Analysis of the fire hazard posed by petrol stations in Stellenbosch and the extent to which planning acknowledges risk

Thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy in Disaster Risk Science and Development in the Faculty of Arts & Social Science at Stellenbosch University.

By

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DEDICATION

I dedicate this to my entire family for the love, sacrifice, patience they have shown over the years. They have confronted difficult moments and endured such sacrifices with broad smiles without complaining. My parents, Nxoboyi and Nowandile Qonono and siblings namely, Tandiwe, Lungile, Pakama and Mandisa from the bottom of my heart thank you for everything. To my late brothers Mphumzeni and Vuyisile Qonono, I love you. God bless you.

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ABSTRACT

The study aimed to investigate the extent to which land-use planning in Stellenbosch, South Africa, considers the fire-risk posed by petrol stations, and the implications for public safety, as well as preparedness for large fires or explosions. In order to achieve this, the study first identified the land-use types around petrol stations in Stellenbosch, and determined the extent to which their locations comply with the international and national planning regulations. Petrol stations within a six-kilometre radius from Stellenbosch's centre were used as study sites. Second, the study examined the risk of fires/explosions at petrol stations. Third, the study investigated Stellenbosch Municipality's institutional preparedness to respond in an event of a fire/explosion at a petrol station. These results suggest that the siting of petrol stations does not comply with the international and national good practices, thus exposing the surrounding developments to fires and explosions. The results also suggests that land-use planning does not consider hazards created by petrol stations. In addition, while observation at petrol stations suggest the potential for major fires, Stellenbosch Municipality's preparedness to respond to petrol station fires appears low, due to the prioritisation of more frequent events.

KEY WORDS**:** Petrol stations, Stellenbosch, Technological hazard, DRR, Land-use planning, Risk analysis.

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OPSOMMING

Die studie beoog om ondersoek in te stel tot watter lands gebruik beplanning in Stellenbosch, Suid Afrika die vuur risiko wat petrol (vulstasies) moontlik kan inhou, en die implikasies daarvan vir publieke vuiligheid. Die studie het land rondom die vulstasies geïdentifiseer en sodoende vas gestel tot watter matter hul voldoen in Stellenbosch met internasionale en nasionale beplanning regulasies. Vulstasies binne ŉ radius van ses kilometers vanaf die Stellenbosch sentrum's was gebruik as studie areas. Tweedens, is die risiko van vuur verhoeding meganismes by vulstasies ondersoek. Derdens, het die studie ondersoek ingestel na Stellenbosch Munisipaliteit se institusionele voorbereidheid om te reageer in die geval van ŉ brand/vuur by ŉ vulstasie. Die resultate dui ook aan dat die gebruik van land beplanning nie gevare oorweeg nie , asook die risiko geassosieerd met vulstasies aangesien daar geen riglyne oorweeg ten opsigte van lokasies uitsluitend sonering skemas. Sluitend is gevind dat die Stellenbosch Munisipaliteit se voorbereidheid om te reageer in geval van ŉ brand by ŉ vulstasie, baie laag is. Dit is as gevolg van prioriteitheid van meer dikwels gevalle.

SLEUTELWOORDE: Vulstasies, Stellenbosch, Tegnologiese gevaar, DRR, Grondgebruikbeplanning, Risiko-analise

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ACRONYMS

AC21	:	Academic Consortium 21
ADPC	:	Asian Disaster Preparedness Centre
AFP	:	Agence France-Presse
ARA	:	Australia Retail Association
CGA	:	Centre for Geographical Analysis
DEADP	:	Department of Environmental Affairs and Development Planning
DM	:	Disaster Management
DMA	:	Disaster Management Act
DPR	:	Department of Petroleum Resource
DRR	:	Disaster Risk Reduction
EIA	:	Environmental Impact Assessment
ECA	:	Environment Conservation Act
EOP	:	Emergency Operational Plan
FP	:	Fire Prevention
FS	:	Fire Service
GDoACELA	:	Gauteng Department of Agriculture, Conservation, Environment and Land Affairs
GEJE	:	Great East Japan Earthquake
GIS	:	Geographic Information System

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GMT	:	Greenwich Meridian Time
GPS	:	Global Positioning System
HSA	:	Health and Safety Authority
HFA	:	Hyogo Framework of Action
IDP	:	Integrated Development Plan
IFLA	:	International Federation of Library Association and Institution
KASUPDA	:	Kaduna State Urban Planning Development Agency
LDCs	:	Less Developed Countries
LPG	:	Liquefied Petroleum Gas
LPG	:	Liquefied Petroleum Gas
LUM	:	Land-use Management
LUPA	:	Land-use Planning Act
MDCs	:	More Developed Countries
NDMF	:	National Disaster Management framework
NEBOSH	:	National Examination Board in Occupational Safety and Health
NEMA	:	National Environmental Management Act
NFPA	:	National Fire Protection Association
NPA	:	National Petroleum Authority
PSO	:	Pakistan State Oil
RSA	:	Republic of South Africa
SABS	:	South African Bureau of Standard

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SANS	:	South African National Standards
SOP	:	Standard Operating Procedure
SP	:	Spatial Planning
SPLUMA	:	Spatial Planning and Land-use Management Act
UK	:	United Kingdom
UKHSA	:	United Kingdom's Health and Safety Authority
UNDP	:	United Nation Development Programme
UNISDR	:	United Nation International Strategy Disaster Reduction
USNFPA	:	United States National Fire Protection Association
WHO	:	World Health Organization

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CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND TO THE STUDY

Society is increasingly dependent on complicated man-made systems and new technologies (Ayyub 2003). According to Cutter (1993), the world will always have technocrats who try to improve the human condition by solving all environmental, medical, military and economic problems with bigger and better technology. The term 'technology' has been defined in technological research in various ways (Thierer 2014). However, for the purpose of this research, the term is defined as "an effort to organise the world for problem-solving so that goods and services can be invented, developed, produced and used" (Hughes 2004:6). The underlying assumption in this definition is that technology, and technological solutions, will only improve the human condition and not degrade it (Cutter 1993). However, this is not always the case. The 18th century industrial revolution, which marks a change of human economic conditions from an agrarian society to an industrial one, is such a historical example (Kitson & Michie 2014). Firstly, due to the negative impacts of the industrial development on the environment, characterised by thick smog and smoke which hung over cities in the United Kingdom (UK). Secondly, by the problems associated with the provision of services such as water supply, sanitation, street-cleaning and open spaces, which could not keep pace with expanding urban populations, especially after 1830, resulting in epidemics of cholera, typhoid and other diseases (Elliott 2010). Brooks (1973) argues that while the main purpose of technology is development and better living, the risk of death and destruction associated with technology is rising. In an increasingly technological society, the notion of progress persists (Kate & Kasperson 1983). However, technology can also constitute a hazard.

1.1.1. Concept of risk and its analysis in the context of petrol stations

Risk is a combination of the interaction of a hazard, exposure and vulnerability (UNISDR 2009), which can be represented by the three sides of a triangle (see Figure 1). According to Asian Disaster Preparedness Center (ADPC) (n.d) if any one of these sides of the triangle moved upwards, the area of the triangle grows larger, resulting in increased risk. In contrast, if any one of the sides the triangle drops, the area of the triangle grows smaller, reducing risk (ADPC n.d). If any of the sides of the triangle are eliminated (hazard, vulnerability or exposure) there would be no risk (ADPC n.d). This is the basic principle of risk analysis.

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Figure 1: The Risk Triangle

Source: Asian Disaster Preparedness Center (ADPC) n.d

A hazard is defined as "a dangerous event that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods and services, social and economic disruption and, or environmental damage" (UNISDR 2009:17). Technological hazards refer to a "dangerous event" (UNISDR 2009:17) that emanates from "technology invented, developed, produced and used" (Hughes 2004:6). This may include industrial pollution, nuclear radiation, toxic waste, dam failures, transport accidents, factory explosions, fires and chemical spills in petrol stations, that can result in loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption and/or environmental damage (UNISDR 2009).

In this context, petrol stations present health and safety concerns, especially the potential for fires owing to the toxicity and flammability of the liquid and gaseous products (Australia Retail Association (ARA) 2009). Petrol stations are, therefore, one type of technological invention that poses a threat to individuals, society and surrounding environments (Cutter 1993). It is for this reason that this research analyses the hazard posed by petrol stations in Stellenbosch, the extent to which this is incorporated into land-use planning, and the consequence for urban public safety.

1.1.2. Defining petrol stations

Petrol stations are critical facilities that often contain large quantities of hazardous materials (hazmat) (Australia Retail Association (ARA) 2009). Hanekom (2001), Genovese (2004) and

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Spencer (2004) believe that a petrol station could refer to any petroleum facility, service station, public garage, highway filling station and/or fuel depot that sells fuel and lubricants for motor vehicles. Mohammed et al. (2014) refer to a petrol station as any land, building or equipment used for the sale or dispensing of petrol or oil for motor vehicles. According to Ayodele (2011), nearly all petrol stations sell petrol or diesel. Some petrol stations carry specialty fuels such as liquefied petroleum gas (LPG), natural gas, hydrogen, biodiesel, kerosene, or butane, while others add shops or convenience stores to their primary business (Ayodele 2011). The potentially hazardous nature of these facilities necessitates special care in their design and location in order to avoid fires or explosions (Ahmed et al. 2011). Even though these facilities may have different names depending on the part of the world (See Table 1), the purpose remains the same (Mshelia et al. 2015): a structure or building where petroleum products are sold to motorists or other users.

Table 1: Names of fuel facility in different countries.

Country	**Name**
Australia	Service station
Canada	Garage, Fuelling station or a Gasbar
India	Petrol pump
Japan	Gasoline
Nigeria	Filling station
UK & South Africa	Garage
USA	Gas station

Source: Mshelia et al. (2015).

While noting the differences in terminology used to describe facilities selling fuel, the term consistently applied and used in this research is that of ‘petrol station’. The use of this term

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does not in any way imply petrol to be the only petroleum product sold. The term ‘petrol station’ is applied in this research because, according to UK’s Health and Safety Authority (UKHSA) (2018), petrol gives off highly flammable vapour even at very low temperatures, which makes petrol the single most dangerous petroleum product with respect to fire risk. Therefore, the use of the term ‘petrol station’ underscores the volatility of petroleum products that can easily catch fire, affecting the whole facility, as well as people and the surrounding environment. This thesis also refers to major fires, recognising that these may often be associated with explosions.

1.1.3. Basic principles of fire; fire risk and hazard at petrol stations

Fire is a rapid chemical process in which oxygen combines with another substance in the presence of a source of heat (National Examination Board in Occupational Safety and Health (NEBOSH) 2016). The reaction of these elements is called combustion, which gives off heat, light and flames (NEBOSH 2016). Before a fire can start, three components need to be present and in sufficient quantities: heat, combustible material (fuel) and oxygen (NEBOSH 2016). Heat is a source of ignition and anything that gives off heat can start a fire. Importantly, the ignition source is not necessarily a flame, spark or fire itself but the heat they give off (NEBOSH2016). Combustible material refers to any material that will ignite and burn, or will add appreciable heat to an ambient fire (National Fire Protection Association (NFPA) 2011). The described conditions are present in petrol stations and can generate fires. The storage, supply and distribution of flammable liquid and gaseous products, combined with the repeated movement of vehicles and the presence of members of the public, can lead to fires at petrol stations (ARA 2009).

Cutter (1993) argues that technological hazards arising from the individual or societal use of technology pose some very unique challenges. Most often, technological hazards spread quickly and pose some unique management challenges (Cutter 1993). This is especially the case at petrol stations (ARA 2009). For instance, the threat of technological fire hazards often results in panic (Cutter 1993). This was illustrated in October 2017, when a manager at a petrol station in Durban, South Africa, sprayed a smoking customer with a fire extinguisher (Mercury Reporter 2017). This precautionary action led to an argument between the smoking customer and the petrol station manager (Mercury Reporter 2017). Moreover, Cutter (1993) argues that because members of the public, including customers, cannot necessarily see, hear, smell or taste hazardous material, they may be unaware of the threat of fires at petrol stations. This

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makes an analysis of the fire hazards at petrol stations necessary, with a view to mitigating the potential for a disaster.

The exposed persons, infrastructure and properties at petrol stations vary in their levels of vulnerability. Vulnerability refers to the characteristics of persons, a group or properties and their situation that influence their capacity to anticipate, cope with, resist or recover from the impact of hazards (Wisner et al. 2004). The differentiation in the levels of vulnerability, although not limited to these factors, is based on characteristics such as wealth, gender, age, access to information, disability and health status etc. (Cardona et al. 2012). For instance, elderly, disabled or sick people, and those living in properties without insurance, would be more vulnerable compared to young and healthy people, or those living in insured properties. This is because old, sick and disabled people cannot move fast and find it harder to evacuate if a disaster happens. This was the case during Great East Japan Earthquake (GEJE) in March 2011, where causalities and deaths were concentrated amongst people fifty years and older (Khazai et al. 2011; Norio et al. 2011).

1.1.4. Impacts of petrol station fires on exposed and vulnerable elements: international cases

In the eastern part of Accra, Ghana’s capital city, at approximately 7:30 pm (19:30 Greenwich Meridian Time (GTM)) 2017, a liquefied gas filling station and nearby petrol station caught fire and exploded, killing seven, and injuring over 132 people (Aljazeera 2017). The explosion began at a state-owned GOIL liquefied natural gas station and spread to a Total petrol station across the street, sending a giant fireball high into the night sky and forcing frightened residents to flee to the nearby grounds of the University of Ghana (Aljazeera 2017). A number of cars were burnt as the fire spread *(*Aljazeera 2017*).* In June 2015, a blast at a petrol station near a busy downtown intersection in Accra killed more than 150 people, who were sheltering there from heavy rain and flooding (Aljazeera 2017). Furthermore, in May 2017, several people were injured when a tanker discharging natural gas exploded in the western city of Takoradi, Ghana (Agence France-Presse (AFP) 2017).

The technological fire incidents in petrol stations in Ghana are not unique. In France, more than 270 fire accidents at petrol stations were reported between 1958 and 2007 (ARA 2009). Moreover, the United States (US) National Fire Protection Association (NFPA) (2011) reported responding to an average of 5 020 fires at service or gas stations per year during a

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five-year period between 2004 and 2008. These fires caused an annual average of two civilian deaths, 48 civilian fire injuries, and $20 million in direct property damage (NFPA 2011). In China, in Shaanxi Province, an oil tanker exploded at a petrol station while it was being refilled (Newsflare 2016). The whole station then caught fire and several people, including the lorry driver and eight firefighters, were injured (Newsflare 2016). Vegetation within an approximately 50 metre radius were burnt out (Newsflare 2018).

As in factories and chemical industries, a fire at a petrol station can potentially cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods and services, social and economic disruption and, or environmental damage. Numerous studies identify the safety concerns associated with petrol stations, both in developed and developing countries (see, for example, McCarthy et al. 1998; Gattas et al. 2001; Cezar-Vaz MR et al. 2012; Monney et al. 2015). According to a World Health Organization (WHO) (2004) report, more than 2.3 million lives, and properties worth more than 4.5 billion US Dollars, are lost to fires associated with mishandling of petroleum products in African countries. Between 2007 and 2014, approximately 11 Liquefied Petroleum Gas (LPG)-related accidents in Ghana killed more than 39 people, leaving approximately 186 others with various degrees of injuries (Bokpe 2015). Similarly, roughly 41 accidents occurred between 1992 and 2003 in Korea, with 25 cases (61%) being fire and explosions related to LPG pumps (Nouri et al. 2009). In addition, according to statistics in Tehran, approximately 22 871 fire incidents were reported between 2002 and 2006, of which 480 cases were related to petrol stations (Nouri et al. 2009).

1.1.5. Impacts of petrol station fires on exposed and vulnerable elements: South African cases

There have also been several instances of fires in South Africa. On the 18th of April 2015, at 11:03 am (GMT), a petrol tanker exploded at a filling station on the N3, in Cato Ridge, in Kwazulu-Natal (ENCA 2015), but no deaths or injuries were reported. In March 2016, there was large petrol and diesel fire at the Mvoti Ultra City on the N2, near Stanger, in Kwa-Zulu Natal, in which three trucks and three homes were destroyed (Venktess 2016). The N2 freeway at the Mvoti Ultra City was completely closed to traffic because of the fire, and the thick black plume of smoke that rose from the three vehicles (Savides 2016). This fire incident was reportedly caused by spark from a generator which was used to pump diesel (Savides 2016). In Cape Town, in the Western Cape, approximately 268 fire incidence relating to petrol stations

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were recorded between 2009 and 2017 (City of Cape Town Open Data Portal 2018). Recently, during the service delivery protest in Mitchells Plain, Cape Town, a petrol station was reportedly torched by the angry protestors (ENCA 2018). However, there were no significant injuries, deaths or property damage reported (ENCA 2018; City of Cape Town Open Data Portal 2018). In light of the dangers posed by petrol stations, it is of utmost importance that a safe distance should be established between petrol stations and residential apartments, schools, shopping malls and other sensitive facilities (Zhou & Liu 2011). This can be done to get the maximum benefit from land, while at the same time minimising significant risks for urban public safety.

1.2. RESEARCH PROBLEM AND RATIONALE

There has been no research on the fire hazard posed by petrol stations in Stellenbosch or in South Africa generally. Most of the academic literature on South Africa has focused on issues relating to fuel prices and the economic benefits of petrol stations, fuel demand and health impacts (see respectively Bennett 1990; Hadland 2002; Moolla & Curtis 2013; Moolla & Curtis 2015). None of these studies relate to fire safety in and around petrol stations, despite the abundant evidence for potential fires. This may have compromised the safety of the public. A case in point for an example is the Mvoti Ultra City fire of 2016, discussed above, where three homes near the Ultra city petrol station were destroyed. This example illustrates that the potential for fires suggests that petrol stations should be at a safe distance from residential areas, commercial centres, schools, and community halls etc. However, the proximity of residential areas, commercial centres, schools, and community halls to petrol stations in Stellenbosch and elsewhere suggests that the hazard potential has not been taken into account in planning. Land-use planning has a critical role to play in ensuring the safety of the public. The purpose of land-use planning is to resolve conflicts and reduce the risks associated with the location of dangerous facilities (Smith 2004). At its simplest, land-use zoning should aim to separate densely populated areas from dangerous materials and their associated transport routes and reduce exposure to hazards through the creation of buffer zones around dangerous facilities (Smith 2004). However, the threat posed by petrol stations is poorly studied, with the result that it is often inadequately integrated into land-use planning (Walker et al. 2000). This is jeopardising the safety of the general public.

