a technological disaster. The research therefore introduces the concept of business continuity as integral element of the regulatory management process. Proper business continuity planning is essential to ensure sustainability in revenue, production and wealth creation. By taking this approach, the role of insurance against asset damage and revenue losses becomes evident.

- The concept of sustainable development is introduced. It applies to social communities around hazardous facilities as well as business enterprises that own or operate the facilities. Hazardous facilities are self-destructive. In the case of a major incident, the facility explodes, burn down or is decommissioned permanently if a toxic gas was released in an uncontrollable manner. Legislation should make it mandatory for owners and operators to replace destroyed or decommissioned hazardous facilities with improved, state-of-the-art technology and operating protocols. In this way the safe and reliable operation of the facility as a commercial productive unit will be extended, while the safety of surrounding communities will be enhanced at the same time.

- A much stronger focus is placed in this research on biophysical environmental damage as an integral part of the regulatory management process for hazardous facilities. By doing so, the net of potential disastrous impacts is cast much wider, to include faunal and floral life. At the same time the research points out that a clear distinction should be made between health and safety legislation on the one hand and environmental legislation on the other.

- Land-use development planning at and around hazardous facilities is added to the regulatory management process. This aspect is seriously lacking in South African health and safety legislation. The planning includes the locality of new hazardous facilities in existing communities as well as the locality of new populated infrastructure near existing hazardous facilities. Proper integrated land-use planning for the development of hazardous facilities and community infrastructure forms an important part of sustainable development in the form of integrated and inclusive development plans, to reduce the health and safety risks of people exposed to hazardous facilities.

- The research points out that optimised legislation is an essential prerequisite for an efficient health and safety regulatory management regime. Regulatory overlaps and repetition should be avoided through the formulation of one integrated piece of legislation under one coordinating competent authority. The administration of similar legislation by more than one competent authority spells disarray and confusion and does not serve the bigger cause, namely protection of the health and safety of people. At best, such overlapping legislation serves only political agendas.

The research opens up new, unexplored territory for the formulation of more comprehensive and effective health and safety legislation for hazardous facilities.

10.2.9 Conclusions about conforming major hazard installations in South Africa

The attributes of enterprises that conformed to the critical success factors were found to be as follows:

- The majority of these enterprises consisted of companies that are listed on a stock exchange and are therefore under strict supervision of their public shareholders.

- Many of the conforming companies trade globally and are therefore subject to international operating requirements such as the ISO-14001 and OHS-18000 international standards for environmental and health and safety management respectively.

- Conformance with the critical success factors is a function of the knowledge, skills, experience and attitude of the employees who are tasked with the responsibility of health and safety supervision and management.

- Management involvement at board level in health and safety matters was a prominent attribute in all conforming enterprises.

- Successful enterprises did not view compliance with the MHI Regulations as a burden, financially or administratively. They rather welcome it as an essential aid to their day-to-day safe management of the major hazard installation.

10.2.10 Conclusions about non-conforming major hazard installations in South Africa

The attributes of enterprises that did not conform to the critical success factors were found to be as follows:

- Government enterprises at provincial and local level were generally non-conforming. These include hospitals where flammable gas installations exist for boiler fuel, water treatment plants where toxic chlorine gas is used as disinfectant and municipalities that manage new community developments near major hazard installations.

- Low employee morale was found to be a strong contributing factor to non-conformance. There are of course many reasons for it, but the most notable ones were lack of training, lack of sufficient human resources and budget constraints.

- Many small enterprises, such as distributors of liquid petroleum gas and chemical producers, considered the MHI Regulations as a burden, both financially and administratively. Expenditure on an accredited major hazard installation risk assessor and the implementation of risk mitigation measures were seen as financial barriers to trade. On the administrative side, liaison with the authorities at national, provincial and local government level was highlighted as operational obstacles, primarily due to a lack of decision-making capacity and time delays.
  It was noted that small enterprises generally had a stronger focus on profit-making than on the safety of their major hazard installation operations. This aspect featured especially strong among young entrepreneurs. They would much rather

appoint an independent consultant to take care of the health and safety of their operations than spend managerial time on managing it themselves.

10.2.11 General conclusions about the major hazard installation industry

- Without exception, the authorities on all three governance levels took a rational yet firm stance on cases of noncompliance. It was found that they understood the need for support of industrial development as a prime prerequisite for employment and wealth creation, but that it has to take place in a responsible manner, in full compliance with local health and safety legislation.
- The political climate in South Africa strongly influenced the responses from respondents. Owners and operators of major hazard installations has varying degrees of distrust in the competence of government officials, especially in the emergency services on local government level.

- Small enterprises comprised entrepreneurs who built their businesses from the ground and would do anything to protect its wellbeing. The owners and operators of these major hazard installations are serious about their legal compliance and their relationship with surrounding communities, because they regard it as *"assurance"* that they would stay in long-term business. They would conform to the critical success factors, but only just and follow an approach of *"do as little as possible, at a low cost, just to comply"*.

- The complexity and overlapping of health and safety legislation and environmental legislation is a concern for all respondents, some more than other. This finding was particularly notable among small and medium enterprises who included many entrepreneurs and had minimum resources at their disposal such as financial capital, legal back-up and human resources.

10.2.12 Elements of uncertainty in the model

While the model is based on seven proven theoretical concepts, which have been researched in depth by several experts and although the model has been validated against local and international case studies as well as existing local legislating, there remains some elements of uncertainty, both in terms of design and implementation of the model. These elements are listed as follows:

- The design of the model assumes open and free interaction between the environmental, social and hazardous facility domains as dictated by Systems Theory. However, such interaction may be impeded as a result of a variety of factors, most notably legislation and political power play, communication barriers and filters, socio-economic status, governing regime and the level of community vulnerability and education. The interaction of the system may be distorted and unbalanced in the beginning, especially with regard to straightening out overlapping legislation, but may reach equilibrium over time towards the implementation phase of the model. The formulation of a new regulatory framework, guided by the model, will have to be done in close consultation with all interested and affected parties.

- The successful implementation of the model depends primarily on a healthy political environment, as is required for any regulation-formulation process. A concomitant prerequisite is the acceptance of a new regulatory dispensation by hazardous facility owners or operators and communities at large. Resistance to change is a common social phenomenon. The implementation of the model will have to be done in a pragmatic way, as depicted in Figure 8.5, and must be facilitated with a strong public communications campaign.

10.3 Recommendations

As on outcome of this study, the following recommendations are put forward:

10.3.1 The proposed regulatory management model must be presented to South African government at national, provincial and local level, for consideration in the formulation of future health and safety legislation. It is recognised that the full implementation of the model is likely to take several years, but the earlier a beginning is made, the better.

10.3.2 One competent authority must be established in South Africa for the regulation of health and safety across all industries. This will avoid duplication of resources, for example in the Department of Labour, the Department of Environmental Affairs and the Department of Energy. It will also eliminate confusion among stakeholders on who is actually the competent authority. This would be similar to what is being done in the UK through the regulating powers of the HSE.

10.3.3 The results of this study should be published in relevant international journals in order to obtain expert feedback on the applicability of the model in other countries.

10.3.4 The model developed in this study is a conceptual guide for legislation formulation. The real value of the regulatory management model lies in its practical application. The ultimate aim is to formulate effective legislation for the protection of the health, safety and well-being of people and the protection of business assets, in order to maintain long-term sustainability. It can be achieved by ensuring that the following prerequisites are met:

- The task to formulate legislation against the background provided by the model, should be assigned to a well-composed team of people. The team should include representatives from at least the following groups:
  - Owners and operators of hazardous facilities.
  - Government officials on national, provincial and local level.
  - Local and international experts, including academics, in the field of disaster management.
  - Communities.
  - Disaster management practitioners.
  - Environmental management practitioners.
  - Risk assessment practitioners.

- The task team should function under the chairmanship of a national safety regulator.
- Quantitative risk norms should be specified for each specific hazardous facility, for individual and societal risk. In this way ambiguity and uncertainties in the interpretation of risk levels will be minimised.
- The formulated draft legislation must be presented to all stakeholders in a consultative manner for comment prior to its promulgation.

10.4 Further research

A list of topics with potential for further research is provided in this section. These topics were identified as the research progressed and were excluded from the study, because they fall outside the scope of the research. The topics that are listed here for potential further research stem from the study, and it is believed that they can make a substantial contribution to a better understanding of technological hazards and their consequences. It is important to expand on the work in this study in order to ensure that the science of major hazard installation disaster risk management stays alive and keeps growing.

The following topics are proposed for further research:

10.4.1 A critical evaluation of the new Major Hazard Installation Regulations in South Africa

At the time of completion of this study, the Department of Labour is facilitating a process of review of the MHI Regulations of 2001. Information about the possible outcome is very limited for obvious reasons of confidentiality. It is known that the Department sought advice from the UK HSE and it is therefore likely that the new regulations will contain at least some elements of the UK COMAH regulations. A critical evaluation of the new regulations against the model that originated from this study would serve an important purpose for future health and safety regulations that are developed for application in all spheres of hazardous facility industries South Africa.

10.4.2 Community vulnerability as a vital component in the legislatory process and decision-making instrument for hazardous technological installations in South Africa

This study provides sufficient evidence that the vulnerability, coping capacity and resilience of communities near major hazard installations are not considered in quantitative risk assessment methodologies in South Africa.

10.4.3 Can disasters from hazardous technological installations have benefits?

It is known that some natural disasters can have ecological benefits, such as wild fires that stimulate new vegetation growth and flash floods that clear rivers of silt. The question is whether technological disasters can also have certain benefits and for whom. Aspects that come to mind are the opportunity to replace old and outdated plant and equipment with long-term state-of-the art technology, the opportunity to install process equipment that is safer as well as short-term employment creation for the duration of replacement construction work. However, any potential benefit has to be balanced against the loss of lives.

10.4.4 Land-use planning around major hazard installations: A new approach for South Africa to reduce the vulnerability of communities against human-induced technological disasters

Land-use planning as a spatial development planning tool to enhance the health and safety of communities near major hazard installations, does not receive sufficient priority in South Africa and probably in many other countries in the world (refer to the Bhopal disaster in India). There are several cases in South Africa where major hazard installations were established in days when there were no community developments near them. Over time, however, the vacant land around the installations was made available for human occupation. One reason for this was that local authorities saw in it opportunities to generate income through levies and taxes.

There are two planning issues at stake: the development of new infrastructure and residential units near or around existing major hazard installations, and the development of new major hazard installations near existing residential developments and infrastructure. It is a two-way approach that should take into consideration all the elements of the disaster management cycle, such as community vulnerability, coping capacity, resilience, emergency response, disaster recovery and business continuity.

10.4.5 Decision-making criteria for the authorisation of major hazard installations in South Africa: A new approach in community vulnerability and technological disaster risk reduction

In addition to proper land-use planning near major hazard installations, there should be more clearly defined and practicable criteria that can be applied when applications for the establishment of major hazard installations are presented to local authorities. These criteria may include the installation of processes and equipment that would protect the health and safety of surrounding communities, the capability of the applicant to design and implement proper disaster recovery plans, including a master plan for business continuity. The latter has in any event already become part of sustainable corporate governance, as contained in the King III report (2009).

10.4.6 The relationship between major hazard installation authorisation and operation and community developmental needs in South Africa as a vital regulatory matter

Land is a scarce resource and is becoming scarcer every day as the human population grows. Land owned by industrialists where major hazard installations operate, is seen as a privilege of the rich capitalists, which deprives poor and disadvantaged communities of a decent livelihood. How wrong or right this view is, is not the point – it is a reality that creates antagonism among communities with regard to industrial development, especially if such developments are of a hazardous nature. There is industry on the one side and the community on the other and local authorities have the challenge to maintain a balance between the two. It is a long-term, continuous and variable process and one of constant interaction between two main components, where systems theory can play a strong role.