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1.3. THE AIMS AND OBJECTIVES OF THE STUDY

The aim of this research was to investigate the level of compliance with national laws governing land-use development in and around petrol stations. The research focuses on petrol stations within a six-kilometre radius of the Stellenbosch Post Office, in Stellenbosch, South Africa.

The objectives of the research were to:

a. Identify petrol stations in Stellenbosch, determine the land-use type around petrol stations, and the extent to which the positioning of petrol stations in Stellenbosch complies with international and national planning regulations.
b. Examine the risk of fires at petrol stations by observing risk behaviours and the availability of fire prevention equipment.
c. Investigate Stellenbosch Municipality's preparedness to respond in the event of a fire at a petrol station.

The results stemming from this study will be of value to the Cape Winelands District Municipality's Disaster Management Centre, Stellenbosch Municipality's fire services and the Municipality's Land-use Management (LUM) office. It can aid in policy making at various scales. It also contributes to the literature on technological hazards in South Africa, particularly the threat posed by petrol stations, and implications for planning. The research findings could assist Stellenbosch Municipality in developing comprehensive mitigation measures and responses to fires at petrol stations, as well as public awareness campaigns for communities living in proximity to petrol stations. The information generated will support effective disaster risk reduction (DRR) with respect to petrol stations. The approach could also be used to assess fire risk elsewhere in South Africa.

1.4. THESIS OUTLINE

The thesis is broken down into six chapters. This first chapter sets the scene. The second chapter provides an overview of the literature on technological hazards and the changing urban landscape characterised by the proliferation of petrol stations in urban areas. It reviews international and local literature on disasters at the petrol stations, highlighting contributing factors, as well as the role of land-use planning and disaster management in DRR. The chapter also discusses international best practices on siting of petrol stations, which frames this

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research. The third chapter provides an extensive description of the research methodology, challenges and the limitations of the study. The fourth and fifth chapters present the study results and analyse the findings with respect to themes in the literature. Chapter six provides concluding remarks coupled with recommendations on how the fire hazard posed by petrol stations can be reduced to prevent a disaster at a petrol station in Stellenbosch.

1.5. SUMMARY OF THE CHAPTER

This chapter provided the introduction to the study. It identified a need to analyse the risk of technological fire hazards at petrol stations in Stellenbosch, in order to protect and ensure the safety of people in the town. This study is the first such risk analysis for Stellenbosch, and a review of the literature suggests, for South Africa as a whole. The chapter also provided the aims and objectives of the study, study significance and how the thesis is organised. The following chapter reviews the academic literature relating to technological fire hazards.

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CHAPTER TWO: TECHNOLOGICAL HAZARDS AND THEIR MANIFESTATION IN URBAN AREAS

2.1. INTRODUCTION

This chapter examines the existing academic literature framing the research, including definitions, ideas, concepts, theories, key perspectives and critiques, and the findings of relevant studies. This study is positioned within the fields of DRR and urban planning. Birkmann et al. (2013: 194) argue that "reducing risk from hazards of natural origin is a major challenge at present". The same argument is applicable to technological hazards, particularly owing to their complexity and evolving form. Continuous technological innovation means that reducing the threat posed by technological hazards requires a flexible, dynamic DRR approach. For that reason, this chapter is concerned with the identification, assessment and reduction of disaster risks relating to the technological hazards and the implications for urban land-use planning.

The chapter starts with the definition of the key concepts such as technological hazards, DRR, land-use planning, disaster risk and risk analysis. This is followed by discussion of technological hazards, their origins and evolution in urban areas. The chapter moves on to discuss DRR approaches that can reduce the risk of fires at the petrol stations. The literature in other fields is given attention in the chapter, as it relates to the overarching approach, and specifically, to the concept of technological hazards.

2.2. DEFINITION OF THE MAJOR CONCEPTS

Hazards are " dangerous events that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods and services, social and economic disruption and, or environmental damage" (UNISDR 2009:17).

Risk is the combination of the probability of an event happening and its negative consequences (UNISDR 2009).

Technological hazards are dangerous events originating from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. These may include industrial pollution, nuclear radiation, toxic waste, dam failures, transport accidents, factory explosions, fires and chemical spills (Hewitt 1997; UNISDR 2004).

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Disaster risk refers to "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity" (UNISDR 2017: n.p). It is the likely result of the hazard occurring and resulting in damage or loss to exposed elements, be it infrastructure, social assets or human beings (UNISDR 2004; Smith 2004).

Disaster Risk Reduction (DRR) refers to a systematic effort to reduce disaster risk by minimising exposure of elements to hazards, reducing the vulnerability of people and property through better land management practices, and improving preparedness (UNISDR 2009). DRR is the policy objective of disaster risk management, and its goals and objectives are defined in disaster risk reduction strategies and plans (UNISDR 2017).

Risk analysis is a structured procedure to evaluate qualitatively and/or quantitatively the threat posed by hazards and vulnerability to their effects (Christou et al. 1999). The aim is to aid decision-making related to DRR (Christou et al. 1999). Risk analysis entails firstly, identification of hazards, and the characteristics of hazards such as their location, intensity, frequency and probability; secondly, the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and thirdly, evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios (UNISDR 2017).

Land-use planning refers to "physical and socio-economic planning that determines the means and assesses the values or limitations of various options in which land is to be utilised, with the corresponding effects on different segments of the population or interests of a community taken into account in resulting decisions" (UNISDR 2009:19).

2.3. UNDERSTANDING TECHNOLOGICAL HAZARDS

Cutter (1993) defines technological hazard as the interaction between technology, society and the environment. Cutter (1993) argues that technological hazards are a product of our society and not acts of God or extreme geophysical events. They are the product of failures in technological systems and shortcomings in the political, social, and economic systems that govern the use of technology (Cutter 1993). Smith (2004) concurs with Cutter (1993) and argues that technological hazards arise from human negligence, actions or inactions when dealing with dangerous technologies. Therefore, technological hazards are not threats 'in and of themselves', but are linked to greater social behaviours, particularly lifestyle factors which

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are likely to increase human errors in decision-making (Smith 2004). Hence, Cutter (1993) and Smith (2004) articulate technological hazards as human-induced events. For example, misinformation, ill-health, substance abuse and/or depression, amongst other factors, may affect an individual's capacity and state of mind to act timeously and correctly when dealing with technology or chemical substances, thus increasing fallibility in decision-making (Smith 2004). This may increase the probability (risk) of a potential threat (hazard) resulting in a disaster. Smith (2004) argues that technological disasters that arise from acts of terror and warfare, like the use of atomic bombs in Hiroshima and Nagasaki during WWII (History.com 2009) and the 2001 terrorist attacks in New York and Washington (National Research Council of the National Academies 2006), are examples of deliberate harmful use of technology. Smith (2004) argues that these are acts of violence and not accidents. Accidents are unfortunate incidents that happen unexpectedly and unintentionally, typically resulting in damage or injury (Oxford dictionary n.d). Therefore, Hiroshima and Nagasaki and the 2001 terrorist attacks cannot be referred to as technological disasters but sociological disasters (Smith 2004).

The term 'technological hazards' has been applied in different ways in the literature, ranging from a single toxic chemical to an entire industry like nuclear power (Smith 2004). Health risks from prolonged exposure to chemicals or dangerous waste have sometimes been conceptualised as technological hazards (Cutter 1993). Showalter & Myers (1994) have drawn attention to natural-technology (na-tech) disasters, in what they referred to as hybrid disasters. In this context, natural-technology or hybrid disasters occur when natural hazards such as earthquakes or floods result in spills of oil, chemicals or radioactive materials (Showalter & Myers 1994). The GEJE, which led to the Fukushima nuclear accident, is a classic example of a 'na-tech' or 'hybrid' disaster (Norio et al. 2011). The earthquake caused a massive tsunami which swept away structures and infrastructure (Norio et al. 2011). The earthquake and tsunami resulted in a nuclear crisis in the Fukushima Genshiryoku and Fukushima Hatsudensho and Onagawa nuclear power plants (Norio et al. 2011). These nuclear power plants are close to each other on Japan's east coast (see Figure 2). The proximity of these nuclear power plants to each other (demonstrated in Figure 2) suggest high levels of risk owing to increased hazard, exposure and vulnerability (Asian Disaster Preparedness Center (ADPC) n.d). The nuclear power plants at Fukushima Genshiryoku (also referred to as Fukushima Daiichi) and Hatsudensho (sometimes called Fukushima Daini), were severely affected by the earthquake and tsunami, resulting in radiation leaks from the nuclear reactors. These threatened local people, and polluted water, vegetables and milk (Norio et al. 2011). Onagawa nuclear power

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plant to the north of Fukushima Daiichi experienced extremely high levels of ground motion from the earthquake (Ryu & Meshkati 2014). The motion in Onagawa nuclear power plant was characterised as the strongest shaking any nuclear power plant has ever experienced from an earthquake (Ryu & Meshkati 2014). However, the Onagawa nuclear power plant was able to withstand the earthquake; it was "safely shutdown" and was "remarkably undamaged" (Ryu & Meshkati 2014). Some researchers (Peters et al. 2008; Franchina et al. 2011; Pescaroli et al. 2015) have referred to complex events such as the Fukushima incidents as cascading disasters.

Figure 2: Japan's Nuclear Energy Plants

Source: Ryu & Meshkati (2014)

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In an increasingly complex technological society, technological hazards are a growing threat to people and their environment (Krejsa 1997). This is the consequence of the globalization of production, industrialization, and the risk of accidents connected with production, processes, transportation and waste management (Krejsa 1997). These hazards are often associated with the release of dangerous chemical substances, because of accidents, or with the production of toxins when fires occur (Krejsa 1997). The most severe technological accidents have affected thousands of people, both in developed and developing countries (Krejsa 1997). The records indicate that technological accidents were first experienced or recorded in More Developed Countries (MDCs) and subsequently in Less Developed Countries (LDCs) (Smith 2004). Table 2 shows some examples of recorded technological accidents, the location and year in which they occurred, and their impact. According to Silei (n.d:n.p) in "the 19th century, more especially after the second half of the century, industrial accidents, maritime disasters, railway and public transportation wrecks became unavoidable aspects of most advanced societies". These accidents resulted in the introduction of technological disaster risk reduction measures through policy intervention and legislation.

Table 2: Technological disasters in MDCs and LDCs

Developed countries		Year	Type of incident	Impacts
	London England	1666	Structure fire	Approximately 13 200 houses burned down
	Puente's Spain	1802	Collapse of the Dam	More than 608 people died
	Halifax Canada	1917	Cargo explosion	More than 1200 people died
Developing countries				
	Brazil	1984	Petroleum Spillage	Aproximatel 500 deaths
	Mexico	1984	Liquidified petroleum gas leakage	More than 452 people died and over 300 000 left homeless
	India Bhopal	1984	Toxic gas leakage from an urban factory	2000 deaths, 34 000 eye defects and 200 000 people displaced

Source: Smith (2004)

As Silei (n.d:n.p) concisely puts it, "all these disasters contributed to place the question of the adoption of safety standards in legislation and policy decision-making to prevent further accidents and insure the safety of persons". Comprehensive safety laws to reduce industrial disasters were developed in MDCs in the 1970s (Smith 2004). For example, the UK passed a Health and Safety at Work Act in 1974 to improve industrial safety (UK Government 1974). With regards to fire, MDCs improved fire regulations and the efficiency of fire-fighting services (Smith 2004). Even with such developments, however, technological disasters

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continued to increase (Smith 2004). Technological disasters were first recorded in LDCs in late 1970s and early 1980s, owing to proliferation of new technologies, which was facilitated by the process of industrialization and an era of mass consumption (Silei n.d.; Krejsa 1997). The LDCs experienced similar problems in relation to the management of these new technological developments, owing to their inexperience in managing the negative externalities emerging from new technological innovations (Smith 2004). Silei (n.d) refers to this process as the globalisation of technological hazards and risk. The year 1984 was a turning point, when three industrial accidents in LDCs resulted in about 3 500 deaths, leaving over 200 000 people homeless (Smith 2004). The incident in Bhopal, India in 1984 is singled out as the world's deadliest industrial accident (Smith 2004). The other two incidents were a petroleum spillage in Campos Basin, Rio de Janeiro, Brazil, and an LPG gas explosion in San Juan Ixhuatepec, Mexico City. "These three technological disasters resulted in more deaths in one year than all technological disasters combined since WWII" (Smith 2004:233).

South Africa has also experienced technological disasters. The recent explosion at a Denel munitions depot near Somerset West on the 3rd of September 2018 is an example. The explosion resulted in eight deaths, four injuries and nearby property damage (Evans 2018). The plant contained 400 buildings, each with blast walls to prevent a chain reaction in the event of an explosion, but the explosion destroyed an entire building and surrounding blast walls (Gous & Hyman 2018). The plant is reportedly one of the largest of its kind in the world and is South Africa's only large-calibre munitions production facility (Gous & Hyman 2018).

Technological hazards have changed over time and space with the evolution, and increasing sophistication, of technology forming components of complex urban systems (Iossifova 2016). The emergence of cars as the popular mode of road transport created new hazards (Rodrigue 2017).The introduction of the internal combustion engine in the 1800s resulted in the large-scale mechanization of transportation modes, especially road transport (Rodrigue 2017). This was followed by the proliferation of cars, buses and trucks and the establishment of vast highway networks (Rodrigue 2017). The increase of urban populations and growth in the number of cars and other vehicles increased demand for fuel, and by extension petrol stations, and expansion of the petroleum industry (Mohammed et al. 2014). Petrol stations are now a common feature in urban centres across the world (Monney et al. 2015). However, petrol stations are associated with hazards, and as Table 3 shows, there have been many disasters at petrol stations globally.

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Table 3: Examples of disasters at petrol stations globally

Year (s)	**Country**	**Fatalities and injuries**
1958 & 2007	France	A total of 270 fire accidents (ARA 2009)
2004 & 2008	United States (US)	An average of 5 020 fires at service or gas stations per year
2009 & 2017	South Africa (Cape Town)	No significant injuries, deaths or property damage reported (ENCA 2018; City of Cape Town Open Data Portal 2018)
2015	South Africa (Kwazulu-Natal)	Approximately 3 trucks & 3 homes were destroyed (Venktess 2016)
2015	Ghana (capital city Accra)	More than 150 killed (Aljazeera 2017)
2016	China	Several people, including the lorry driver and 8 firefighters, were injured (Newsflare 2016).
2017	Ghana (eastern part of capital city Accra))	Approximately 7 people killed, 132 seriously injured (Aljazeera 2017).
2017	Ghana (western city of Takoradi)	Unknown injuries (Aljazeera 2017)

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2.4. PETROL STATIONS AS HAZARDS

While the causes of fires vary, Ahmed et al. (2011) categorise underlying causal and amplifying factors as social, technical, political, economic, administrative and institutional. According to Ahmed et al. (2011) failures in human behaviours, lifestyle and processes are the primary causes of fires at petrol stations. In Pakistan, for example, Pakistan State Oil (PSO) reported 130 minor accidents at petrol stations between July 2002 and June 2007, with the primary cause identified as negligence (Corporate Environment Report 2007). In Malaysia, on the other hand, 224 cases were attributed to carelessness in 2008 (Ahmed et al. 2011). Mechanical faults and small petrol leakages also contributed to fire ignitions in Malaysia (Ahmed et al. 2011). Electrostatic charges generated by the human body can also cause fires (Ahmed et al. 2011). Once the electrostatic charges interact with weather, clothing, and car seat material (Babrauskas 2003 & 2005), people can start fires accidentally just by entering and exiting their vehicle during refuelling (Renkes 2004). Hazmat trucks also pose a threat during their operation and maintenance (Melcheersa 2001). In Malaysia, for instance, a hazmat truck driver felt dizzy and fell while filling his vehicle, resulting in a fire (Ahmed et al. 2011). Ahmed et al. (2011) also describe a fire caused by a petrol attendant who collapsed due to a heart attack.

2.5. PLANNING AND RISK GENERATION

The impacts of technological accidents are increased where there is development in proximity to dangerous sites, such as where petrol stations are in densely populated areas (Christou et al. 1999). However, it appears that hazard potential is not always considered systematically when locating petrol stations, increasing the exposure of surrounding communities. In countries where planning regulations are available, they are often not properly implemented (Christou et al. 1999), hence the extensive damage at petrol stations reported in many countries (NFPA 2011; WHO 2004; Bokpe 2015 etc). Examples from Ghana are used often in this section to demonstrate the significance of the links between planning and risk generation.

For example Oteng-Ababio (2016:402), studying the Melcom disaster, in which the six-story Melcom shopping centre collapsed in Accra, Ghana, in 2012, notes that “technological incidents are easily forgotten which signifies the inevitable broader social consequences and penalty people pay for the lack of institutional memory, learning and risk preparedness”. He argues that these consequences indicate weak institutional arrangements for DRR, characterised by a fragmented approach (Oteng-Ababio 2016). For example, he found that the

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development planning process in Ghana does not include local inter-agency cooperation amongst institutions or departments at the local government level, despite Section 12 (1) of the local government law, Act 462, stipulating that local government institutions be involved in development planning processes in Ghana (Oteng-Ababio 2016). According to Oteng-Ababio (2016), the development planning process in Ghana is dominated by central government agencies. This means that institutions or departments at national level make most development planning decisions, often in a siloed manner, and exclude institutions or departments at the local government level. He attributes the collapse of the Melcom building to the lack of inter-agency cooperation between central government and local government agencies (Oteng-Ababio 2016). In addition, while the Town and Country Department, the Survey Department and the National Development Planning Commission are required by law to collaborate in their planning role, this legislation does not clearly recognise DRR as a concern (Oteng-Ababio 2016). The likely consequence of this individualistic development approach is failed development. Pelling (2003: ii) argues that "disasters can result in failed development, but failures in development planning can also lead to disaster risk". This was the case in the Melcom disaster in Ghana. Even the director of planning in the Kumasi Metropolitan area admitted that, in many instances, after acquiring the land, developers build without the planning permission (Yeboah & Obeng-Odoom 2010), signalling weak institutional arrangements.

Satterthwaite (2011) argues that properly governed cities with strong institutions can significantly reduce the likelihood of disasters, as well as their magnitude. In 2014, speaking at the General Assembly Informal Thematic Debate on Disaster Risk Reduction, United Nation's (UN) Secretary-General Ban Ki-moon (United Nations Office for Disaster Risk Reduction (UNISDR) 2014: n.p) argued "the more governments, UN agencies, organisations, business and civil society understand risk and vulnerability, the better equipped they will be to mitigate disasters when they strike and save more lives".

However, such institutional learning and risk preparedness should be embedded within an integrated DRR approach. For that reason, it is essential that disaster risk reduction is mainstreamed into development and land-use planning at the national, provincial and local level (Sutanta et al. 2012). Land-use planning can help to mitigate disasters and reduce risk by "discouraging high-density settlements and construction of key installations in hazard-prone areas, control of population density and expansion, and in the siting of service routes for

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transport, power, water, sewage and other critical facilities" (UNISDR 2009:19). Sutanta et al. (2012) argue that land-use planning can play a fundamental role in DRR by ensuring that it:

a. Prevents current and future development in highly dangerous areas
b. Classifies different land into classes based on exposure and the level of risk
c. Makes land-use categories legally binding, including criminalising unauthorised development in hazardous zones

However, although there is clear evidence of the relationship between the two fields (land-use planning and disaster management), and shared concern for ensuring the safety of people and their environment (Britton & Lindsey 1995), land-use planning and disaster management remain largely siloed. A typical example is Ghana's case of the Melcom disaster demonstrated above (Oteng-Ababio 2016). Britton & Lindsey (1995) argue that land-use planning concentrates on development priorities, with little, if any, attention to risk reduction. For example, land-use planning often focuses on accommodating the increasing urban population and promoting economic development, through housing projects, conservation of the natural environment, and upgrading of the debilitated urban structures.

2.6. PERSPECTIVES ON THE SITING OF PETROL STATIONS

According to Mahmood et al. (2015), petrol stations should be located not only in places where they are accessible, but also cause as little danger and congestion as possible. This means the installation of petrol stations should be in line with the principles of DRR (Sutanta et al. 2012), while at the same time meeting the development demands of population increase, economic development, nature conservation and urban renewal (Britton & Lindsey 1995). Such an integrated approach would effectively bridge the existing disconnect between land-use planning and DRR, promote sustainable development, and ensure the safety of the public. The location of petrol stations in densely populated areas, where they pose a threat to local communities, goes against DRR and sustainable development principles, with serious implications for public safety.

Research indicates that over concentration of petrol stations in a small area within a city has resulted in problems like traffic congestion, health risks, fires and explosions, and in some cases, hampered emergency response (Sur & Sokhi 2006; Sangotola et al. 2015). For example, the government of Ghana argues that installing too many petrol stations in Accra and other major cities in Ghana is unsafe and unsustainable (Myjoyonline 2016). The petrol station fire

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in Accra in 2015, which led to seven civilian deaths and injured over 132 people (Aljazeera 2017), could arguably have been associated with the high number of petrol stations in Accra in proximity to housing developments. Following this fire, the National Petroleum Authority of Ghana (NPA) established new regulations on the siting and operation of filling stations in the country, as a risk reduction measure (Myjoyonline 2016). The NPA of Ghana directed that no filling stations can be built less than 200 meters away from a residence (MyJoyOnline 2017).

Smith (2004) and Mshelia et al. (2015) argue that facilities such as petrol stations in the urban environment should be located away from schools, hospitals and densely populated areas. However, they do not indicate how far away these should be, as they recognise the distance may be influenced by local context and conditions. Moreover, they observe that, globally, there are no universal standards with respect to exactly how far away petrol stations should be from other developments. Mshelia et al. (2015) argue that safe distances should be determined through a scientific risk assessment, where countries develop their own specific set of requirements, guided by their own legal land-use framework and risk assessment approaches.

In South Africa, there is legislation guiding land-use planning. This is informed by the broader principles in South Africa's Constitution (South Africa (Republic of) 1996). Land-use planning is regulated by legislation at all three spheres of government in the Western Cape:

a. National level: The Spatial Planning and Land-use Management Act, 2013 (Act 16 of 2013) (SPLUMA) and the Municipal Systems Act, 2000 (Act 32 of 2000)
b. Provincial level: The Western Cape Land-use Planning Act, 2014 (Act 3 of 2014) (LUPA) and the Western Cape Land-use Planning Act Regulations, 2015
c. Local level: Municipal Bylaws (Western Cape Government 2018)

SPLUMA broadly encompasses spatial planning, land-use management, land development management principles, and norms and standards that should be developed by all municipalities (South Africa (Republic of) 2013). Flowing from these broader principles of the SPLUMA is the LUPA which outlines different functions of municipalities (South Africa (Republic of) 2013). Chapter 2 Section (2) of LUPA, argues that municipalities must regulate, among others, the development, adoption, amendment and review of a zoning schemes, and the enforcement by the Municipality of its by-laws and decisions regarding land-use planning (Western Cape Government 2018). However, Stellenbosch Municipality does not have local standards with respect to the siting of petrol stations in its zoning scheme and land-use planning by-laws. On

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the other hand, the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (hereafter referred as GDoACELA) has a set of procedures for siting petrol stations (Environmental Impact Assessment 2002). These guidelines are known as Environmental Impact Assessment (EIA) Administrative Guidelines for the Construction and Upgrading of Filling Stations and Associated Tank Installations and were developed in March 2002 (EIA 2002). The EIA guidelines stipulate that new petrol stations will not be approved where they are:

a. within 100 metres of residential properties, schools, or hospitals, unless it can be clearly demonstrated that there will be no significant noise, visual intrusion, safety concerns or fumes and smells;
b. within three kilometres of an existing filling station in an urban, built-up or residential area (and within 25 kilometres driving distance of an existing filling station in other instances, such as in rural areas, and along highways and national roads); or
c. within a sensitive area such as wetlands, alongside rivers etc.

According to Kruger (2012) the limitation on the distance between filling stations outlined above was influenced by international experience, views of interested persons and legislative obligations under Environment Conservation Act (ECA) and National Environmental Management Act (NEMA). Therefore, while this is a Gauteng-based guideline, the guideline reflects good practice regarding the siting of petrol stations (Kruger 2012).

2.7. INTERNATIONAL BEST PRACTICES ON THE LOCATION OF PETROL STATIONS.

Countries follow different risk assessment methodologies including a consequence-based approach, a risk-based approach and use of generic distances (Christou et al. 1999). The consequence-based assessment methodology focuses on several conceivable event scenarios, while the risk-based assessment methodology assesses the probability of the possible event scenario (Christou et al. 1999). The generic safe distance approach focuses on the type of activities instead of a detailed risk analysis of land-use type (Christou et al. 1999). This is derived from an expert judgement mainly based on historical experience, the effects of similar establishments, or environmental impact of a plant or installation (Christou et al. 1999). It is based on the principle that land-uses which are not compatible with each other should be separated by a buffer distance (Christou et al. 1999). However, they do not stipulate what these

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buffer distances should be, as the extent depends on the type of industrial activity or quantity and type of hazardous substance involved (Christou et al. 1999). In Spain, for example, Spanish scientists calculated the levels of an aromatic compound (benzene) and a hydrocarbon (n-hexane) at three Murcia petrol stations, near the petrol pumps and surrounding areas, to determine the distance at which the petrol stations can be considered hazardous (Mail online 2011). The analysis considered several factors, such as the number of petrol pumps, the amount of fuel drawn from them, traffic intensity, the type of surrounding buildings, and weather conditions (Mail online 2011). Based on their assessment they concluded that a minimum distance of 50 metres is required between petrol stations and housing developments (Mail online 2011). They also concluded that 'especially vulnerable' facilities such as hospitals, health centres, schools and old people's homes, should be at least 100 metres away (Mail online 2011). In Nigeria, the Department of Petroleum Resource (DPR) stipulates that a petrol station should be located a minimum of 50 meters away from built-up areas, to create a buffer zone devoted to non-residential land-use (DPR 2007). Petrol stations should be at least 100 meters from schools, hospitals, theatres, clinics and other public and semi-public buildings (DPR 2007). The regulations state that there should be a distance of at least 15 meters from the edge of the road to the nearest pump (DPR 2007). In addition, the DPR states that petrol stations should be located at least 400 meters apart (DPR 2007). To approve a new development, they stipulate that there should be no more than four other petrol stations within a two-kilometre radius of the proposed site (DPR 2007).

The safe distance assessment approach followed by the GDoACELA in South Africa, Ghana, Spain and Nigeria respectively suggests a consensus. First, petrol stations should be no nearer than 50 metres from residential buildings, and there should be a distance of at least 100 meters between petrol stations facilities such as hospitals, health centres, schools and old people’s homes. Secondly, there should be minimum safety distance between petrol stations. In South Africa’s GDoACELA guidelines, a minimum safety distance is three kilometres (EIA 2002), while it is two kilometres in Nigeria (DPR 2007). The following section discusses the extent to which the international community adheres to these good practices.

2.8. ADHERENCE TO GLOBAL BEST PRACTICES AND THE REASONS

Globally, many countries do not seem to adhere to the standards. For example in Nigeria, research conducted at approximately 153 petrol stations in the Niger Delta Region shows that only 35 (23%) petrol stations conform to the DPR (2007) guideline of 400 metres between

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stations, while 118 (77%) were in breach of the guideline (Arokoyu et al 2015). Moreover, only 50 (33%) petrol stations conformed with the rule that the nearest pumps should be at least 15 meters away from the edge of the road; 103 (67%) petrol stations did not (Arokoyu et al 2015). Similar cases were identified in the townships of Maiduguri and Jere (Mshelia et al 2015). However, this phenomenon is not unique to Nigeria. In Accra, Ghana, a survey of 33 petrol stations found that 60% were built less than 200 meters away from a residence (Baffour et al n.d). In the province of Baghdad, in Iraq, it was discovered that the location of petrol stations did not consider the standards and requirements established by the competent authorities (Mahmood et al. 2015).

The literature advances varying reasons for non-compliance with good practices. The Kaduna State Urban Planning Development Agency (KASUPDA) found that there was a high demand for land for services, including petrol stations, in Nigeria's many cities (Tah 2017). This often resulted in a scramble for land and the building of illegal petrol stations. This has led to haphazard development and the deliberate location of petrol stations in unsuitable areas that are highly exposed to hazards (Tah 2017). In addition, petrol stations are a lucrative business in Nigeria (Mshelia et al 2015), creating incentives to bypass the rules (Mshelia et al 2015). In the province of Baghdad in Iraq, non-conformity with the planning standards for the distribution of petrol stations has jeopardised the safety of surrounding developments (Mahmood et al. 2015). According to Mahmood et al. (2015:854) "this has led to the planning problems which adversely affect the role of the fuel stations in the provision of service to the citizens". While Mahmood et al. (2015) do not explicate these standards; they indicate population density of the area as factor which should be considered when locating petrol stations. This appears, not to have been considered in the province of Baghdad in Iraq as distribution pattern of petrol stations suggest discrepancy in the spatial distribution (Mahmood et al. 2015). This failure to meet guidelines places in jeopardy developments around petrol stations. In this context, institutional capacity to anticipate and prepare for potential emergencies at the petrol stations is necessary. The following section discuses a framework for disaster preparedness.

2.9. INSTITUTIONAL DISASTER PREPAREDNESS FOR EFFECTIVE RESPONSE: A CRITICAL COMPONENT OF DRR

The challenge to reduce the impact of disasters and make risk reduction an important element of development policies and programmes is outlined in the Hyogo Framework of Action (HFA)

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2005-2015 (UNISDR 2008). The HFA called for countries to pursue three strategic goals aimed at (1) integrating DRR into sustainable development policies and plans and (2) creating institutions and capacities to build resilience and systematically incorporate risk reduction plans into disaster preparedness (UNISDR 2008). The Hyogo Framework also defined five priorities for action with the fifth priority being disaster preparedness for effective response in all spheres. The framework further outlined in this regard collective and individual roles and duties of the key stakeholders with government being the critical role player in any country's disaster situation.

The HFA provides a framework on how to meet the challenge of being prepared to. While land-use planning can help to mitigate disasters and reduce risk (Sutanta et al. n.d), disaster preparedness can help to anticipate and respond effectively to the impact of likely, imminent or current hazard events or conditions (UNISDR 2008). This is a critical component of DRR (Coppola 2015). However, it should be supported by formal institutional, legal and budgetary capacities (UNISDR 2008). Many different entities and individuals should conduct disaster preparedness activities, including emergency response agencies, government workers, businesses and the public (Coppola 2015: 275). Preparedness to respond to disasters includes engaging in a variety of activities such as Emergency Operational Planning (EOP), exercises and drills, developing warning systems and public education etc. (Coppola 2015). This includes knowing what to do in a disaster's aftermath, how to do what needs to be done and being equipped with the right tools and information to act effectively.

Responding to any disaster is guaranteed to be unique, complex and confusing, hence it is good practice for institutions to engage in emergency and disaster response planning, which establishes clear jurisdictional roles and responsibilities (Coppola 2015). The onset of a disaster is not the time to start planning. The most systematic approach used to plan for disasters is through the creation of an emergency operational plan (Coppola 2015). This should be followed by exercises and drills. Exercises potentially reemphasize points made in training programmes, and test the system, exposing gaps that otherwise might have been overlooked (Coppola 2015). Drills are most effective when they mimic real-life situations (Coppola 2015). Rehearsing response procedures also provides opportunities for the evaluation and improvement of preparedness plans (Twigg 2004; Coppola 2015).

There are a range of other factors that are critical for preparedness. Equipment, such as fire suppression tools designed to limit the spread of fires, increases the effectiveness of response

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agencies (Coppola 2015) - although access to this equipment is driven by resources. Public education is the backbone of effective public preparedness efforts. This involves creating public awareness about hazards and risk (Coppola 2015). Once the public is made aware, they are likely to change their behaviour to reduce their exposure to hazards and their overall vulnerability to their effects (UNISDR 2008). Warning systems must be designed to reach a full range of possible recipients within their communities (UNISDR 2008). These preparedness activities are explored in Chapter 5 and further discussed critically in the context technological fires at petrol stations in Stellenbosch.

2.10. SUMMARY OF THE CHAPTER

The chapter examined areas of literature which have shaped the research: the definition of the major concepts such as technological hazards, DRR, land-use planning, disaster risk and risk analysis. It discussed technological hazards and disasters in the urban context, their causes and impacts and how they have changed with time and space globally, including the growth in the petroleum industry, and by extension petrol stations. Both local and international literature suggests that petrol stations create the risk of fires and indicate a need for careful risk assessment to guide the development of such facilities. The literature also highlights the need for the integration of DRR into land-use planning to ensure sustainable and safe development around petrol stations – although the fields remain siloed in most countries. Local and international guidelines for the location of petrol stations were explored, with a view to identifying good practices. These suggest that petrol stations should be 50 metres from residential buildings, and at least 100 metres from facilities such as hospitals, health centres, schools and old people's homes. Petrol stations should also be at least two kilometres apart. These good practice guidelines will be further explored in the context of Stellenbosch in Chapter 4.

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CHAPTER THREE: RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter outlines the research approach and methodology followed to achieve the research aim and objectives. It describes the study area in some detail and the criteria used to select the study area. The chapter further describes the approach to data collection and analysis and reflects on the limitations of the study. The chapter concludes with a discussion of the ethical considerations related to the study.

3.2. GEOGRAPHICAL LOCATION OF THE STUDY AREA

Stellenbosch is located in the Cape Winelands District Municipality in the Western Cape Province, South Africa (see Figure 3). It is situated approximately 50 kilometres from Cape Town, along the banks of the Eerste River, and is flanked by the N1 and N2 highways (International Federation of Library Association and Institution (IIFLA) 2015). The town's global positioning coordinates system is -33° 55' 55.5816" South (S) and 18° 51' 36.5436" East(E) (IFLA 2015).

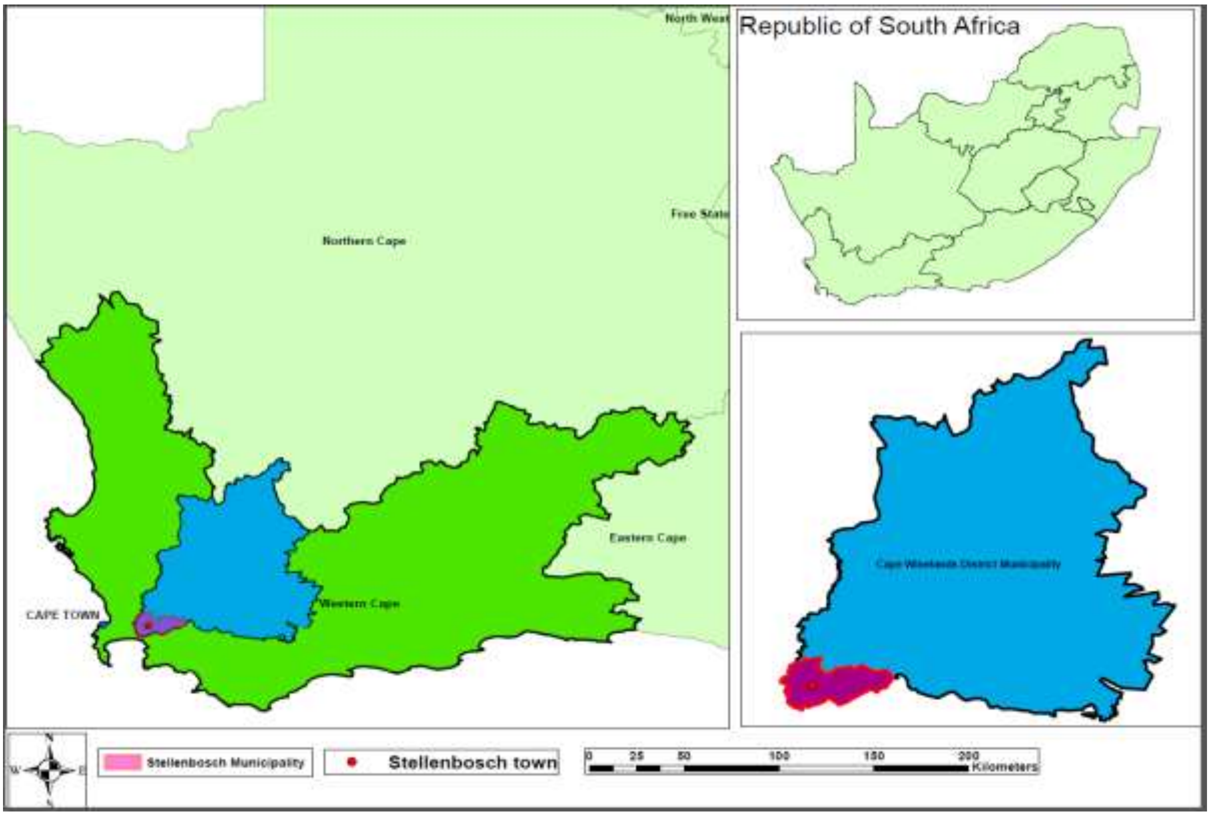

Figure 3: Location of Stellenbosch in Western Cape, South Africa.