10.4.7 Possible endogenous and exogenous triggers of human-induced technological disasters caused by major hazard installations in high-population areas in South Africa

The focus of such research could be on an internal and external identification and evaluation of triggers that could create explosion, fires and the atmospheric release of toxic gases from major hazard installations. The triggers can include human-induced ones as well as technological deficiencies and others.

10.4.8 Planning for the prevention of disasters caused by hazardous technological installations

At present the focus in South African legislation on major hazard installations is more on disaster response emergency management than on disaster prevention. It is proposed that the full disaster management cycle should be considered in the planning process, including process design measures, vulnerability, disaster recovery, the role of insurance and business continuation.

10.4.9 Risk mitigation and disaster recovery measures versus the socio-economic benefits of technological major hazard installations for humankind: A cost-benefit approach

This research would focus on the economy of major hazard installations and their benefits to humankind. A cost-benefit analysis could be performed with the cost of mitigation and disaster recovery measures on the one hand and the potential for wealth creation by technological installations on the other. A sensitivity analysis can be performed, with varying degrees of social risk that the installation poses to society. The outcome of the research could help potential investors in major hazard installations to make sound socio-economic decisions.

10.4.10 Assessing the risks of major hazard installations from a community perspective

This research would focus on the development of a risk assessment methodology that follows from the legislatory model in Chapter 9 of this study. Existing quantitative risk assessment methods, for example as prescribed in the MHI Regulations of 2001, can be used as point of departure. Critical elements of the proposed new risk assessment methodology would include community vulnerability, coping capacity and resilience as external focus. An internal focus would include sustainability risks such as the vulnerability of the enterprise, disaster recovery and business continuity.

10.4.11 Recovery from disasters caused by major hazard installations in South Africa

Existing legislation, at least in South Africa, focuses entirely on pre-disaster emergency planning with an approach of, if a disaster happens, how the impacts can be mitigated. The proposed research on this topic would investigate measures that can be designed and implemented to ensure that the enterprise per se can recover as quickly and effectively as possible after a technological disaster, so that the benefits of the installation can be regained. The research would strongly focus on disaster recovery theory, business continuity theory, short-term insurance theory and sustainability theory. Vulnerability theory can also be explored, but from an enterprise perspective, not a community perspective.

10.4.12 Why is there a difference between small, medium and large enterprises and between various industries in terms of the health and safety critical success factors?

The data obtained from respondents as owners or operators of hazardous facilities can be analysed further to provide in-depth answers to the following questions:

- Why are there differences between small, medium and large enterprises that house hazardous installations in terms of the various health and safety critical success factors?

- Why are there differences between the various industries in terms of the various health and safety critical success factors with regard to hazardous facilities?

- Does the size of an enterprise make a difference in the way that hazardous facilities are managed in order to comply with prevailing legislation?

- Does the type of industry make a difference in the way that hazardous facilities are managed in order to comply with prevailing legislation?

10.4.13 Quantification of community and institutional vulnerability, resilience and coping capacity for hazardous technological facilities

The assessment of vulnerability as related to hazardous technological facilities has to be a two-prong process. An endogenous process must be followed whereby the vulnerability of the receptor institution (the company or enterprise that owns or operates the facility) is assessed. However, an equivalent, exogenous process must also be followed whereby the vulnerability of the receptor communities is assessed. From these assessments a set of quantitative vulnerability indicators must be developed for both receptor groups. Tantamount to this assessment process is the relationship between resilience and coping capacity that must be explored on institutional and socio-economical level. Are these three concepts the same with regard to technological hazards? If they are different, what is their individual mathematical relationship and what is their collective relationship with vulnerability?

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Annexures

Annexure 1: List of questions posed to operators of major hazard installations in South Africa

No	Interview question
1	Is there an on-site health and safety emergency response plan at the major hazard installation site?
2	If there is an on-site emergency response plan, does it specifically describe how the health and safety of employees at and communities around the major hazard installation will be protected?
3	Does the owner or operator of the major hazard installation make a deliberate effort to liaise frequently with employees and neighbouring communities with regard to the health and safety risks imposed upon them as a result of the existence of the installation?
4	Is the owner or operator of the major hazard installation familiar with and do they understand the term "community or people vulnerability"?
5	Is the owner or operator of the major hazard installation familiar with and do they understand the term "employee and community coping capacity" with regard to a disaster?
6	Is the owner or operator of the major hazard installation familiar with and understands the term "employee and community resilience" with regard to a disaster?
7	Is the owner or operator of the major hazard installation familiar with and do they understand the term "sustainable development and living"?
8	The existing major hazard installation legislation is not South Africa specific, but based on foreign legislation and guidelines. Should South Africa therefore be considered to be a follower, not a leader?
9	Is the legislation relevant to major hazard installation operations overlapping and are there some common elements, but they are contained in different Acts administered by different state departments, each with its own political agendas and motivational forces?
10	Does the owner or operator of the major hazard installation fully understand the health and safety impacts that their hazardous installation could have on employees and neighbouring communities?
11	Does the owner or operator of the major hazard installation know exactly who their business and community neighbours are?
12	Does the owner or operator of the hazardous installation know exactly what the implications are of being classified as a major hazard installation under the MHI Regulations?
13	Does the owner or operator of the major hazard installation know clearly how the MHI Regulations fit into the overall OHS Act?
14	Does the owner or operator of the major hazard installation find it difficult to differentiate between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning tjeir installation?
15	Does the owner or operator of the major hazard installation understand and accept the criteria used to classify an installation as a major hazard installation under the MHI Regulations?
16	Does the owner or operator of the major hazard installation know exactly what the role is of the local emergency services in the prevention of and response to a major incident?
17	Does the owner or operator of the major hazard installation believe that local emergency services are generally competent and have sufficient knowledge of the MHI Regulations?

Annexure 1: List of questions posed to operators of major hazard installations in South Africa *(continued)*

No	Interview question
18	Is the owner or operator of the major hazard installation willing to disclose historical major incidents or near misses which occurred on the premises?
19	Can the owner or operator of the major hazard installation provide historical statistics of major incidents that occurred in South Africa?
20	Is the owner or operator of the major hazard installation committed to implementing the recommended risk mitigation measures as identified in the risk assessment study, in line with the ALARP principle?
21	Does the owner or operator of the major hazard installation have a knowledge and understanding of the need for proper land-use planning near hazardous installations?