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3.3. GEOGRAPHICAL CONTEXT OF STELLENBOSCH

The town was established in 1680 by the Governor of the Cape, 28 years after the establishment of Cape Town (Nicks n.d). The town resembles the pre-colonial settlements of the land along Eerste River whose main aspects were in place by 1710 (Nicks n.d). Its streets were aligned at right angles to the contours and furrows for irrigation and drinking water to flow to each property (Nicks n.d). Buildings were built along the edges of the blocks so as reduce their impact on land for cultivation (Nicks n.d). This planning pattern reflected proximal links with the natural environment that the town relied upon for water, food, fibre and building material (Nicks n.d). During this period energy requirements were very limited, water moved by gravity and transport was supplied by animals. There were no cars, trucks, pumps, generators and refrigerators (Nicks n.d). This meant that the need to travel and transport goods had to be minimised (Nicks n.d).

The beginning of the modern economy in 1870's in South Africa advanced regional transport, beginning with the railways (Nicks n.d). There was greater mobility of commuters and freight (Nicks n.d). Stellenbosch was not affected by these major changes until 1920's (Nicks n.d). The first major changes following the 1920's in Stellenbosch includes the advent of motor cars for those who could afford them, post union transformation of local government and the emergence of scientific town planning, as well as advancement of urban engineering technology (Nicks n.d). At this point, Stellenbosch town spread into the surrounding countryside as walking distances were no longer a constraint (Nicks n.d). The second major changes in spatial planning of Stellenbosch was under the apartheid period which was characterised by the emergence of areas such as Franschhoek north, Cloetesville, Idas Valley and Kayamandi (Nicks n.d). During this period, the area demarcated today as Stellenbosch Municipality fell into three jurisdictions: Stellenbosch (town) Municipality, Franschhoek Municipality and Stellenbosch Divisional Council (Nicks n.d). The third set of changes occurred after 1994. The three municipalities were amalgamated into one (Stellenbosch Municipality), forming part of the Cape Winelands District Municipality (Nicks n.d). The existing design of the Stellenbosch town today is influenced by the town's historical planning.

3.4. DESCRIPTION OF THE STUDY AREA: THE TOWN OF STELLENBOSCH

The town of Stellenbosch is the second oldest colonial town in South Africa, after Cape Town, and is one of the smallest towns in the Western Cape, South Africa (Academic Consortium 21 (AC21) 2014). It covers an area of approximately 812 square kilometres

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with a population of more than 167 572 people (Stellenbosch Municipality IDP 2016/17). The study examined petrol stations in Stellenbosch situated within a six-kilometre radius from the town's centre. Stellenbosch was used because it is relatively a small town and was easily accessible to the researcher.

There are approximately 18 petrol stations in Stellenbosch. However, the study selected nine petrol stations that fall within a six-kilometre radius from the town centre, measured from Stellenbosch's central Post Office. The Post Office's global positioning coordinates system are -33° 55' 55.5816" South (S) and 18° 51' 36.5436" East(E) (IFLA 2015). A six-kilometre buffer from the post office was created in ArcMap and petrol stations falling within this area were selected as study sites. The six-kilometre buffer from the post office was determined using a shapefile for Stellenbosch, obtained from Stellenbosch University's Centre for Geographic Analysis (CGA). However, Google Earth was used to identify the location of the relevant petrol stations. The following nine petrol stations were identified and mapped in ArcMap (Figure 4). Figure 4 shows the location of petrol stations in the study area.

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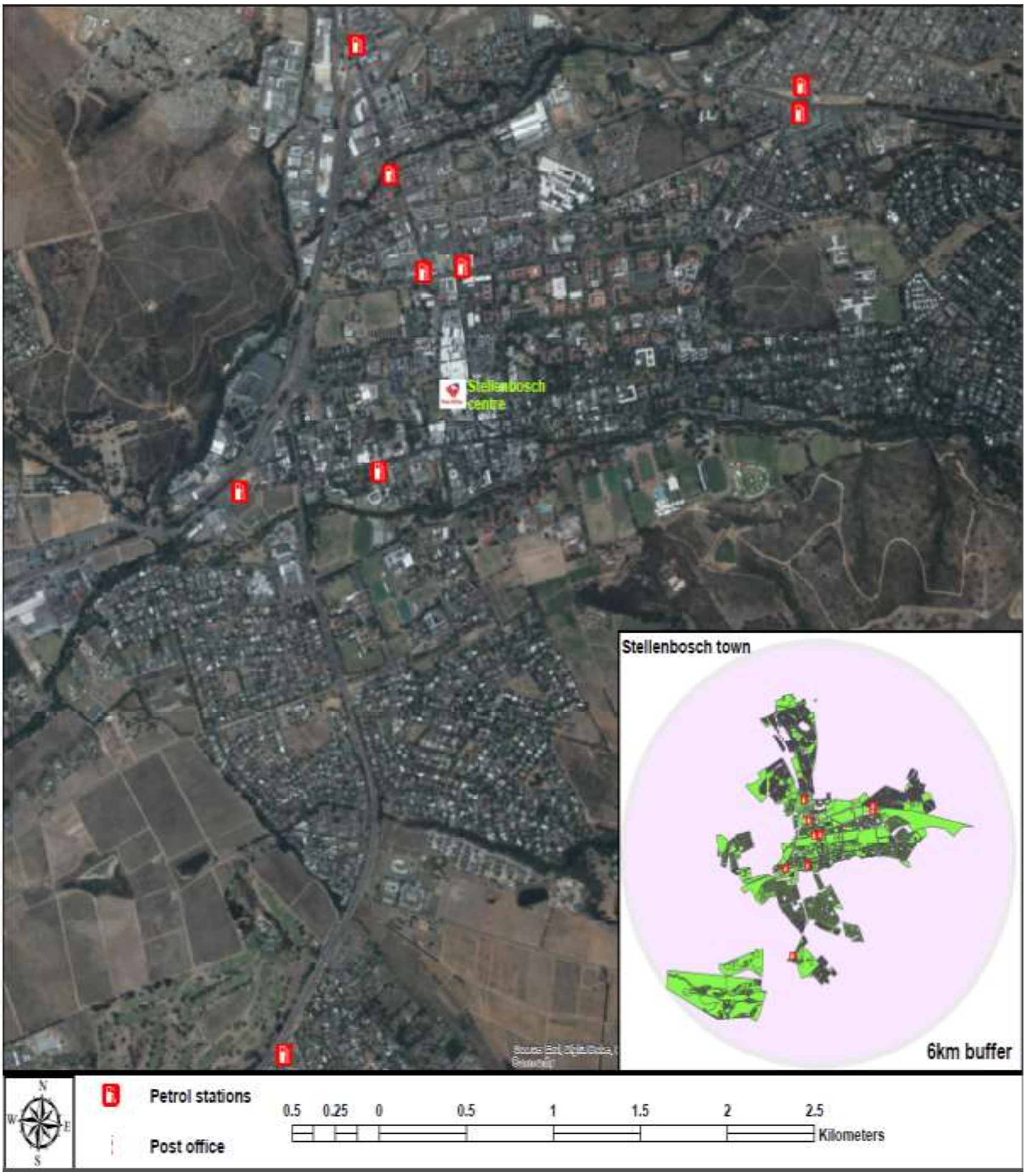

Figure 4: Location of the petrol stations in Stellenbosch

3.5. DATA COLLECTION AND ANALYSIS

This study used a two-prong or mixed research approach consisting of the collection and analysis of geospatial data and qualitative data collection and analysis. Qualitative data collection methods study things in their original settings, to make sense of or interpret phenomena in terms of the meanings people bring to them (Denzin & Lincoln 2011). This was

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complemented by geospatial data collection, which examines the distribution and location of geographical data over space and time (Lwin et al. 2014).

Mixed research methods "…combine the methods in a way that achieves complementary strengths and non-overlapping weakness" (Johnson & Owuegbuzie 2004:18). The main reason for using a two-prong approach was thus to combine the strengths of methods while at same time addressing the weakness of each. For example, geospatial data was used in this study to identify the location and distribution of geographical objects, such as natural or constructed features; however, this does not provide insight into why built features are positioned as they are (Johnson & Owuegbuzie 2004). A qualitative approach provides useful supplementary data. In this study, the qualitative research sought to understand the rationale for the location and distribution of features. It also sought to investigate the legislative environment, the institutional infrastructure and land-use decisions governing the development of petrol stations, and planning for responding to petrol station fires. Finally, the researcher visited all the petrol stations to collect observational data on each site.

3.6. QUALITATIVE DATA COLLECTION

Two qualitative data collection instruments were used. The first comprised an open-ended interview schedule for key stakeholders and the second an observational data collection matrix.

3.6.1. In-depth interviews

In-depth interviews were conducted with four key governmental role-players from Stellenbosch Municipality's Disaster Management (DM) function, Fire Prevention (FP) also referred to as Fire Service (FS) generally known as Stellenbosch Fire and Rescue Services, Land-use Management (LUM) and the Traffic Department. An interview was also conducted with experts from a planning unit at Stellenbosch University. The in-depth interviews were conducted using a semi-structured interview guide, containing open-ended questions. The interview with DM focused on preparedness plans to respond to emergencies at petrol stations, awareness programmes regarding fire hazards for communities living close to petrol stations, as well as institutional roles and responsibilities with respect to responding to fire emergencies. An in-depth interview with FP/FS was also conducted to understand their role in fire emergency management, obtain statistics on fires at petrol stations and explore emergency response challenges. The in-depth interviews conducted with the Municipality's LUM and the planner from Stellenbosch University focused on understanding land-use rules, guidelines and

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regulations, as well as legislation informing the siting of petrol stations in relation to other facilities. Interviews with the Traffic Department sought to establish routes with high volumes of traffic through Stellenbosch, escape options and the implications for emergency response services, as well as their role in planning decisions.

The interviews were recorded with a tape recorder and notes taken in writing. A deliberate or purposeful sampling approach was used. This involves targeting participants specifically for their knowledge and insight with respect to the research questions (Ravitch & Carl 2016). The in-depth interviews were transcribed by the researcher. Through the process of interviews and transcription, the researcher became familiar with the data and thus was able to identify emerging themes across the data from the start. The emerging themes were compared to the broader theoretical literature to identify gaps and complementary and contrasting findings.

3.6.2. Observational data collection

Data was also collected through observation. Observation is a data collection technique that can be either structured or unstructured (Punch 2014). The observation was structured using an adapted version of the South African Bureau of Standards (SABS) Petrol Station Fire Safety Standards checklist. The observation was carried out for approximately 15-30 minutes. The length of the observation depended primarily on how busy a petrol station was. In busy petrol stations a maximum time of 30 minutes was spent observing. While the methodology initially included a survey of petrol station managers, scoping research found that managers were wary of and reluctant to speak to the researcher, despite a letter of support provided by his supervisor. For this reason, the research focused only on the facilities visible in and around the precinct of petrol stations. The checklist assisted in identifying hazards, risk behaviours, fire prevention and fire suppression equipment at petrol stations.

The SABS is a statutory body that was established in terms of the Standards Act, 1945 (Act No. 24 of 1945) and operates in terms of the latest edition of the Standards Act, 2008 (Act No. 8 of 2008). As the national standardisation institution in South Africa, it is mandated to:

a. Develop, promote and maintain South African National Standards (SANS)
b. Promote quality in connection with commodities, products and services
c. Ensure conformity in assessment services and requirements established in terms the Standard Act (SABS n.d).

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The SABS checklist was adapted to comprise variables that could be assessed through observation alone, and incorporated international good practices identified in the literature. The adapted Petrol Station Fire Safety Standard Checklist was structured into two components which focused on risk behaviours and fire prevention at petrol stations. Risk behaviours focused on technical factors and human behaviour that could potentially cause fires at petrol stations such as smoking, open flames etc. Fire prevention mechanisms included observation of (a) existing fire safety measures, (b) control of ignition sources or sources of fuel, (c) fire detection and warning, and (d) means of escape (see Appendix E). Photographs were also taken on sites.

3.7. GEOSPATIAL DATA COLLECTION AND ANALYSIS

The geospatial data collection sought to identify the spatial location and distribution of petrol stations in Stellenbosch. It also sought to compare the location of these petrol stations in relation to fire emergency response services, hospitals as well as developments such as residential apartments, schools, community halls etc. The geographic location of petrol stations in the study area was determined using Google Earth and confirmed with a mobile GPS handset during visits to each station. The GPS points, presenting both latitude and longitude, were compiled in an Excel spreadsheet and converted to decimal degrees (DD) to make them compatible with ArcMap. The following formula was used:

***Latitudes*: "(Degree South+ (Minutes South/60) + (Seconds south/3600))"**
***Longitudes*: "Degree East+ (Minutes East/60) + (Seconds East/3600))".**

Source: Centre for Geographical Analysis (CGA) extracted from an Introduction to GIS Guide Book (n.d)

After conversion into decimal degrees, the excel spread was saved in .csv file format compatible with ArcMap. The .csv file was then imported into ArcMap to show petrol stations as geographical points or features. Shapefile for the town of Stellenbosch, roads and streets were acquired from CGA. The six-kilometre radius from the Post office was determined using the Stellenbosch shapefile. A 2017 recently updated buildings shapefile compiled by Eskom was obtained from Umvoto Africa (Pty) (Ltd) on 22 of November 2017. Umvoto was identified through Internet search for GIS consulting companies. They provided the required data free of

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charge. The Eskom buildings layer covers the Western Cape and Eastern Cape Provinces. The Eskom buildings falling within the study area were extracted in ArcMap using a geo-processing tool.

3.6. LIMITATIONS OF THE STUDY

The study encountered the following challenges. Firstly, the Eskom buildings shapefile layer excluded new developments and did not represent all land-use types around petrol stations. Some land-use had to be identified manually on Google Earth and through site visits. Secondly, due to time and cost constraints, the study was limited only to petrol stations that were within six kilometres of the town centre in Stellenbosch. Thirdly, petrol station managers, workers and those living in houses and apartments surrounding petrol stations were not interviewed. While the methodology initially included a survey of petrol station managers, scoping research found that managers were wary of and reluctant to speak to the researcher, despite a letter of support provided by his supervisor.

3.8. ETHICAL CONSIDERATIONS

This study was conducted in line with established norms and standards for ethical social research. Ethical clearance for the study was obtained from the University of Stellenbosch Humanities Research Ethics Committee (see Appendix A). Informed consent was obtained from respondents before proceeding to interview them, along with permission to record the interview. Respondents could terminate the interview at any time. A letter from the researcher's supervisor was obtained to assist in approaching informants for interview. This explained that the study was for academic purposes and for obtaining of Master's qualification. The results are presented in a manner that ensures the anonymity of respondents.

3.9. SUMMARY OF THE CHAPTER

The chapter presented the location of the study area and provided reasons for selecting the area. It described the approach to collecting and analysing the data. The methodology included the collection and analysis of geospatial and qualitative data. Finally, the sampling method, data analysis, limitations and ethical considerations were, discussed. The following chapter presents the results.

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CHAPTER FOUR: LAND-USE PLANNING GUIDELINES FOR PETROL STATIONS IN STELLENBOSCH

4.1. INTRODUCTION

This chapter presents the findings of the research. It discusses the geospatial analysis regarding the spatial location and distribution of petrol stations in Stellenbosch, and the surrounding development patterns. The chapter discusses the land-use planning guidelines as well as legislation informing the siting of petrol stations in relation to other facilities or land-uses in Stellenbosch.

As discussed in Chapter 2, there are neither provincial nor national guidelines on the siting of petrol stations in relation to residential apartments, schools, hospitals etc. – although there is a land-use procedure that the Municipality follows for the building of petrol stations and development in general. In the absence of standards, the 2002 EIA development guidelines used in Gauteng, and discussed in Chapter 2, were applied. These EIA development guidelines stipulate a generic safe distance of 100 metres between petrol stations and residential properties, schools, or hospitals and a three-kilometre distance between petrol stations.

4.2. SPATIAL LOCATION AND DISTRIBUTION OF PETROL STATIONS IN STELLENBOSCH

In Stellenbosch, nine petrol stations were identified within a six-kilometre radius from the Post Office. They are not equally distributed spatially. Along the main roads (the R310 and R304), there are four petrol stations, with three located on the R310 and one on the R304 (see Figure 5). The three petrol stations on the R310 are petrol stations #7, #8 and #9. The one petrol station on the R304 is petrol station #6. There are five other petrol stations located along secondary roads, avenues and streets: #1, #2, #3, #4 and #5. The R310, running in an easterly direction from the town has two petrol stations in close proximity to each other. These petrol stations are #7 and #9. The distance between them is less than 200 meters and they are on opposite sides of the road. Of the nine petrol stations, these are the nearest to each other. The next closest are petrol stations #3 and #4 on secondary road, with less than 300 metres between them. Petrol station #8 on R310 is found to the south west of the town. According to Gauteng's guidelines and international good practice the acceptable distance between petrol stations should be at least three-kilometres. These spatial locational guidelines prohibits two or more petrol stations

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within three-kilometres. The circles in Figure 5 represent three-kilometres from the petrol stations within the study area. The Figure below illustrates that approximately seven petrol stations are within three-kilometre radius of each other.

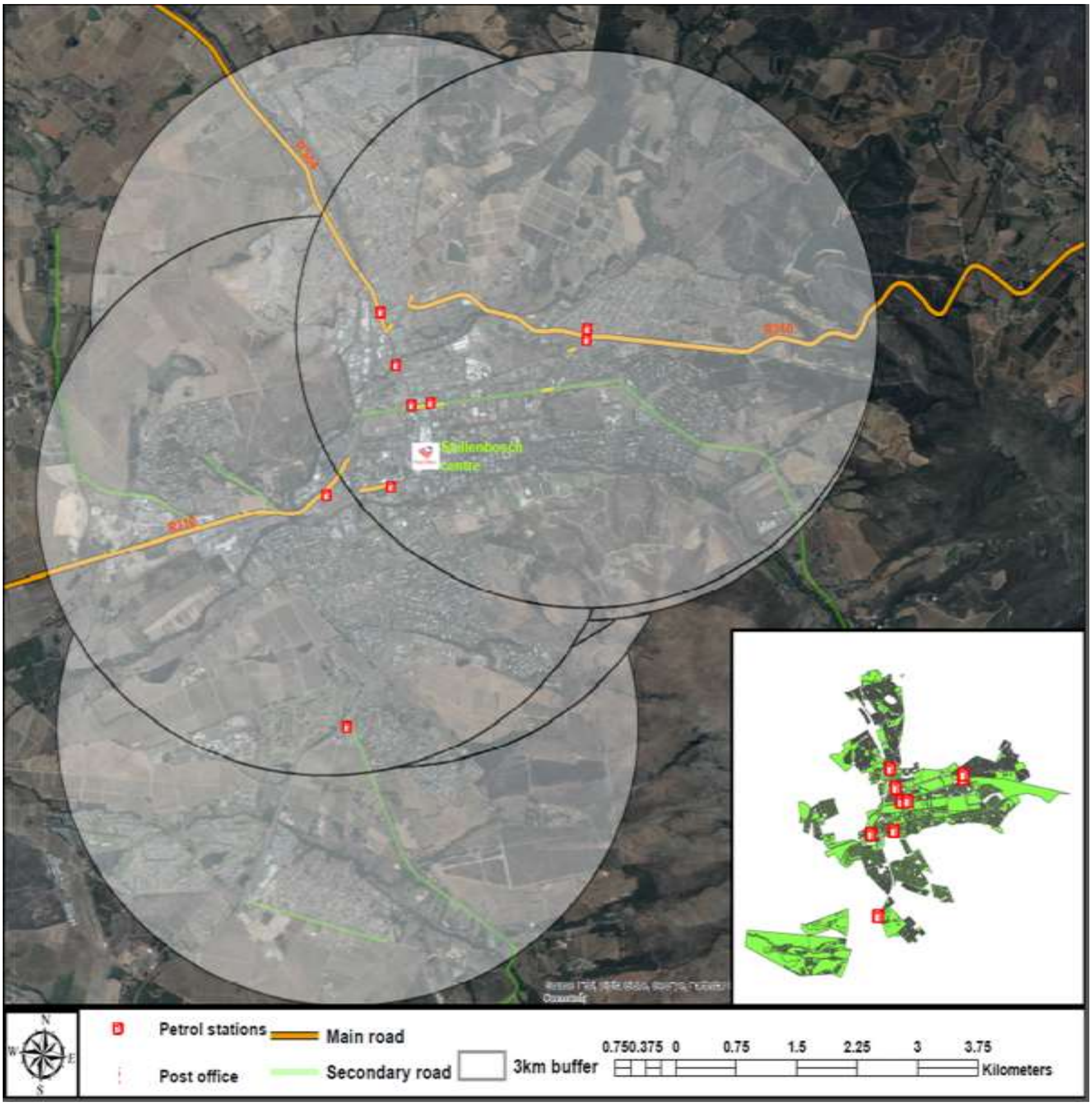

Figure 5: Spatial location of petrol stations in Stellenbosch

4.3. CONFORMITY OF PETROL STATIONS WITH DEVELOPMENT GOOD PRACTICES IN STELLENBOSCH

The siting of petrol stations in Stellenbosch conforms neither to Gauteng's guidelines nor international good practice. In several instances, development, in the form of residential

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apartments, hostels and commercial buildings, has occurred near petrol stations. In addition, seven petrol stations were within a three-kilometre radius of each other. In this respect the findings are similar to the cases in Nigeria where the siting of petrol stations in Maiduguri and Jere does not conform to Nigeria's DPR guidelines.

4.3.1. Land-use developments at petrol stations in Stellenbosch

As Table 4 shows, different land-use developments are found immediately in and around the petrol stations. These land-use types are classified as commercial activity, dwellings, hostels and other buildings. The classification of these land-use developments is based on the Eskom buildings layer provided by Umvoto Africa (Pty) (Ltd) and site observation. In this classification, commercial activity refers to any activity that involves buying and selling, including convenience stores, fast food restaurants, laundromats, warehouses and retail stores, factory shops etc. Dwellings comprise any self-contained unit of accommodation such as a house, an apartment block, mobile home, or other 'substantial' residential structure. A hostel is defined as an establishment which provides lodging for a specific group of people, such as students, workers or travellers. Other buildings refer to any structure that belongs either to institutions, i.e. government or university buildings, or structures used for an unknown or unidentified activity. These land-use types are not evenly distributed around the petrol stations. Some petrol stations have more dwellings and hostels close to them, while others have commercial buildings with no dwellings or hostels. Several petrol stations were attached to convenience stores. Some petrol stations have primarily residential apartments around them, while others have more commercial buildings (see Table 4).

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Table 4: Land-use development in and around petrol stations

Petrol stations	Land-use developments in and surrounding petrol stations
#1	Commercial buildings
#2	Commercial buildings
#3	Residential building & commercial buildings
#4	University building, hostel and commercial buildings
#5	Hostel, commercial building & other buildings
#6	Residential building & commercial buildings
#7	Residential buildings & commercial buildings
#8	Commercial buildings
#9	Commercial building & other buildings

4.3.2. Development within 100 metres radius from the petrol stations.

In terms of Gauteng's EIA guidelines, petrol stations should not be within 100 metres of residential properties, schools, or hospitals, unless it can be clearly demonstrated that there will be no impact in terms of noise, visual intrusion, safety considerations or fumes and smells. However, the analysis shows that many petrol stations are located close to surrounding developments. In fact, none of the petrol stations conform to these guidelines, as there are dwellings, particularly residential houses and hostels, within 100 metres of the petrol stations Figures 6, 7, 8, 9 and 10 show maps with a 100-metre buffer around petrol stations and the surrounding land-use developments. In each of the petrol stations a 100-metre buffer is illustrated by the light orange circles. Petrol station are illustrated by the red and white logo at the centre of the circle. Dwellings within 100-metre buffer is indicated by small dots with

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tourmaline green colour. The zoomed out insert map shows the spatial location of petrol station under focus in relation to others in a red circle northern part of the town. Figure 6 reveals that there are dwellings at a closer range to the petrol station. This petrol station is located in the north of the town.

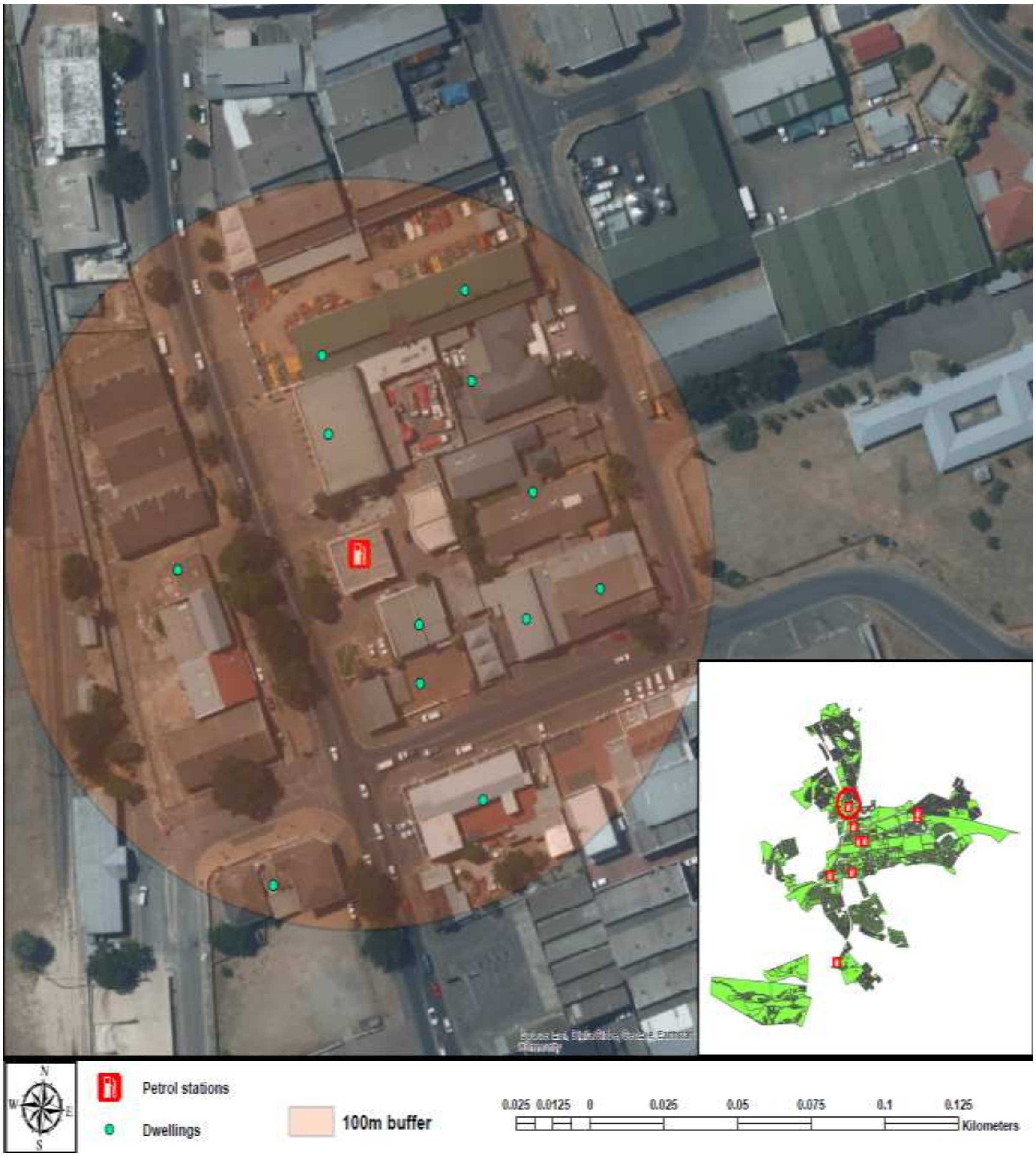

Figure 6: Dwellings within 100 meters of the petrol station in northern Stellenbosch

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Figure 7 reveals that there are dwellings at a closer range to the petrol stations. The Figure also shows is a fire station closer to the two petrol stations that belongs to Stellenbosch Local Municipality east of the town. These petrol stations are located in the east of the town.

Figure 7: Dwellings within 100 meters of the petrol stations in eastern Stellenbosch

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Figure 8 below shows that there are dwellings, commercial buildings, hostels and other buildings at a close range to the petrol stations. Two petrol stations are at very close range to each other while one petrol stations appears to be further from two. These petrol stations are located in the centre of the town.

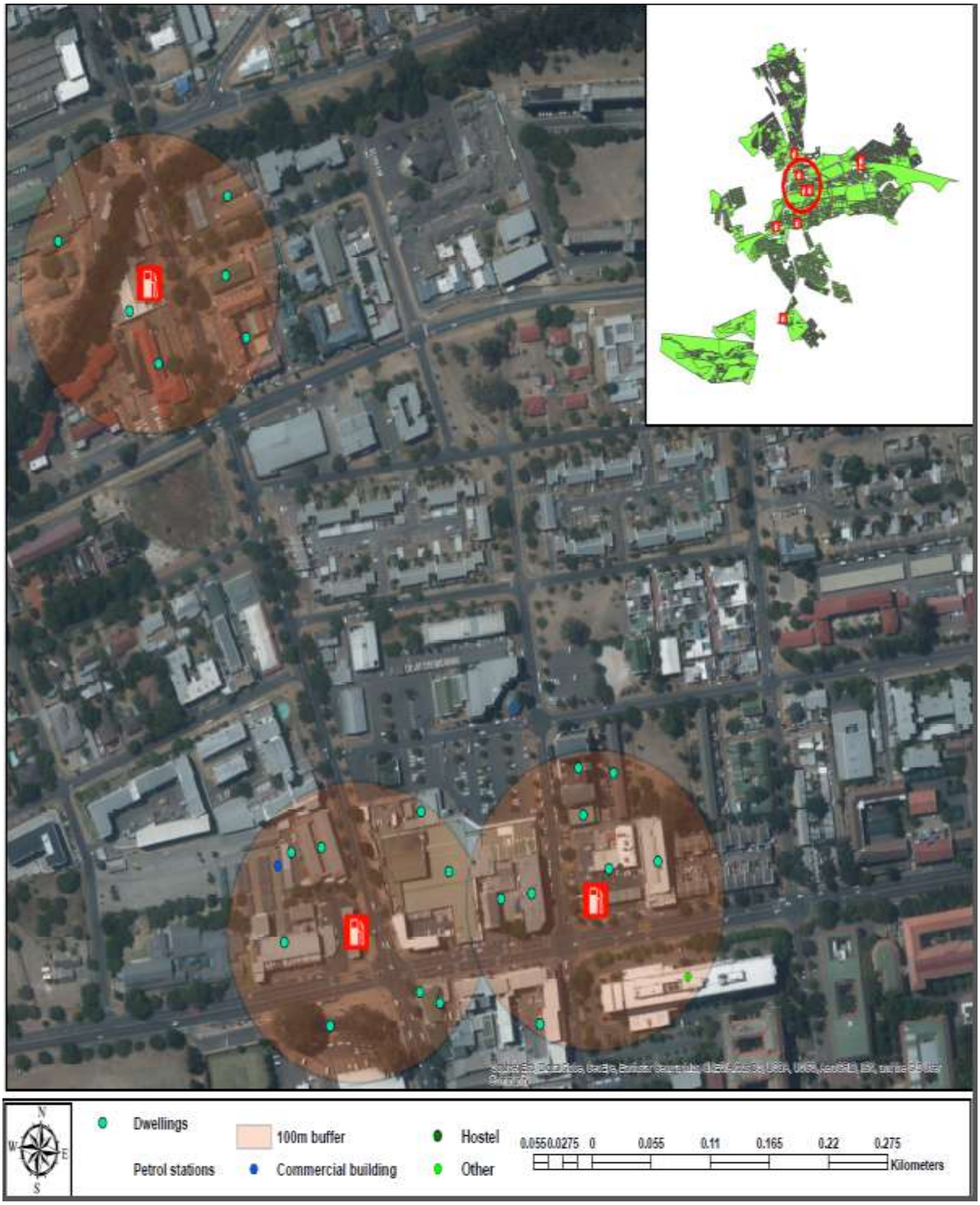

Figure 8: Dwellings within 100 meters of the petrol stations in central Stellenbosch

Figure 9 also shows that there are dwellings at a closer range to the petrol stations. It appears there is more dwellings closer to the petrol station on the east than there one on the west. These petrol stations are located in the south-centre of the town.

Figure 9: Dwellings within 100 meters of the petrol stations in south-central Stellenbosch

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Figure 10 shows that there are dwellings, hostels and other buildings at a close range to the petrol station. This petrol station is located far south of the town.

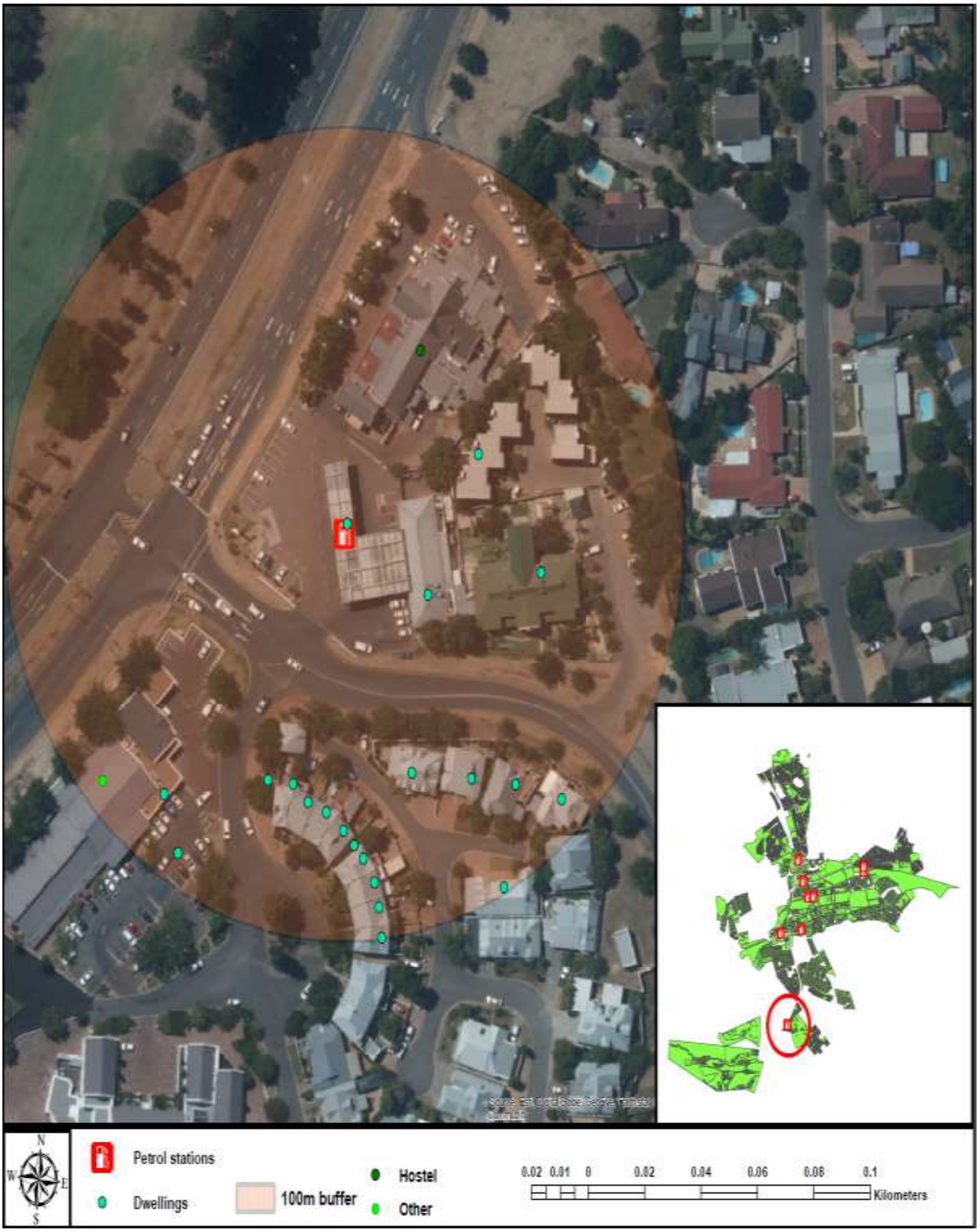

Figure 10: Dwellings within a100 meters of the petrol stations in southern Stellenbosch

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4.3.3. Analysis of the maps

Approximately 100 buildings were found to be located within 100 metres of petrol stations (shown by the orange circles in Figures 6, 7, 8, 9 and 10). As shown in Table 4 on p.38, the building types found within 100 metres of the petrol stations included commercial structures, dwellings, hostels and other buildings. Some petrol stations have only one type of development nearby, while others have a combination of two or more. Residential dwellings and 'other' structures, such as government and university buildings, are the most common (see Figure 11). However, the classification of these land-use developments on the Eskom buildings shapefile as illustrated in Figure 14 suggests that majority of building types around petrol stations are 'dwellings' and 'other' followed by 'commercial structures' and 'hostels'. To the contrary, site observations indicate that there are commercial structures, as all nine petrol stations were located close to commercial buildings (see Table 4 on p.38). This is because of the mixed land-use in Stellenbosch. While Eskom spatial layer may have identified one land use type in an area, multiple land-uses were observed. Site observation suggests that some properties, especially multi-storey buildings contain shops as well as accommodation.