Annexure 2: Structured discussions with international experts in risk management and regulation

1. The Health and Safety Executive, London. One respondent was interviewed.

- In 2011 Prof Ragnar Löfstedt was appointed to conduct a review of health and safety legislation in use in the UK with the aim of rationalising legislation. Can you elaborate on it?

  Response

  The review of legislation was initiated by the new UK government at the time, with the aim of reducing red tape in legislation. The process that HSE facilitates is to bring in new legislation as replacements for old legislation through a process of "bartering". The Löfstedt report was generally well received and endorsed by all stakeholders. The coordination and alignment of UK legislation with that of the European Union make things very difficult. It has become a very complex process.

- In disaster management theory much emphasis is placed on the assessment of communities prone to disasters in terms of their vulnerability, coping capacity and resilience. In South Africa research is currently being conducted in this field, aimed at the integration of community vulnerability assessment into the health and safety risk assessment of major hazard installations. Currently the focus is on the installation and how it would impact on surrounding communities. We propose a different approach whereby the focus is also put on an assessment of the surrounding or potential future communities. What are your views on this?

  Response

  It is an interesting idea that sounds important. It is not done in the UK at present.

2. The Institute of Business Continuity Management in London, UK. One respondent was interviewed.

- The assessment of health and safety risks associated with major hazard installations in South Africa and the UK does not include business recovery measures to ensure business continuity. What are your recommendations for the achievement of business continuity in a major hazard business environment?

Response

The preparation and implementation of business continuity plans is now formally prescribed in the King III Report on corporate governance. The plan should not only consider fixed assets, but also cash flow requirements and human capital. Insurance of assets and loss of income is important as well as unemployment insurance for employees.

- Should business continuity plans form part of the overall health and safety risk management cycle for major hazard installations?

Response

Disaster recovery is already an element of the risk management cycle and business continuity should form part of it. It is a new concept to integrate business continuity into health and safety risk management and it will probably take several years to get fully entrenched as a standard management tool.

Annexure 3: The facilitation of a structured workshop on risk management and regulation

Theme of the workshop

A critical evaluation of commonalities and exclusions between the MHI Regulations and the Disaster Management Act in South Africa

Attendance register

1. Mr Alfonso Niemand, DiMTEC, University of the Free State (Facilitator)
2. Dr Herman Booysen, Aurecon Group
3. Mr Hayden Koch, Ekurhuleni Emergency Services
4. Mrs Rachel Aphane, Department of Labour
5. Mr Curtis Mashimbye, DiMTEC, University of the Free State
6. Mr Kim Clayton, TotalGaz
7. Mrs Alice Ncube, DiMTEC, University of the Free State
8. Mrs Olivia Kungumao, DiMTEC, University of the Free State
9. Mr Brett Goodwill, eThekwini Municipality Disaster Management
10. Mrs Jamila Kalilombe, eThekwini Municipality Disaster Management
11. Mr Wilfred Mkhwanazi, eThekwini Municipality Disaster Management
12. Mr Sandile Dladla, eThekwini Municipality Emergency Services
13. Mrs Nonhlanhla Mkhwanazi, eThekwini Municipality Emergency Services
14. Mr Alba Maipisi, DiMTEC, University of the Free State
15. Mr M Fenla, DiMTEC, University of the Free State
16. Mrs Fumiso Muyambo, DiMTEC, University of the Free State
17. Mr Johannes Belle, DiMTEC, University of the Free State
18. Prof Dusan Sakulski, Office of the Free State Premier
19. Prof Andries Jordaan, DiMTEC, University of the Free State

Matters arising from the workshop

1. The workshop deliberated on natural disasters as well as human-induced (major hazard installations) disasters.
2. Communication with communities before, during and after a disaster is crucial. However, the National Key Point Act prohibits all communication about strategic installations. It leaves a gap in legislation.

3. Communities need to be educated about the risks posed by possible disasters with regard to preparedness, emergency response and recovery activities.
4. Transportation of hazardous materials under the National Road Traffic Act is a serious matter that needs more attention. Apparently the Department of Cooperative Governance and Traditional Affairs (COGTA) is currently investigating the transportation of hazardous goods. Other relevant departments such as Labour are unaware of this investigation.
5. Working with tribal authorities is a big problem. They do not always obey the laws of the country. They see themselves as above the law.
6. The Land Development Act of 2013 plays an important role in the prevention of the impacts of disasters on newly established communities and infrastructure.
7. The burden on local authorities is too onerous with regard to human-induced disasters. They need more legislative support.
8. There should be clearer and more consistent communication between government departments at national, provincial and local level.
9. Politicians always have hidden motives, irrespective of legislatory requirements.
10. Illegal land invasion is a big problem in South Africa and worldwide. People settle next to major hazard installations such as chemical plants and in areas prone to natural disasters such as flood plains. Illegal settlements are sometimes politically motivated, which makes the relocation of vulnerable communities almost impossible. Furthermore, their human rights are protected.
11. Education of communities is very difficult, mainly due to high levels of illiteracy. Community attendance of public information meetings means nothing. They come for the food or in the hope that they will be given jobs.
12. Industry is frustrated by the need for liaison with so many different government departments on the same safety issues, such as the Department of Environmental Affairs, the Department of Water Affairs and Sanitation, local government emergency services and the Department of Labour. The authorisation channels are complex and decisions take too long, which creates delays and a financial risk for investors.
13. Adequate communication with communities is not well legislated as far as human-induced safety risks are concerned.

14. The use in South Africa of UK legislation developed by HSE is problematic. South Africa has totally different local social circumstances. UK legislation needs to be adapted for the markets in South Africa.
15. There is a lack of funds to remunerate experts in law-making committees in South Africa.
16. The ward councillor structures in local government should be used more effectively to facilitate communication with communities.
17. Local authorities must be trained better and informed better about all facets of disasters.
18. The risk assessment modelling techniques for major hazard installations need to be standardised.
19. The onus should be on the risk owners to communicate with communities about health and safety issues. It is not the role of local government or accredited risk assessors.
20. The National Water Act must also be considered with regard to flood disasters.
21. Changes in the political system are another important trigger of business continuity management. Cases in point: Nigeria, Zimbabwe.
22. Social and labour unrest risks should form part of business continuity management.
23. Insurance against disasters is complex and difficult to enforce through legislation.

Pertinent questions that were discussed

- How can we improve the implementation of legislation? Example: Mines are sold and rehabilitation becomes the responsibility of the new owners, without proper provision for the required capital. It creates serious environmental threats such as acid groundwater or dust. How can this be linked to the Disaster Management Act?

  Consensus decision
  Look at the future. Nothing can be done about past mining activities. Legalise a fund or reserve to finance rehabilitation. Can the same be done with major hazardous factories? Obtain advice from overseas companies and governments. One department such as the Department of Cooperative Governance and Traditional Affairs (COGTA) must drive the disaster implications of closed mines and factories.

- Should the assessment of community disaster vulnerability be included in the MHI legislation? Should the assessment of community disaster coping capacity be included in the MHI legislation? Should the assessment of community disaster resilience be included in the MHI legislation?

  Consensus decision
  Rehabilitation of closed mines and factories after closure must form part of future legislation. The Disaster Management Act must be moved from COGTA to the offices of the State President at national level, the Premier at provincial level and the Municipal Manager at local level. There must be cross-reference between the MHI Regulations and the Disaster Management Act.

- Should businesses (factories) be compelled to also compile and implement a business continuity plan as part of its emergency response planning? Should businesses (factories) be compelled to provide proof of adequate insurance against disasters in view of the vulnerability of employees to loss of income?

  Consensus decision
  All businesses should have a business continuity plan anyway, as part of their day-to-day management. The Unemployment Insurance Fund (UIF) protects employees in case of company disasters also. South Africa must have an open economy with minimum regulation. The free market must dictate. Do not regulate insurance requirements. Look at the recommendations of the King III report on corporate governance.

- Should major hazard installations rather be governed by the Department of Cooperative Governance and Traditional Affairs under the Disaster Management Act and not by Department of Labour?

  Consensus decision
  COGTA has only a coordination role under the Disaster Management Act. The department has no authority as it relies on other departments to take action in case of a disaster and to enforce the law. The Disaster Management Act should be moved to a different department.

- Is there a need for integration of the various safety legislation such as OHS, Mine Health and Safety, nuclear regulator, environmental management, water affairs and sanitation, safety at sports and recreational events?

  Consensus decision
  In South Africa there are too many pieces of legislation that are trying to take care of the same safety issues. Legislation has to be reduced and rationalised. Refer to the Löfstedt review in 2011 in the UK.

Annexure 4: Detailed analysis of the quantitative research results for small, medium and large enterprises

No	Critical success factor	Small facility				Medium facility				Large facility				Control total	Total Yes	Total Yes %
		Total	Yes	No	% Yes	Total	Yes	No	% Yes	Total	Yes	No	% Yes			
1	There is an on-site health and safety emergency response plan at the hazardous installation site	264	179	85	68	90	62	28	69	19	11	8	58	373	252	67,6
2	If there is an on-site emergency response plan, it specifically describes how the health and safety of communities around the hazardous installation will be protected	264	9	255	3	90	3	87	3	19	1	18	5	373	13	3,6
3	The owner or operator of the hazardous installation makes a deliberate effort to liaise frequently with neighbouring communities with regard to the health and safety risks imposed upon them as a result of the existence of the installation	264	23	241	9	90	7	83	8	19	2	17	11	373	32	8,6
4	The owner or operator of the hazardous installation is familiar with, understands the term "community or people vulnerability"	264	1	263	0,4	90	1	89	1	19	1	18	5	373	3	0,8
5	The owner or operator of the hazardous installation is familiar with, understands the term "community coping capacity" with regard to a disaster	264	1	263	0,4	90	0	90	0	19	1	18	5	373	2	0,5

Annexure 4: Detailed analysis of the quantitative research results for small, medium and large enterprises *(continued)*

No	Critical success factor	Small facility				Medium facility				Large facility				Control total	Total Yes	Total Yes %
		Total	Yes	No	% Yes	Total	Yes	No	% Yes	Total	Yes	No	% Yes			
6	The owner or operator of the hazardous installation is familiar with, understands the term "community health and safety resilience" with regard to a disaster.	264	8	256	3	90	3	87	3	19	0	19	0	373	11	2,9
7	The owner or operator of the hazardous installation is familiar with, understands the term "sustainable development and living"	264	10	254	4	90	3	87	3	19	1	18	5	373	14	3,8
8	The existing major hazard installation legislation is not SA specific, but is based on foreign legislation and guidelines. South Africa is therefore considered to be a follower, not a leader.	264	252	12	96	90	86	4	96	19	18	1	95	373	356	95,4
9	The legislation relevant to hazardous installation operations is overlapping. There are some definite common elements, but it is contained in different Acts that are administered by different departments, each with its own political agendas and motivational forces. This is confusing and inefficient legislation.	264	259	5	98	90	89	1	99	19	18	1	95	373	366	98,1

Annexure 4: Detailed analysis of the quantitative research results for small, medium and large enterprises *(continued)*

No	Critical success factor	Small facility				Medium facility				Large facility				Control total	Total Yes	Total Yes %
		Total	Yes	No	% Yes	Total	Yes	No	% Yes	Total	Yes	No	% Yes			
10	The owner or operator of the hazardous installation fully understands the health and safety impacts that their hazardous installation could have on neighbouring communities	264	13	251	5	90	4	86	4	19	1	18	5	373	18	4,8
11	The owner or operator of the hazardous installation knows exactly who their business and community neighbours are	264	48	216	18	90	17	73	19	19	2	17	11	373	67	18,0
12	The owner or operator of the hazardous installation knows exactly what the implications are of being classified as a major hazard installation under the MHI Regulations	264	12	252	5	90	4	86	4	19	1	18	5	373	17	4,6
13	The owner or operator of the hazardous installation knows clearly how the MHI Regulations fit into the overall OHS Act	264	211	53	80	90	72	18	80	19	15	4	79	373	298	79,9