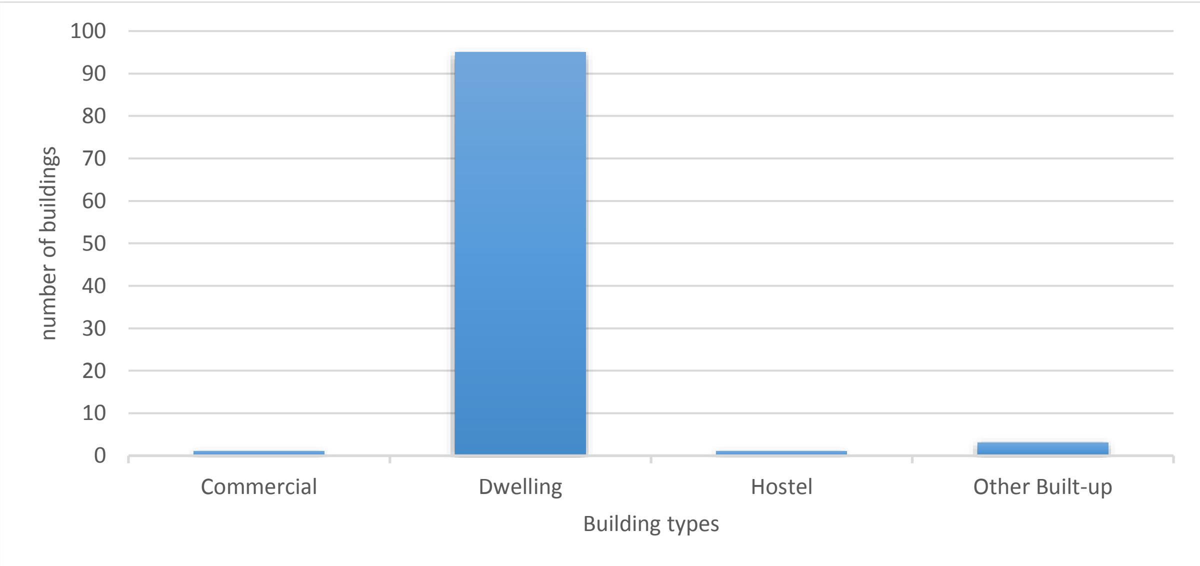

Figure 11: Land-use development within 100 metres buffer of petrol stations

There is a hospital within the six-kilometre study area. The EIA guidelines (EIA 2002) in very specific terms stipulate that critical facilities such as hospitals should not to be within 100 metres of petrol stations. The analysis suggests that the hospital is placed suitably far away from the petrol stations. The distance between the hospital and the nearest two petrol stations,

#7 and #4, is 833 metres and 973 metres respectively (see Figure 12 below). Figure 12 demonstrates spatial location of the Stellenbosch Provincial Hospital in relation to petrol stations in the study area. The two arrows are pointed at hospital from the nearest petrol stations. The Figure also demonstrates a 100-metre buffer with the light red circles and petrol stations illustrated by the red and white logo at the centre of the circles. Development within the 100-metre radius of the petrol station is shown by small dots with tourmaline green. The star with a red represent a fire stations in town.

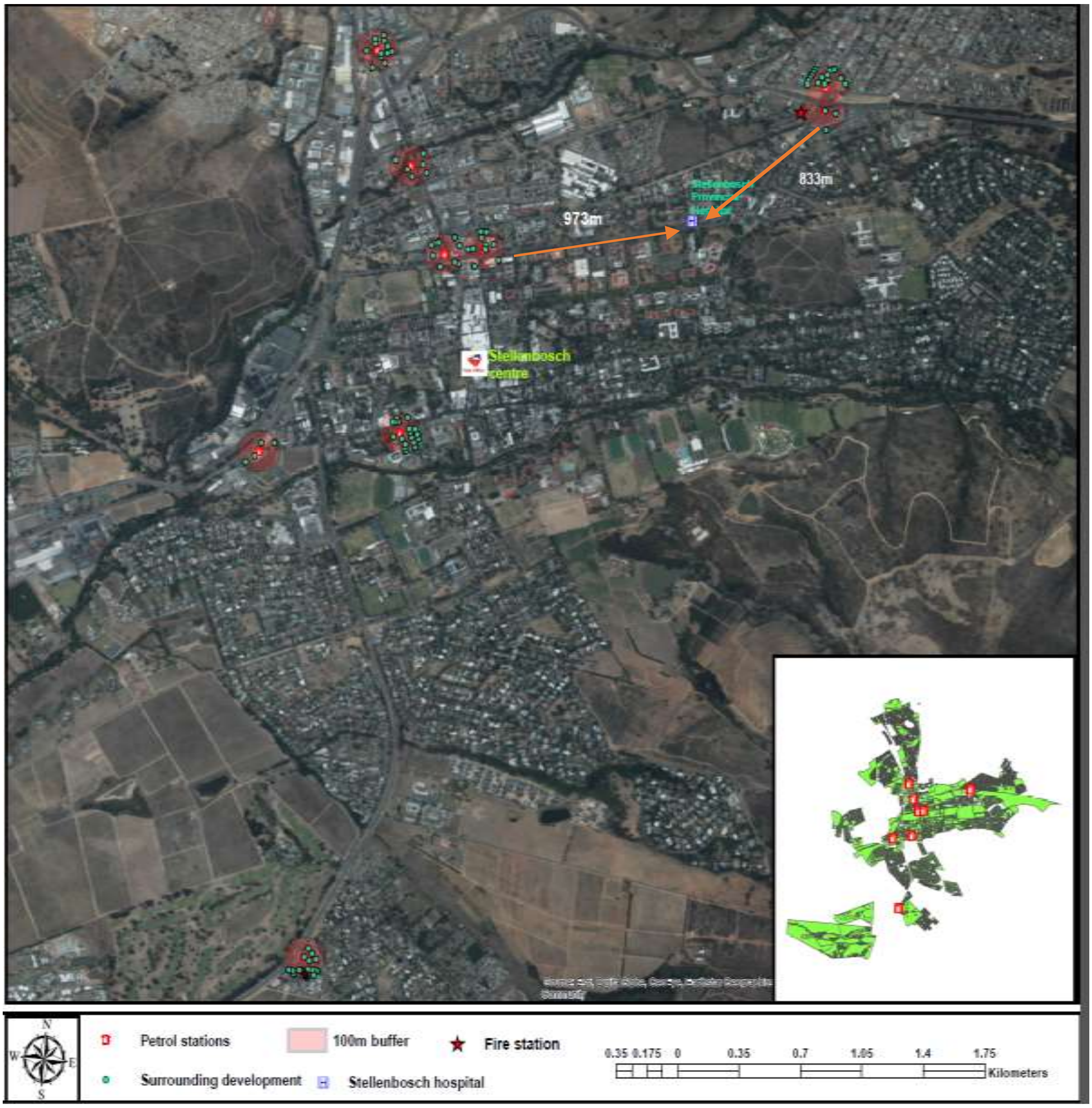

Figure 12: Land-use development within 100 metres buffer at the petrol stations

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4.4. LAND-USE PLANNING GUIDELINES AND REGULATIONS IN STELLENBOSCH

Interviews with municipal role-players were conducted with the department responsible for LUP in Stellenbosch Municipality. The interviews aimed to understand land-use rules, guidelines and regulations, as well as legislation informing the siting of petrol stations in relation to other facilities. The department responsible for LUP in Stellenbosch Municipality consists of two units: Spatial Planning (SP) and LUM. The SP unit is responsible for strategic planning and deals broadly with the Municipality's urban renewal strategy. The urban renewal strategy focuses on high density and low-density housing and upgrading of dilapidated buildings. The LUM unit, on the other hand, implements the zoning scheme. The LUM unit ensures compliance with, and the implementation of, the parameters established in the zoning scheme. A zoning scheme is a legal document that records all land-use rights on properties in its area of jurisdiction (Stellenbosch Municipality 2017). It also includes regulations restricting these rights and how they can be exercised. The Municipality uses the zoning policy to guide land-use planning.

4.5. LAND-USE DEVELOPMENT PROCEDURE IN STELLENBOSCH

In Stellenbosch, as elsewhere, individuals or developers wishing to build on land are expected to conduct an EIA and obtain approval from the Provincial Department of Environmental Affairs and Planning (DEADP). Once DEADP approves a development, a developer must apply to the Municipality for permission to develop the area. The purpose of the application is to ensure that developments comply with the municipal zoning scheme and prevent illegal land-use development. The Municipality considers any developments bypassing this step as illegal. However, those interviewed noted that illegal developments are not unusual. Notwithstanding the EIA, the Municipality conducts its own risk evaluation of the proposed development when a developer submits their proposed plans. A developer is required to submit multiple development plans and indicate the preferred option, with supporting reasons for their choice. The LUP department then circulates the development plan proposal to other relevant departments and functions, including DM, FP, and traffic and civil engineering, to identify and consider any shortcomings and effects regarding their respective functions. These role-players provide feedback to the LUP department, where they have an opportunity to raise any concerns. The developer is expected to address concerns before their plans can be approved.

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4.6. ZONING POLICY IN STELLENBOSCH

Stellenbosch Municipality uses its own unique zoning scheme. As with any other municipality, the zoning scheme is tailored to the Municipality's developmental and strategic priorities. However, the Municipality does not have a specific policy in relation to the location of petrol stations. In interviews with municipal role players noted that the Municipality's zoning scheme/policy regulations do dictate the features of petrol stations. Under the 1996 zoning scheme regulations, petrol station buildings should cover 75% of the site area; be a maximum of three storeys high; setback three metres from roads (five metres on proclaimed Main Roads); and 10 metres from other zones such as shops (Stellenbosch Municipality 2012 :32). This was amended in 1998, to include additional provisions. These include that the entrance and exit to and from petrol stations or public garages must be:

a. not less than 30 metres from the point where a proclaimed or planned main road intersects any other road, or the nearest point of an intersection where traffic is controlled, or is proposed to be controlled, by a traffic signal or traffic island;
b. not less than one and a half metres from the side boundary of the premises; and
c. not less than 10 metres from the corner of an intersection that is 10 metres wide or five metres from the point where the line of splay (or site line) meets the road boundary.

These additional amendments are aimed at managing and ensuring the free, unobstructed and safe flow of traffic. They did not consider fire-safety at petrol stations. This is because stakeholders such as DM and FP/FS do not perceive petrol stations as potentially hazardous sites, as there have been no major fires or accidents in Stellenbosch.

The Municipality does have a policy regarding the location of other land-uses, such as clubs or liquor stores, with no clubs or liquor stores allowed near schools, churches or clinics. Interviews with DM and FP/FS stakeholders indicated that petrol stations are not a priority hazard. Fires at petrol stations are not included in DM's priority hazard list. While most stakeholders perceived the risk of a fire at a petrol station to be low, the municipal planner acknowledged the potential danger, noting that there are also health and environmental hazards associated with petrol stations. The planner emphasised that the role of land-use planning is to enforce and ensure compliance with the zoning scheme. If the risks associated with petrol stations and the distance between developments are not identified in the zoning scheme, these will not be considered in developing land. He also indicated that developers "invest huge

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capital in building petrol stations; planners do not intensively look at risks imposed by such developments but focus on the economic benefits to the local community and municipality" (LUP department Interviews 2018). This is a classic example of the fragmented land-use planning approach demonstrated by Britton & Lindsey (1995) and Sutanta et al. (n.d). This promotes economic development at the expense of safety.

According to FS and DM records, there have been no significant fires or accidents at petrol stations in Stellenbosch. Nonetheless, the planner recommended that the Municipality should craft and develop a policy that deals with the siting of petrol stations, to for example, ensure that petrol stations are located a safe distance from one another. However, he also highlighted that Stellenbosch is a historical town, with available land already developed. The current planning in Stellenbosch reflects decisions made years ago, although in some cases developments have been upgraded. While he stressed a need for measures to protect residents, when asked if he could consider the EIA guidelines developed by the GDAoACELA, he argued that "each town has a unique environment; therefore, I believe that these guidelines would not be useful in the sense of applicability to Stellenbosch or any other town other than in Gauteng".

4.7. SUMMARY OF THE CHAPTER

The land-use regulations regarding the development of petrol stations in Stellenbosch are not in line with good practice suggested in the literature, or local guidelines, such as those used in Gauteng. The hazard posed by petrol stations are not considered by land-use developers and municipal officials in Stellenbosch. This is seemingly due to low levels of danger perception owing to absence of fire accidents at petrol stations in Stellenbosch. Currently, development of residential and other land-uses is allowed extremely close to petrol stations. The following chapter presents the levels of the institutional preparedness to respond to fires at the petrol stations and protect surrounding developments.

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CHAPTER FIVE: EMERGENCY RESPONSE PREPAREDNESS FOR PETROL STATION FIRE ACCIDENTS IN STELLENBOSCH

5.1. INTRODUCTION

Considering the closeness of the residential housing developments to petrol stations and to each other, this chapter examines how well prepared Stellenbosch Municipality is to respond to a large fire at a petrol station. The chapter also discusses the related institutional management challenges facing the Municipality, as well as risk behaviours and fire prevention measures at petrol stations. This information was established through interviews with DM, FS/FP and the Traffic Department, as well as site observation.

5.2. EMERGENCY RESPONSE PREPAREDNESS PLAN

Stellenbosch Municipality developed a Disaster Management Plan in May 2017, which establishes governance procedures and arrangements for disaster risk management, including preparing for and responding to disasters within the Municipality (Stellenbosch Municipality 2017). The HFA and Sendia framework argues that plans are critical for effective response (Coppola 2015). The Stellenbosch Municipality’s Disaster Management Plan consists of four key coordinated processes and institutional arrangements: for disaster management; risk assessment and establishing a risk profile; disaster risk reduction planning; and disaster preparedness (Stellenbosch Municipality 2017). Responsibility for reducing disaster risk, preparing for and responding to disasters is shared by all local municipal departments and employees, the Cape Winelands District Municipality, provincial and national organs of state and all sectors of society (Stellenbosch Municipality 2017). Stellenbosch Local Municipality is required by the Disaster Management Act 57 of 2002 to conduct risk assessments and identify disaster risks threatening the Municipality and to develop risk reduction and preparedness plans for the identified threats (Disaster Management Act (DMA) 2002). This systematic process aims to create an environment conducive for institutions and community organizations to understand and reduce risk. The national disaster management framework of 2005 is a legal instrument specified by the Act to guide integrated action, by providing a coherent, transparent and inclusive policy on disaster management appropriate for the whole South Africa (National Disaster Management framework (NDMF) 2005).

Pursuant to the legislative obligation outlined above, Stellenbosch Local Municipality in the 2017 Disaster Management Plan identified 20 priority hazards (Stellenbosch Municipality 2017). Petrol station fires were not included (see Table 5). In interviews with municipal role players, it was explained that the Municipality prioritises hazards according to their frequency, hence rare or hypothetical events are excluded. However, respondents from DM agreed that fires at petrol stations are possible and that having no experience of fighting these fires has lowered the Fire and Rescue Service's preparedness for fires should they occur. Moreover, the prioritisation of hazards in Stellenbosch Local Municipality may also be inaccurate. Although hazards are supposed be determined by their frequency, frequent events such as informal settlement fires are not listed. A recent study suggests that between 2015 and 2017, 104 informal dwellings and 22 houses were destroyed by fire (Mugamu 2018).

Table 5: Priority hazards in Stellenbosch Municipality.

1.	Fire – Veld & Runaway Fires
2.	Dam Wall Failure: Idas Valley
3.	Floods
4.	Chemical spills: Hazmat incidents
5.	Explosive storage: (fuel, gas)
6.	Environmental pollution: (air, water, ground contamination, pesticides)
7.	IT – Failure of system: Access to info
8.	Infrastructure Decay : No / dysfunctional infrastructure / service delivery (sewerage, toilets, grey water, electricity)
9.	Transport incidents (road, railway accidents)
10.	Rock Falls
11.	Aircraft accidents
12.	Seismic: Earthquakes
13.	Erosion
14.	Communicable disease: (H1N1 Influenza (Swine Flu)
15.	Insufficient hydrants
16.	Power failure
17.	Strikes / Social conflict
18.	Climate change: (high/strong winds, severe heat/cold)
19.	Poverty
20.	Chlorine stations

Source: Stellenbosch Municipality (2017:15).