Annexure 4: Detailed analysis of the quantitative research results for small, medium and large enterprises *(continued)*

No	Critical success factor	Small facility				Medium facility				Large facility				Control total	Total Yes	Total Yes %
		Total	Yes	No	% Yes	Total	Yes	No	% Yes	Total	Yes	No	% Yes			
14	The owner or operator of the hazardous installation finds it difficult to differentiate between the role of the Department of Labour and the Department of Environmental Affairs with regard to the administration and enforcement of legislation concerning their hazardous installation	264	225	39	85	90	77	13	86	19	17	2	90	373	319	85,5
15	The owner or operator of the hazardous installation understands and accepts the criteria used to classify an installation as a major hazard installation under the MHI Regulations	264	10	254	4	90	3	87	3	19	1	18	5	373	14	3,8
16	The owner or operator of the hazardous installation knows exactly what the role is of the local emergency services in the prevention of and response to a major incident	264	90	174	34	90	34	56	38	19	4	15	21	373	128	34,3

Annexure 4: Detailed analysis of the quantitative research results for small, medium and large enterprises *(continued)*

No	Critical success factor	Small facility				Medium facility				Large facility				Control total	Total Yes	Total Yes %
		Total	Yes	No	% Yes	Total	Yes	No	% Yes	Total	Yes	No	% Yes			
17	The owner or operator of the hazardous installation believes that local emergency services are generally incompetent and has little knowledge of the MHI Regulations	264	257	7	97	90	88	2	98	19	17	2	90	373	362	97,1
18	The owner or operator of the hazardous installation is willing to disclose historical major incidents or near misses that occurred on the premises.	264	9	255	3	90	3	87	3	19	0	19	0	373	12	3,2
19	The owner or operator of the hazardous installation can provide historical statistics of major incidents that occurred in South Africa	264	15	249	6	90	5	85	6	19	1	18	5	373	21	5,6
20	The owner or operator of the hazardous installation is committed to implementing recommended risk mitigation measures as identified in the risk assessment study in line with the ALARP principle	264	262	2	99	90	89	1	99	19	19	0	100	373	370	99,2
21	The owner or operator of the hazardous installation has a knowledge and understanding of the need for proper land-use planning near hazardous installations	264	5	259	2	90	2	88	2	19	0	19	0	373	7	1,9

Annexure 5: The links between health and safety regulatory critical success factors, the subsystems of a regulatory domain and the facility, community and environment domains (Source: Author)

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
1. Health and safety emergency response plan	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
2. Protection of the health and safety of employees and communities	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
3. Frequent communication with employees and communities	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
4. Employee and community vulnerability	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
5. Employee and community coping capacity	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Hazard and risk identification • Emergency preparedness and disaster response • Communication	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
6. Employee and community resilience	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Emergency preparedness and disaster response • Communication	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
7. Sustainable development and living	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
8. Country leadership in legislation formulation	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
9. Non-overlapping, non-repetitive and optimised health and safety legislation	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
10. Health and safety impacts on employees and communities	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

<table>
<tr><th>Health and safety critical success factor for legislation</th><th>Connected subsystems of a regulatory domain</th><th>Resultant regulatory domain</th></tr>
<tr><td rowspan="3">11. Relationship with community neighbours</td><td>Hazard and risk identification
Emergency preparedness and disaster response
Disaster recovery and rehabilitation
Communication</td><td>Hazardous facility</td></tr>
<tr><td>Vulnerability: Hazard exposure, coping capacity and resilience of community
Social sustainability
Land-use planning</td><td>Community</td></tr>
<tr><td>Social needs
Political needs
Economic needs
Technological needs
Legal needs
Biophysical needs</td><td>Environment</td></tr>
</table>

<table>
<tr><th>Health and safety critical success factor for legislation</th><th>Connected subsystems of a regulatory domain</th><th>Resultant regulatory domain</th></tr>
<tr><td rowspan="3">12. Clear understanding of the MHI Regulations</td><td>Vulnerability: Hazard exposure, coping capacity and resilience of employees
Assets
Hazard and risk identification
Economic sustainability and business continuity
Emergency preparedness and disaster response
Disaster recovery and rehabilitation
Communication
Operational controls</td><td>Hazardous facility</td></tr>
<tr><td>Vulnerability: Hazard exposure, coping capacity and resilience of community
Social sustainability
Land-use planning</td><td>Community</td></tr>
<tr><td>Social needs
Political needs
Economic needs
Technological needs
Legal needs
Biophysical needs</td><td>Environment</td></tr>
</table>

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
13. Clear understanding of the overarching OHS Act	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
14. Clear differentiation between the roles of the Department of Labour and the Department of Environmental Affairs	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
15. Clear understanding and acceptance of the MHI classification criteria	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
16. Clear understanding of the role of the local emergency services	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
17. Competence of the local emergency services	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Hazard and risk identification • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
18. Historical record of major incidents or near misses at the hazardous facility premises	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
19. Historical record of major incidents or near misses at all hazardous facilities in South Africa	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
20. Commitment to the implementation of risk mitigation measures	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Assets • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Health and safety critical success factor for legislation	Connected subsystems of a regulatory domain	Resultant regulatory domain
21. Proper land-use planning near hazardous installations	• Vulnerability: Hazard exposure, coping capacity and resilience of employees • Hazard and risk identification • Economic sustainability and business continuity • Emergency preparedness and disaster response • Disaster recovery and rehabilitation • Communication • Operational controls	Hazardous facility
	• Vulnerability: Hazard exposure, coping capacity and resilience of community • Social sustainability • Land-use planning	Community
	• Social needs • Political needs • Economic needs • Technological needs • Legal needs • Biophysical needs	Environment

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author)

DOMAIN		
Environment	**Social**	**Facility**
• Air pollution • Soil pollution • Surface water pollution • Groundwater pollution • Measurement of air contaminants • Measurement of soil contamination • Measurement of surface water contaminants • Measurement of ground water contaminants • Potential xenobiotic substances • Internal environmental audits • Internal health and safety audits • Daily plant inspection • Preventative maintenance programme • Management of general waste • Management of hazardous waste • Waste recycling	• Quantitative health and safety risk assessment by competent person • Health and safety committee • Compile internal health and safety audit protocol • Conduct internal health and safety audits • Daily plant inspection • Preventative Maintenance programme • **On-site emergency plan** ○ Compilation date ○ Revision date ○ Define emergency categories ○ Potential natural emergencies ○ Potential human-induced emergencies ○ Potential internal sources of emergencies ○ Impact of all internal emergencies ○ Key personnel with responsibilities	• **Typical hazardous facilities** ○ Chemical production facilities ○ Chemical storage facilities ○ Chemical handling facilities ○ Aircraft ○ Ships ○ Trains ○ Road vehicles ○ Power Lines ○ Buildings ○ Structures ○ Bridges ○ Open cast mining ○ Underground mining ○ Gantries • **Hazard and operability studies** ○ Piping and instrumentation drawings ○ Flows

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

<table>
<tr><th colspan="3">DOMAIN</th></tr>
<tr><th>Environment</th><th>Social</th><th>Facility</th></tr>
<tr>
<td>• On-site emergency plan
○ Compilation date
○ Revision date
○ Define emergency categories
○ Potential natural emergencies
○ Potential human-induced emergencies
○ Potential internal sources of emergencies
○ Impact of all internal emergencies
○ Impact of all external emergencies
○ Response actions tailored for the facility
○ Key personnel with responsibilities
○ Contact information of key personnel
○ List of local emergency responders
○ Contact details of local emergency responders
○ Contact details of individuals for additional information and explanation of duties</td>
<td>○ Contact information of key personnel Impact of all external emergencies
○ Response actions tailored for the facility
○ List of local emergency responders
○ Contact details of local emergency responders
○ Contact details of individuals for additional information and explanation of duties
○ Rescue operations for employees
○ Rescue operations for community
○ Medical assistance for employees
○ Medical assistance for community
○ Personal information on employees
○ Conditions for evacuation
○ Evacuation procedure for employees
○ Evacuation procedure for communities
○ Clear chain of command
○ Designate specific evacuation official</td>
<td>○ Pressures
○ Temperatures
○ Contaminants
○ What-if analysis
○ Potential deviation analysis
○ Task teams of about 8 people (engineers, operators, safety personnel, health and safety representative, top management operational director level, designer)
• Safe-operating procedures
• Selection of operators
• Qualifications of operators
• Experience of operators Training of operators on work procedures
• Training of operators in health and safety matters for employees
• Training of operators in hazard risks and hazard identification</td>
</tr>
</table>

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
○ Rescue operations for community ○ Rescue operations for employees ○ Medical assistance for employees ○ Medical assistance for community ○ Personal information on employees ○ Conditions for evacuation ○ Evacuation procedure for employees ○ Evacuation procedure for communities ○ Clear chain of command ○ Designate specific evacuation official with a standby ○ Designate specific official for operational shutdown ○ Actions required for the various categories of emergencies ○ Persons(s) to stay behind to shut down critical operations ○ Specific evacuation routes for employees	○ Designate specific official for operational shutdown ○ Actions required for the various categories of emergencies ○ Persons(s) to stay behind to shut down critical operations ○ Specific evacuation routes for employees ○ Specific evacuation routes for community ○ Assistance to people with disabilities ○ One or more assembly areas where employees will gather ○ One or more assembly areas where community will gather ○ Method of accounting for all employees ○ Method of accounting for all visitors ○ Method of accounting for community members ○ Method of notification to local authorities	• Quantitative hazard identification with health and safety risk assessment by competent team • Health and safety committee • Compile Internal health and safety audit protocol • Conduct internal health and safety audits • Daily plant inspection • Preventative maintenance programme • **On-site emergency plan** ○ Compilation date ○ Revision date ○ Define emergency categories ○ Potential natural emergencies

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
○ Specific evacuation routes for community ○ Assistance to people with disabilities ○ One or more assembly areas where employees will gather ○ One or more assembly areas where community will gather ○ Method of accounting for all employees ○ Method of accounting for all visitors ○ Method of accounting for community members ○ Method of notification to local authorities ○ Method of alerting all employees ○ Method of alerting communities ○ Training of employees in emergency procedures ○ Retraining of employees in emergency procedures ○ Regular emergency drills ○ Prepare news media statements	○ Method of alerting all employees Method of alerting communities ○ Training of employees in emergency procedures ○ Retraining of employees in emergency ○ procedures ○ Regular emergency drills ○ Prepare news media statements ○ Internal approval of news media statements ○ Corporate spokesperson • Training of all employees in on-site emergency plan • Personal protective clothing • Personal protective equipment • Develop vulnerability indicators for employees • Develop vulnerability indicators for community	○ Potential human-induced emergencies ○ Potential internal sources of emergencies ○ Impact of all internal emergencies ○ Impact of all external emergencies ○ Response actions tailored for the facility ○ Key personnel with responsibilities ○ Contact information of key personnel ○ List of local emergency responders ○ Contact details of local emergency responders ○ Contact details of individuals for additional information and explanation of duties ○ Rescue operations for employees ○ Rescue operations for community ○ Medical assistance for employees ○ Medical assistance for community ○ Personal information on employees ○ Conditions for evacuation