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5.3. INSTITUTIONAL MANAGEMENT

Stellenbosch Municipality is responsible for responding to fires at petrol stations or events within the urban footprint, and the District Municipality for everything outside it, such as wildland fires. In a written reply to questions, a Stellenbosch Municipality official indicated that in terms the Municipal Structures Act, 1998 (Act 117 of 1998) (as amended) Section 84(1) (j) there is a strict "segregation of powers between "C" [District] and [B or local] Municipalities". Section 84(1) states that a District Municipality has the following functions and powers in respect to fires:

a. planning, co-ordination and regulation of fire services;
b. specialised firefighting services such as mountain, veld and chemical fire services;
c. co-ordinating the standardisation of infrastructure, vehicles, equipment and procedures; and,
d. training of fire officers in the Cape Winelands District Municipality.

Neither Stellenbosch Municipality, nor the Cape Winelands District Municipality are responsible for conducting fire drills at petrol stations (this responsibility lies with the landowners and/or petrol station managers). However, it could be argued that both DM and FP/FS, in their efforts to ensure adequate preparedness for fires, should test their own preparedness levels, raise awareness about how to respond in the event of a fire, as well as identify escape and alternate routes that the public and responders would need to use. The municipal FP/FS and DM officials indicated that the Municipality had visited a few shops, restaurants, commercial centres and one petrol station (station #5) to distribute the (now old) number to call in emergencies. This implies that, prior to this, the emergency number was unknown, and is now obsolete. The visit did not include any other awareness raising or oversight activities.

5.4. THE MUNICIPALITY'S STANDARD OPERATING PROCEDURES

The municipal role players indicated that the Municipality's Standard Operating Procedures (SOPs) have not been tested with respect to a fire at a petrol station. The SOPs facilitate and guide collaborative efforts between different municipal departments and institutions during an emergency. Figure 13 shows the departments involved in disaster coordination and response, as explained by the municipal officials. Under existing SOPs, an emergency call reporting a fire or fire-related emergency is received at the Stellenbosch Local Municipality's DM call

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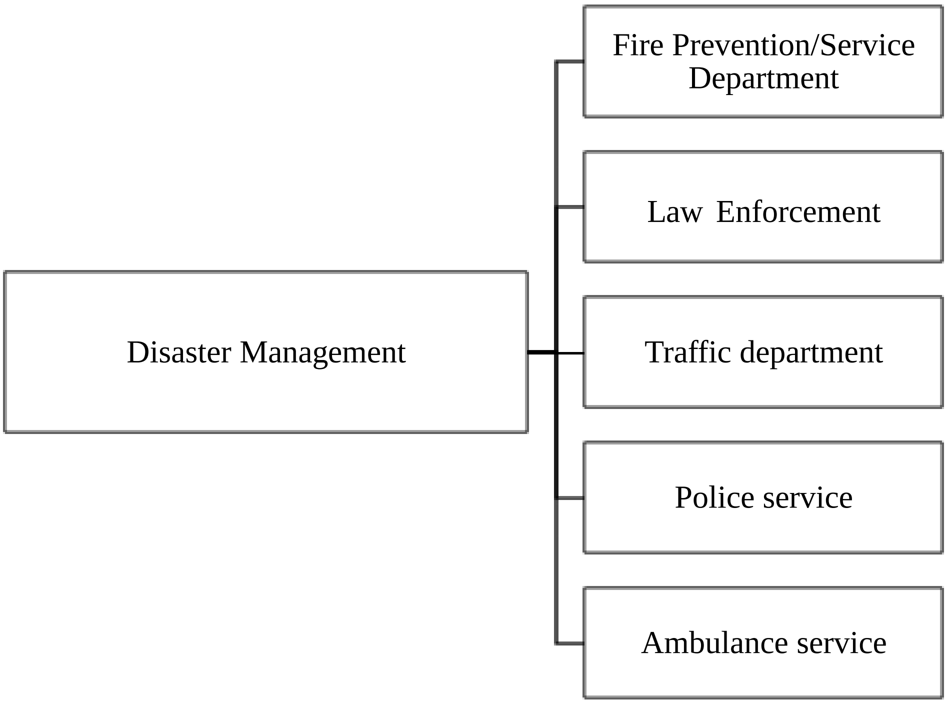
centre and is then redirected to FP/FS, Law Enforcement or Police, the Traffic department or other relevant institutions. All these departments should play a unique but complementary role during an emergency in Stellenbosch. The Police and Law Enforcement, for instance, are responsible for crowd control, while the Traffic department focuses on road closures and coordinating emergency routes. Nonetheless, as noted by a respondent from DM in Stellenbosch Local Municipality, a "SOP cannot be a cut and paste exercise, as responding to a structure fire in an informal settlement [as opposed to] a petrol station is a unique exercise", as the substances involved require different treatment. He argued that the SOP has been standardised to the extent that it ignores the uniqueness of different kinds of fires. An interviewee suggested that a specialised SOP should be developed to cater for an accident or fire at a petrol station (DM department interviews 2018). This would need to be tested through fire drills.



Source: Author's own.

Figure 13: SOP in Stellenbosch Municipality.

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FP/FS in Stellenbosch Municipality share the same premises as DM in the local municipality, enabling effective communication between the two departments. FP/FS indicated that their role is to respond to structure fires in Stellenbosch, including petrol station fires. However, as mentioned earlier, there have been no major fires at petrol stations in Stellenbosch, which could undermine preparedness. Moreover, respondents indicated that the Municipal FP/FS has limited human resources and equipment, which could hamper an effective response should there be a major fire. They argued that should this happen, they would work closely with the Cape Winelands District Municipality's Disaster Management Centre to fill gaps. It was noted that the distance between the fire station and petrol stations, especially those further out of town, could present a challenge during peak traffic hours. According to traffic department, peak hours in Stellenbosch are in the morning (6:30 - 8:30) and in the evening (4:15 - 6:30). Figure 14, below, shows petrol stations and their proximity to congested routes. The Figure represents roads experiencing high, medium and low peak-hour traffic volumes in red, light green and dark green respectively. The map is derived from the Google Maps live traffic flows observed over a two-week period. Overall, the map suggests that the majority of the petrol stations are found near routes where peak-hour traffic flows are high, resulting in traffic congestion. This is the case in all the petrol stations except stations #1 and #5 in north east of the town, where peak-hour traffic volumes are medium to low (see Figure 14). Such congestioncould potentially increase response times, with well-developed fires harder to control and extinguish.

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Source: extracted from Google Map 2018

Figure 14 : Live & typical traffic flow during peak hours in Stellenbosch

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5.5. FIRE SAFETY AT THE PETROL STATIONS IN STELLENBOSCH

This section explores risk behaviours at petrol stations that could potentially lead to fires and the prevention measures adopted at petrol stations. It discusses the findings identified through observation and the application of the adapted Fire Safety Standards Checklist. As noted earlier, this focused only on facilities visible in and around petrol station precincts and is supplemented by photographs of the stations. It focused on the source components of fire - heat, combustible material (fuel) and oxygen - and the extent to which there were measures evident to address these.

5.6. RISK BEHAVIOURS

Heat, and anything that gives off heat, can ignite fires where there is enough fuel and oxygen (NEBOSH 2016). In this regard, it is widely accepted that motorists can prevent fires by switching off their engines when filling their cars, and by not smoking. In this respect, the checklist examined risky behaviours, such as motorists not switching off their cars, or smoking.

Despite clear warning signs posted at each pump requesting customers to “Turn off Engine”, in several cases – particularly at petrol stations #6 and #8 - cars were filled while their engines were still running, creating the risk of fires. In petrol station #6, a group of customers who went to the convenience store, stood approximately 12-22 meters from a pump and smoked cigars for approximately two minutes. While there is no recommended minimum distance at which smoking, or flames can be considered safe, intuitively this kind of activity appears to create the potential for fires. In this respect, Cutter (1993) argues that the public often does not appreciate the dangers of technological fire hazards, sometimes with devastating results. Fortunately, in this instance, there was no harm done. In petrol stations #6 and #9 different sizes of EASiGas containers were observed in the precinct (see Table 6). It appears these petrol stations are also selling EASiGas, increasing available fuel for fires. In keeping with the literature on technological hazards, the observation data suggests fires are most likely to start due to human behaviour and negligence (Ahmed et al. 2011) and underscores the importance of enforcing safety standards.

5.7. FIRE PREVENTION EQUIPMENT AT PETROL STATIONS

The observation component examined fire prevention mechanisms, including visible evidence of (a) adequate fire safety measures, (b) control of ignition sources or sources of fuel, (c) fire

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detection systems, (d) escape and evacuation planning, and (e) equipment to fight fires. It was observed that all the petrol stations have posted conspicuously warning signs at pumps. These included signs specifying: “No smoking”; “No naked lights”; “Stop engine”; “Switch off cell phones”. However, emergency equipment may have been comprised. For instance, while fire extinguishers were visible and located in areas easily accessible to petrol attendants, some were not protected from weather (see Figure 15). According to Hugo & Montanye (2016) prolonged sun exposure can cause parts to fail and the chemical agents in fire extinguishers to clump together, making them ineffective.

Figure 15: Unprotected Fire Extinguisher at petrol station #6 in Stellenbosch

Source: author’s own

In every petrol station, observations suggest that hose reels may have been too short to reach all the pumps, especially where there were more than five dispensers (see Table 6). There were also frequently no visible absorbents such as sand to mop up spillage in the precinct, and no clear evidence of fire hydrants or assembly/evacuation points. In petrol station #3, the evacuation assembly point was within the precinct (area) of the petrol station, only about 11 meters from the nearest pump. According to municipal respondents, the designated assembly point for petrol station #7 was an open space located at the DM/FS offices, across one of the busiest roads in Stellenbosch. This also presents a threat to the safety of customers and staff.

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Table 6: Summary of the observational checklist at the petrol stations in Stellenbosch

Petrol stations	Time of the observation	Activity	Warning systems/signs	Fire prevention equipment at petrol stations
#1	05:16 (Morning)	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points.
#2	18:40 (Evening)	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points.
#3	18:35 (Evening)	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants. Visible assembly/evacuation points.
#4	19:00 (Evening)	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points.
#5	10:55 (Morning)	Motorist turned engine off	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points.

Continued overleaf…

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Petrol stations	Time observed	Activity	Warning systems/signs	Fire suppression equipment at petrol
#6	10:15	Engine running while refilling. People smoking. EASiGas containers in the precinct	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points
#7	14:03	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points
#8	15:34	Engine running while refilling. Different sizes of EASiGas containers in the precinct	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points
#9	14:30	Motorist turned off engine	Clearly posted in each of the pumps	Fire extinguisher visible and accessible to petrol attendants, no visible absorbents, clear evidence of fire hydrants or assembly/evacuation points

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5.8. SUMMARY OF THE CHAPTER

The research findings suggest that technological fires at petrol stations are not considered a priority hazard in Stellenbosch. This is because the municipality prioritises hazards according to their frequency, and there have been no recorded fires at petrol stations in Stellenbosch. This lack of experience and emphasis may undermine levels of preparedness, leaving Stellenbosch's FP/FS and DM less equipped to deal with a fire emergency at a petrol station. Observation at the research sites suggests that although petrol stations have posted warning signs and have fire extinguishers, there is the potential for fires at petrol stations, indicating an important gap in the Municipality's disaster management planning. Petrol station managers should also carefully consider existing response measures, such as the siting of evacuation and assembly points.

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CHAPTER SIX: DISCUSSION AND CRITICAL ANALYSIS

6.1. INTRODUCTION

The aim of this research was to investigate the extent to which land-use planning in Stellenbosch considers the fire-risk posed by petrol stations, and the implications for public safety. The study also examined the potential for fires at petrol stations and how well prepared the authorities are to respond to such fires. The study focused on petrol stations within a six-kilometre radius of the Stellenbosch Post Office, in Stellenbosch, South Africa.

This chapter will provide a critical discussion and analysis of the findings. It will begin by revisiting the study's aims and objectives, followed by a discussion of the findings. It will then discuss the implications of the findings for the current land-use planning practices, policy, and DRR in Stellenbosch Municipality. It will also provide recommendations on how the land-use planning guidelines can better integrate DRR principles to ensure sustainable development of petrol stations and the safety of those living and working in surrounding developments. Finally, the chapter will conclude with proposals for further research.

6.2. REVISITING THE OBJECTIVES

The research in this thesis had three objectives. The first was to identify petrol stations within six kilometres from central Stellenbosch, the nature and extent of development around the stations and whether these comply with the international and national planning regulations. The second, examined the potential for fires by observing risk behaviours and fire-suppression equipment at petrol stations. The third was to investigate Stellenbosch Municipality's preparedness to respond in the event of a fire at a petrol station.

With respect to the first objective, nine petrol stations were identified within six kilometres from Stellenbosch centre. Contrary to best practice, there was significant development close to petrol stations. Land-uses included (1) commercial activity such as convenience stores, restaurants, fast food stores, liquor stores, (2) dwellings such as residential apartments, (3) hostels and (4) institutional buildings. In addition, it was established that Stellenbosch Municipality does not have any local standards, legislation or policy with respect to the siting of petrol stations. There are also neither provincial nor national guidelines that stipulate the siting of petrol stations in relation to residential homes and apartments, hospitals, schools etc.

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other than those set by SABS. However, the 2002 EIA development guidelines discussed in Chapter 2 stipulate a generic safe distance of 100 metres between petrol stations and residential properties, schools, or hospitals and a three kilometre distance between petrol stations. The study showed that petrol stations in Stellenbosch do not comply with these guidelines. More than 100 residential developments were found to be within 100 metres of petrol stations. Seven petrol stations were found with three kilometres of each other.

In terms of the second objective, the findings suggest the potential for fires. Risky behaviours were observed in petrol stations, which included customers leaving engines running while refilling their cars and smoking. All petrol stations had visible fire suppression equipment, and warning signs, but in some petrol stations fire extinguishers were unprotected from weather.

The final objective was to investigate Stellenbosch Municipality's level of preparedness to respond in the event of a fire at a petrol station. In this regard, it was established that petrol station fires were not considered a priority hazard, and therefore there were no plans in place to deal with such incidents. In addition, the municipality did not conduct emergency drills. These findings indicate that the Municipality is less prepared for petrol station accidents should they occur.

6.1. DISCUSION OF THE FINDINGS

6.1.1. Reflecting on technological hazard literature

Technological hazards are well documented historically (see Brooks 1973; Kate & Kasperson 1983; Cutter 1993; Ayyub 2003) and in the main the literature focuses on technological disasters in urban areas linked to industrial development and factories. The historical technological hazard literature describes technological disasters as unavoidable aspects of most advanced societies in the second half of the 19th century (see Silei n.d; Cutter 1993; Showalter & Myers 1994; Krejsa 1997; Smith 2004). As a result, disaster risk reduction measures, enacted through policy intervention and legislation, were introduced in many countries and contexts (see UK 1974). This reduced deaths and injuries resulting from large industrial accidents. However, technological inventions have continually changed the nature of hazards and created new ones, presenting management challenges (Iossifova 2016), and often resulting in disasters (Brooks 1973). Contemporary society has advanced technologically and become so complex that the successful management and amelioration of technological disasters requires a holistic approach.

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The technological hazards literature identifies petrol stations as a common feature in the global urban landscape. However, the hazard posed by petrol stations is not explored in the technological hazard literature in the South African context. Christou et al. (1999) observed that hazard potential is not always considered systematically when locating petrol stations, increasing the exposure of surrounding communities. They cautioned that the impacts of technological accidents are increased by development in proximity to dangerous sites, such as where petrol stations are in densely populated areas (Christou et al. 1999). The study findings correspond with observations by Christou et al. (1999) that petrol stations are often placed too close to one another and surrounding developments and show that the spacing of petrol stations does not adhere to good practice. The findings show that there has never been a large fire at a petrol station in Stellenbosch, but that an explosion or fire in Stellenbosch could potentially result in extensive damage and even deaths and injuries. The literature on technological hazards suggests that disasters at petrol stations have happened before across the globe and elsewhere in South Africa.

Stellenbosch is not unique in not adhering to best practices. Countries such as Nigeria, Ghana, and Iraq have all been shown to not comply with guidelines (see Baffour et al n.d; Tah 2017; Mshelia et al 2015; Arokoyu et al. 2015). In countries where there are planning regulations, they were often ignored (Christou et al. 1999). While the reasons may vary, the most common relates to the economic benefits of the petrol stations to the local community and municipality (Tah 2017; Mshelia et al 2015). Mshelia et al (2015) argues that petrol stations are lucrative businesses. This means that, in many instances, the economic benefits of petrol stations are emphasised at the expense of safety considerations. Likewise, a planner spoken to in Stellenbosch indicated that because developers invest huge capital in the development of petrol stations, planners tend to focus on the economic benefits.

Moreover, Britton & Lindsey (1995) argue that land-use planning practices in most countries concentrate on development priorities, with little, if any, attention to risk reduction. This appears true in Stellenbosch, where the economic benefits of petrol stations appear to count more than the economic and human costs that could result from a disaster. Unfortunately, it is often only after a disaster that the economic, environmental and human costs of petrol stations are seriously considered. For example, in Ghana, it was only after the 2015 fire in Accra that the National Petroleum Authority of Ghana established new regulations on the siting and operation of filling stations in the country (MyJoyOnline 2017).

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Good practice suggests a generic safe distance of 100 metres between petrol stations and residential properties, schools or hospitals and three kilometres between petrol stations (EIA 2002; DPR 2007; Mail online 2011; Myjoyonline 2016). In Stellenbosch, the findings reveal that the hospital is a reasonable distance, with the closest two petrol stations, #7 and #4, 833 metres and 973 metres away respectively. This also conforms with the minimum distance of 100 metres outlined by the EIA guidelines (EIA 2002). However, there were residences, hostels and university buildings located within 100 metres of petrol stations. Moreover, the findings suggest that petrol stations are built closer together than the three kilometres radius suggested in literature. Seven petrol stations were found within three kilometres distances to each other. This exposes surrounding developments to fire hazards.

6.1.2. Implications of the findings on land-use planning procedure in Stellenbosch

The findings of the study have implications for land-use planning practices in the municipality. The study found that there were accepted land-use planning procedures and practices in place, which require that developers conduct an EIA and apply to the Municipality for permission to develop land. The Municipality, in turn, should consider the proposed development and its level of compliance with the municipal zoning policy. However, it was found that the Municipality's zoning scheme/policy regulations do not dictate how far away residential houses, hospitals, schools etc. should be from petrol stations. It was also found that there were neither provincial nor national guidelines on the siting of petrol stations in South Africa. These findings, together with those on risky practices at petrol stations, identify a need for measures to protect residents from potential fires at petrol stations. Buffer zones surrounding petrol stations should be integrated into the zoning policy. This should also insure that petrol stations are located a safe distance from one another.

6.1.3. Fire-safety at petrol stations

A potential for a fire/explosion breaking out exists in petrol stations. NEBOSH (2016) outlined that heat, and anything that gives off heat, can ignite fires where there is fuel and oxygen. However, for a technological accident to occur technology must interact with humans or society directly or indirectly. Previous studies (Corporate Environment Report 2007; Ahmed et al. 2011) indicate that petrol station accidents are most often due to human failures and negligence, with Cutter (1993) and Smith (2004) identifying technological disasters as human-

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induced events. In keeping with the literature on technological hazards, the observation data suggests that fires could start due to human behaviour and negligence and underscores the importance of enforcing safety standards. For example, it was observed in several cases that cars were filled while their engines were still running, and people were also seen smoking near a pump. The observed risky behaviour echoes Cutter's (1993) argument that the public and customers often do not appreciate the dangers of technological fire hazards. In this respect, Coppola (2015) argues that public education should be the backbone of effective public preparedness efforts. He argues that once the public is made aware, they are likely to change their behaviour to reduce their exposure to hazards and their overall vulnerability (Coppola 2015). However, Stellenbosch Municipality indicated that they have not extensively engaged in public awareness programmes in developments around petrol stations.

That developments are exposed to fires indicates a need for preparedness to respond to incidents – especially as responding to any disaster can be complex and confusing (Coppola 2015). In Stellenbosch, the local municipality plays a critical role in this regard. Interviews with municipal role-players established that Stellenbosch Municipality has a generic Disaster Management Plan for 2017, which establishes governance procedures and arrangements for disaster risk management, including preparing for and responding to disasters within the Municipality (Stellenbosch Municipality 2017). This is identified in the HFA 2005-15, under priority five, as a critical component of effective emergency response (UNISDR 2008). However, this generic plan has not been tested with respect to a disaster at a petrol station. This is because there have never been fires at petrol stations in Stellenbosch, and such incidents are not viewed as a priority. However, responding to petrol station fires cannot be a cut and paste exercise, as these incidents may pose unique challenges such as traffic congestion, and owing to the chemicals present, specialised firefighting equipment. Therefore, as Coppola (2015) argues, specific plans are necessary, and should be linked to exercises and drills. Such exercises help to identify roles and responsibilities, and test the system, exposing gaps that otherwise might have been overlooked (Coppola 2015). Rehearsing response procedures also provides opportunities for the evaluation and improvement of preparedness plans (Twigg 2004; Coppola 2015). However, the research suggests that Stellenbosch Municipality has not tested its own response preparedness, or raised awareness amongst the public about how to respond in the event of a fire or escape and alternate routes. While this is the responsibility of the landowners, it could be argued that the Fires Services and DM should play a leadership role with respect to this issue.

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In addition, Coppola (2015) argues that risk and hazard analysis should be performed to determine the appropriate response to hazard by the relevant body. In Stellenbosch, it is DM that conducts risk assessments and identifies disaster risks threatening the Municipality, and subsequently, develops risk reduction and preparedness plans for the identified disaster risks. Approximately 20 disaster hazards have been identified as priority hazards in Stellenbosch (Stellenbosch Municipality 2017). However, petrol stations are not considered as potential priority hazards, because in Stellenbosch they remain hypothetical and unrealised events.

Coppola (2015) also argues that public education should involve putting warning systems in place. Warning systems (warning signs in the context of petrol stations) must be designed to reach a range of possible recipients (Coppola 2015). All nine petrol stations appear to have understood fire could possibly occur. As result, they have posted conspicuous warning signs at pumps, which customers and petrol attendants can see clearly. Furthermore, Coppola (2015) states that equipment, such as fire extinguishers and other suppression tools, designed to limit spread of fire, are essential and should be accessible and in working order (Coppola 2015). At the petrol stations in Stellenbosch, fire extinguishers were visible and located in areas easily accessible to petrol attendants. However, some were not protected from weather, which could prevent them working properly. Hugo & Montanye (2016) caution that prolonged sun exposure can cause parts to fail and the chemical agents in fire extinguishers to clumped together, making them ineffective. Moreover, in every petrol station, observation data suggest that hose reels may have been too short to reach all the pumps, especially where there were more than five dispensers. There were also frequently no visible absorbents such as sand to mop up possible spillage in the precinct, clear evidence of fire hydrants or assembly/evacuation points. However, Coppola (2015) acknowledges that resources may be a constraint. He states that access to equipment such as firefighting trucks and personnel is mainly driven by resource availability and may influence response effectiveness (Coppola 2015). Therefore, creative ways should be developed to overcome resource constraints.

FP/FS indicated that inadequate human resources (firefighters) and firefighting equipment could hamper an effective response should there be a major fire. However, in such instances, the local municipality should work together with the district municipality to fill the gap. In addition, reaching petrol stations that are further from the fire stations could present a challenge during an emergency at petrol stations, especially at peak traffic hours. This is why it is important, as part of preparedness planning, to engage in exercises to rehearse response

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procedures and evaluate preparedness options (Twigg 2004; Coppola 2015). This could help the municipality determine the approximate time it would practically take for firefighters to reach each petrol station under different traffic conditions.

6.2. SUMMARY & CONCLUSION

The literature on technological hazards and the record of fires at petrol stations globally and locally highlights a need to ensure urban public safety through risk-aware development. Internationally, good practice prevents development near petrol stations, especially of hospitals, health centres, schools and old people's homes and housing. Land-use planning must play and important role in risk reduction. In South Africa, there are few regulations with respect to development around petrol stations, either at the national or provincial level; only Gauteng has developed specific guidelines on the siting of stations. These stipulate that there should be (a) a generic safe distance of 100 metres between petrol stations and residential properties, schools, or hospitals and (b) a three-kilometre distance between petrol stations.

The application of these standards shows that the siting of petrol stations in Stellenbosch does not meet these good practice guidelines. Of the nine petrol stations in the study area, approximately seven petrol stations were within a three-kilometre radius of each other, with two stations on opposite sides of a road less than 200 meters apart, and another two less than 300 metres apart, along the same street. Moreover, the results also reveal that the surrounding developments are located within 100 metres of the petrol stations. Approximately 100 buildings, ranging from dwellings, hostels, commercial and other buildings were found to be located within 100 metres of petrol stations. These findings show that the current land-use model and policies do not recognise the fire hazard posed by petrol stations, and do not adequately protect the public.

At the same time, the Municipality's preparedness to respond to petrol station fires appears low. This is due to the prioritisation of more frequent events. The untested disaster management plan could compromise effective responses during a fire at a petrol station. However, observation of petrol stations suggests the potential for major fires, and the need for both petrol station managers and the authorities to prepare for these events.

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6.3. Recommendations for further research

This study focused on investigating the extent to which land-use planning in Stellenbosch considers the fire-risk posed by petrol stations, and the implications for public safety. Further researcher is recommended. This should focus on bigger towns with larger populations and more complex land-use features. Expanding the research scope to the country's large cities in different provinces would further assist in establishing whether there are guidelines or procedures elsewhere that could guide the siting of petrol stations. It would also help gauge the extent to which petrol stations in South Africa comply with good practices and incorporate the urgent need for risk-aware land-use planning. Future research should also seek to understand levels of preparedness for fires at petrol stations in other towns and the perceptions of the public, petrol station managers and the authorities with respect to the potential fire hazards associated with petrol stations in South Africa.

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APPENDICES

Appendix A: Approval letter to commence research

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

APPROVED WITH STIPULATIONS
REC Humanities New Application Form

15 November 2017

Project number: GEO-2017-1901

Project title: Risk analysis of technological fire hazard in Stellenbosch town Petrol Stations and the implications for land use planning.

Dear Mr Kwanele Qonono

Your REC Humanities New Application Form submitted on 8 November 2017 was reviewed by the REC: Humanities and approved with stipulations.

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
15 November 2017	14 November 2020

REC STIPULATIONS:

The researcher may proceed with the envisaged research provided that the following stipulations, relevant to the approval of the project are adhered to or addressed:

1) The researcher states that institutional permission is not required, yet he seeks to conduct interviews with station managers and their employees during business hours. He is reminded that permission must be obtained from petrol station managers to access their facility and interview their staff during work hours. The researcher must ensure that such permission is confirmed before commencing with interviews/ data collection on the premises. It is also very important that the researcher assures station managers and workers of their confidentiality and anonymity as the questions may evoke concerns of negative consequences should the results show the stations to be non-compliant in certain areas. [RESPONSE REQUIRED]

2) The researcher must confirm where the safe is located where data is stored. It may be prudent to scan hard copy documents into electronic copies soon after data collection is complete. The researcher should note that data should be kept for a period of at least 5 years, particularly if there is an intention to publish. [RESPONSE REQUIRED]

HOW TO RESPOND:

Some of these stipulations may require your response. Where a response is required, you must respond to the REC within **six (6)** months of the date of this letter. Your approval would expire automatically should your response not be received by the REC within 6 months of the date of this letter.

Your response (and all changes requested) must be done directly on the electronic application form on the Infonetica system:https://applyethics.sun.ac.za/Project/Index/2088

Where revision to supporting documents is required, please ensure that you replace all outdated documents on your application form with the revised versions. Please respond to the stipulations in a separate cover letter titled "**Response to REC stipulations**" and attach the cover letter in the section **Additional Information and Documents**.

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (GEO-2017-1901) on any documents or correspondence with the REC concerning your project.

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Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Research Protocol/Proposal	Research proposal 20-17.docx..	06/11/2017	
Data collection tool	RP_Questionnaires	08/11/2017	
Data collection tool	RP_Questionnaires	08/11/2017	
Data collection tool	Additional Discussion guide	08/11/2017	
Informed Consent Form	Consent form	08/11/2017	

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Humanities complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.

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Appendix B: Semi-structured interview for Stellenbosch Municipality Disaster Management (DM) & Fire Prevention (FP)/Fire Service (FS)

1. Is there a disaster management plan in Stellenbosch municipality (link to the document)?

2. Who is responsible to coordinating the response and responding to fire/ explosion in petrol stations? What are the institutional challenges associated with this.

3. Is there a specific response plan to fire emergency in petrol stations? If yes, briefly outline.

4. Are there sufficient personnel and equipment to respond to fires generally?

5. How well equipped are they to respond to multiple events?

6. Would they be able to respond simultaneously to another event (e.g. normal dwelling fire or flood) and an event at a petrol station?

7. Are petrol stations required to have an Assembly point for an emergency? Is this enforced and by who?

8. Are there Emergency exits i.e. primary and secondary evacuation routes out of Stellenbosch should there be an emergency in petrol stations?

9. Does the Disaster Management (DM) run community awareness workshops on fire hazards in petrol stations. If yes how often?

10. What is an average distance from Fire station to the closest petrol stations?

11. Approximately how much time would it take to reach a petrol station for rescue, considering the traffic at different times? Morning, Midday and in the Evening?

12. How can safety be maintained in petrol station and what role should urban planners play in managing development close to potentially hazardous sites like petrol stations?

13. Have there been a fire or an explosion at any petrol station in Stellenbosch. If yes how many incidents, where or which petrol stations (which routes) and who was affected, number of injuries and/or deaths and properties damaged?

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Appendix C: Semi-structured interview for Stellenbosch Traffic Department

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Stellenbosch municipality: Traffic department.

1. What are traffic peak times in Stellenbosch town?

2. Which routes have high traffic volumes in Stellenbosch?

3. What are the areas of responsibility in relation to traffic management in Stellenbosch?

4. What is the role of traffic department in planning decision for an emergency event in terms of i.e escape routes and what are the procedures involved.

5. What would need to be done if there was a fire in one or more of the petrol stations?

6. What are/would be the challenges in terms of traffic management in Stellenbosch town should/would a need to evacuate the town arise?

7. What is the role you see traffic department play in decision making relation to both land use planning and emergency management? More in particular when it comes to siting/location of hazardous land use type i.e petrol stations as well as managing traffic flow during emergency.

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Appendix D: Semi-structured interview for Stellenbosch Land-Use Planning

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<u>Questionnaire for Land Use Planning (LUP): Stellenbosch Municipality</u>

1. **<u>General questions which relate to the academic literature</u>**
2. Explain the structure, set up and hierarchy as well as roles and responsibilities within the town planning department?
3. Overall role of the (LUP) department in context of Stellenbosch Municipality i.e what is department's aim, vision mission to achieve in land use planning about Stellenbosch?
4. What other departments, units or institutions (outside the municipality) does the LUP department collaborate with in order to with achieve the aim, vision mission?
5. What are some of the challenges emerging from this collaborations that relating to land use planning
6. How can those challenges be overcome to ensure sustainable land use in Stellenbosch?
7. Does the (LUP) department consider dangers that can be associated with certain land use type when siting or deciding for a location (zoning)?
8. Is there a legislative or constitutional framework governing land use planning in the municipality in general and specifically detailing where dangerous facilities such as petrochemical works/facilities and refineries, chemical works and production plants, compressed air manufacturers/users such as liquefied petroleum gas (LPG), nitrogen gas, medical oxygen, hydrogen gas etc should/not be placed.
9. Is the legislation enforced minimise, prevent and avoid hazard linked with these land uses.

<u>Specific questions in relation to petrol stations</u>

1. Are petrol stations considered/ perceived dangerous by the land use department?
2. What is the requirement (general and specific) for the location of petrol stations in relation to other land use types such as residential, schools, commercial buildings?
3. What is the requirement (general and specific) for the location of petrol stations in relation to other land use types such as residential, schools, commercial buildings?

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4. Are there specific safety controls/measures that petrol stations should do to ensure safety in and around petrol stations or to protect surrounding land use?
5. Who have the authority or responsible to ensure that these measures are followed?
6. Are there building guidelines and/or type of building material that are mandatory for houses around and /or in the area of petrol stations?
7. Are there any standards that petrol stations should adhere to ensure safety at least from land use planning side?
8. Is there a departmental collaboration between Disaster Management Centre Department, fire service department, Traffic department and Urban Land use planning how can safety of people residing near petrol station be ensured?

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Appendix E: Fire safety standard checklist for petrol stations adopted from sabs combined with the literature

Name of the petrol station			
	Identify the fire hazards/risk		
Ignition source			
Fuel			
Oxygen			
	Identify people at risk/Activity		
Any persons who are in and around the premises should be considered at risk, but there will be some people who require particular attention.	The number of people in the premises of the petrol stations.		
	Employees working at convenience store		
	Petrol Attendants		
	Hazmat drivers		
	Customers		
Surrounding land-use type	Open space		
	Residential buildings		
	Industrial buildings		
	Schools		
	Churches		
	Community Halls		
	Other.		
Adjacency to road	Main road		
	Secondary road		

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	Arterial		
WARNING SIGNS		**Y**	**N**
	Warning signs shall be conspicuously posted at the individual dispensing area incorporating the following wordings:		
	No smoking		
	No naked lights		
	Stop engine		
	Switch off cell phones		
EMERGENCY EQUIPMENT		**Y**	**N**
	Fire Extinguishers: Shall be provided at the individual dispensing units and protected from the weather.		
	Horse reels: Sufficient hose reels coverage shall be provided at the service station		
	Absorbents: A small quantity of absorbent or sand shall be provided at the service Station to mop up any spillage.		
	Fire Hydrant: Fire hydrant must be within any part of the fire engine access road		
	Assembly/Evacuation points		

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Thesis

Title	Start Date	Due Date	Post Date	Marks Available
Kwanele Qonono - Thesis	26 Oct 2018 - 18:29	31 Oct 2018 - 15:00	26 Oct 2018 - 18:29	100

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Submission Details

Submission ID	1028812594
Submission Date	29-Oct-2018 11:59AM (UTC+0200)
Submission Count	1
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Weight letter

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26 October 2018

Subject: Information for examiner of Master of Philosophy Thesis

Dear Examiner

With respect to your examination of Kwanele Qonono's MPhil in Disaster Risk Science and Development Thesis, please note the following:

The thesis is worth 90 credits out of a total 180 credits for the MPhil Programme. This equates to 50% of a full thesis. The one-year MPhil programme includes a 90-credit coursework component and the 90-credit thesis.

Please do not hesitate to contact me, Robyn Pharoah, if you have any queries or require additional information. My details are: robynpharoah@sun.ac.za or (021) 808 9492.

Kind regards,

RPharoah

Robyn Pharoah
Supervisor (and Mphil Programme Coordinator)

Stellenbosch University https://scholar.sun.ac.za

DECLARATION BY SUPERIVSOR WITH REGARD TO THE SUBMISSION OF THESIS/DISSERTATION FOR EXAMINATION

Name of student	Kwanele Qonono
Student number	17592976
Degree programme	MPhil Disaster Risk Science and Development
Title of thesis/dissertation	Risk Analysis of Fire Hazard at Petrol Stations in Stellenbosch and the Implications for Planning
Year of first registration	2017
Department	Research Alliance for Disaster and Risk Reduction
Supervisor	Dr Robyn Pharoah
Co-supervisor(s) [*If applicable*]	N/A

I hereby declare that I **support** the submission of this student's thesis/dissertation for examination. {Delete what is not applicable}

If you do not support the submission, please submit a brief explanation to the Postgraduate Examination Office for inclusion in the student's file. Your correspondence will be treated in strict confidence.

I also confirm that the work has been submitted through Turnitin and I have reviewed the similarity report. The similarity percentage is 16% and I am satisfied that the thesis/dissertation may be sent out for examination in its current form.

26 October 2018

Signature Date

ADDENDUM F(I)
Last updated in March 2018

Faculty of Arts and Social Sciences

[This completed and signed form must be emailed to nickv@sun.ac.za as part of supporting documentation in the zip folder of each higher degrees student during submission.]