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
○ Internal approval of news media statements ○ Corporate spokesperson ○ Availability of fire-fighting equipment • **Environmental incident statistics to be kept in local databank** ○ Date ○ Description of incident ○ Incident type (fire, explosion, toxic gas release) ○ Place ○ Facility affected ○ Severity of incident (number of fatalities, injuries) ○ Near-miss statistics • Probability of a pollution incident as per SA historical stats	• **Vulnerability to natural disasters** ○ Earthquake Flood ○ Wind ○ Wild fire ○ Tsunami ○ Hurricane ○ Heat wave ○ Lightning ○ Volcano • **Communication** ○ Employees and communities ○ Local emergency services ○ Shareholders ○ Local disaster centre ○ Provincial disaster centre ○ National disaster centre ○ Licensing authorities ○ News media	○ Evacuation procedure for employees ○ Evacuation procedure for communities ○ Clear chain of command ○ Designate specific evacuation official with a standby ○ Designate specific official for operational shutdown ○ Actions required for the various categories of emergencies ○ Persons(s) to stay behind to shut down critical operations ○ Specific evacuation routes for employees ○ Specific evacuation routes for community

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
• Probability of a pollution incident as per international stats • Expected frequency of a major pollution incident • **Failure rate of each part of the equipment** ○ Pumps ○ Pipes ○ Flanges ○ Connections ○ Valves ○ Compressors ○ Electrical ○ Heaters ○ Boilers ○ Processing units ○ Storage facilities ○ Pressure gauges ○ Flow meters	○ Replacement personnel ○ Compensation for occupational injuries and diseases • **Incident investigation** ○ Who? ○ What? ○ Where? ○ How? ○ When? ○ Consequences? ○ Money?	○ Assistance to people with disabilities ○ One or more assembly areas where employees will gather ○ One or more assembly areas where community will gather ○ Method of accounting for all employees ○ Method of accounting for all visitors ○ Method of accounting for community members ○ Method of notification to local authorities ○ Method of alerting all employees ○ Method of alerting communities ○ Training of employees in emergency procedures ○ Re-training of employees in emergency procedures ○ Regular emergency drills ○ Prepare news media statements

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
○ Temperature gauges ○ Level indicators ○ Alarm systems Instrumentation • Structural failure • Soil stability • **Vulnerability to natural disasters** ○ Earthquake ○ Flood ○ Wind ○ Wild fire ○ Tsunami ○ Hurricane ○ Heat wave ○ Lightning ○ Volcano • Develop vulnerability indicators • Environmental rehabilitation of soil	• Disaster recovery plan for employees • Disaster recovery plan for community • Adjustment plan based on political changes • MSDS for all hazardous products • Training of operators in MSDS prescriptions • Training of community in MSDS prescriptions • Medical treatment plan for employees • Medical treatment plan for affected community members • Disaster resilience of employees • Disaster resilience of community • Disaster coping capacity of employees • Disaster coping capacity of community • Revision of legislation Consolidate and rationalise existing legislation	○ Internal approval of news media statements ○ Corporate spokesperson ○ Availability of fire-fighting equipment • Personal protective clothing • Personal protective equipment • Training of all operators in health and safety legislation • Training of all employees in on-site emergency plan • Training of management in health and safety legislation • Training of management in on-site emergency plan • Handling of general waste • Handling of hazardous waste • Air pollution • Soil pollution

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**

• Environmental rehabilitation of surface water catchments
• Environmental rehabilitation of underground water
• **Incident investigation**
  ○ Who?
  ○ What?
  ○ Where?
  ○ How?
  ○ When?
  ○ Consequences?
  ○ Money?
• Corrective action plans
• Adjustment plan based on political changes
• MSDS for all hazardous products
• Training of operators in MSDS
• Management of change
• Management of near misses
		• Probability of an incident as per local historical statistics
		• Probability of an incident as per international statistics
		• Expected frequency of a major incident
		• **Failure rate of each part of the equipment**
		  ○ Pumps
		  ○ Pipes
		  ○ Flanges
		  ○ Connections
		  ○ Tanks
		  ○ Valves
		  ○ Compressors
		  ○ Electrical
		  ○ Heaters
		  ○ Boilers
		  ○ Processing units

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
• Medical treatment plan for affected employees • Medical treatment plan for affected community members • Revision of legislation • Liaison with other hazardous facilities on a forum basis • Consolidate and rationalise existing legislation		○ Storage facilities ○ Pressure gauges ○ Flow meters • Surface water pollution • Groundwater pollution • Measurement of air contaminants • Measurement of soil contamination • Measurement of surface water contaminants • Measurement of groundwater contaminants • **Incident statistics to be kept in SA in databank:** ○ Date ○ Description of incident ○ Incident type (fire, explosion, toxic gas release) ○ Place ○ Facility ○ Severity of incident (number of fatalities,

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
		○ injuries) ○ Near-miss statistics to be kept in SA, same as above ○ Temperature gauges ○ Level indicators ○ Alarm systems ○ Instrumentation ○ Structural integrity ○ Soil stability • Vulnerability indicators for hazardous facility • **Vulnerability of facility to natural disasters** ○ Earthquake ○ Volcano ○ Flood ○ Wind ○ Wild fire ○ Tsunami ○ Hurricane

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
		○ Heat wave ○ Lightning • Vulnerability of business entity • **Business continuity** ○ Incident and corporate crisis incidents ○ Recovery of technology, data, plant and equipment ○ Human resources ○ Corporate communication and public relations ○ Workplace recovery ○ Continuation of critical business activities ○ Site recovery • Production continuity • Replacement personnel • **Communication** ○ Employees ○ Local emergency services

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
		○ Communities ○ Shareholders ○ Local disaster centre ○ Provincial disaster centre ○ National disaster centre ○ Licensing authorities ○ News media • **Incident investigation:** ○ Who? ○ What? ○ Where? ○ How? ○ When? ○ Consequences? ○ Money? • Corrective action plans • **Disaster recovery plan** ○ Employees

Annexure 6: Typical application of the model for the regulatory management of hazardous facilities in South Africa (Source: Author) *(continued)*

DOMAIN		
Environment	**Social**	**Facility**
		○ Facility ○ Business • Adjustment plan based on political changes • MSDS for all hazardous products • Training of operators in MSDS • Management of change • Management of near misses • Re-entry into markets • Production replacement plan • Project planning • Resilience of hazardous facility • Resilience of business entity • Revision of legislation • Liaison with other hazardous facilities on a forum basis • Consolidate and rationalise existing legislation