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Analysis of the Fire Hazard Posed by Petrol Stations in Stellenbosch and the Degree of Risk Acknowledgement in Land-Use Planning

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***Abstract*—**Despite the significance and economic benefits of petrol stations in South Africa, these still pose a huge risk of fire and explosion threatening public safety. This research paper examines 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. To achieve this, the research identified the land-use types around petrol stations in Stellenbosch and determined the extent to which their locations comply with the local, national, and international land-use planning regulations. A mixed research method consisting of the collection and analysis of geospatial data and qualitative data was applied, where petrol stations within a six-kilometre radius of Stellenbosch's town centre were utilised as study sites. The research examined the risk of fires/explosions at these petrol stations. The research investigated Stellenbosch Municipality's institutional preparedness to respond in the event of a fire/explosion at these petrol stations. The research observed that siting of petrol stations does not comply with local, national, and international good practices, thus exposing the surrounding developments to fires and explosions. Land-use planning practice does not consider hazards created by petrol stations. Despite the potential for major fires at petrol stations, Stellenbosch Municipality's level of preparedness to respond to petrol station fires appears low due to the prioritisation of more frequent events.

***Keywords*—**petrol stations, technological hazard, DRR, land-use planning, risk analysis.

I. Introduction

THERE is no research on the fire hazard posed by petrol stations in Stellenbosch and in South Africa generally. Academic literature on petrol stations in South Africa has focused on issues relating to fuel prices, economic benefits of petrol stations, fuel demand and supply as well as health impacts [1]-[4]. None of these studies relate to fire safety in and around petrol stations, despite the abundant evidence for potential fires at these facilities. This may have compromised the safety of the public. Several incidences of fires at petrol stations in South Africa have been reported in local news outlets since 2015 [5]-[8]. While these incidences may have not resulted in any significant deaths or injuries, a fuel tank explosion in Boksburg that resulted in over 41 deaths and several critical injuries in December 2022 in South Africa should be an alert of the hazardousness of the Liquefied Petroleum Gas (LPG) and ultimately petrol station storage facilities [9]. Elsewhere in the world, petrol station fires and explosions have resulted in significant human deaths, injuries and severe damage to properties [10]-[18].

To avoid and reduce severity of these incidences and minimise their effects, petrol stations should be located at safe distances 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 hazard potential has not been taken into account in land-use planning. Land-use planning has a critical role to play in ensuring the safety of the public. Its purpose is to resolve conflicts and reduce the risks associated with the location of dangerous facilities [19]. At its simplest, land-use zoning should aim to separate densely populated areas from dangerous facilities and their associated transport routes and reduce exposure to hazards through the creation of buffer zones around dangerous facilities [19]. However, the threat posed by petrol stations is poorly studied, with the result that it is often inadequately integrated into land-use planning [20]. This is jeopardising the safety of the general public.

This research aimed to investigate the level of compliance with national laws governing land-use development in and around petrol stations. The research focused on petrol stations within a six-kilometre radius of the Stellenbosch town centre in Stellenbosch, Western Cape South Africa.

The research objectives were to:

1. 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.
2. Examine the risk of fires at petrol stations by observing risk behaviours and the availability of fire prevention equipment.
3. Investigate Stellenbosch Municipality's preparedness to respond in the event of a fire at a petrol station.

The outcomes stemming of this paper aid in policy making at various levels of government in relation to disaster risk management at petrol stations[1]. It also contributes and fill the

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[1] Petrol stations: any petroleum facility containing large quantities of hazardous materials, used for the sale or dispensing of petrol or oil for motor vehicles such as LPG, natural gas, hydrogen, biodiesel, kerosene, or butane, while others add shops or convenience stores to their primary business [12], [54]-[57], [48]. These facilities are described differently in different parts of the world [39].

gap in the literature on technological hazards[2] in South Africa and elsewhere, particularly the threat posed by petrol stations, and implications for land-use planning[3]. Outcomes further aid into 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 support effective disaster risk reduction[4] (DRR) with respect to petrol stations. The method applied in this research is useful in advancing further research to fire risk analysis[5] elsewhere in South Africa.

II. Study Area

Stellenbosch is located in the Cape Winelands District Municipality in the Western Cape Province, South Africa (see Fig. 1). 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. The town's global positioning coordinate system is -33° 55' 55.5816" South (S) and 18° 51' 36.5436" East (E). 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 utilising the method explained in the below section.

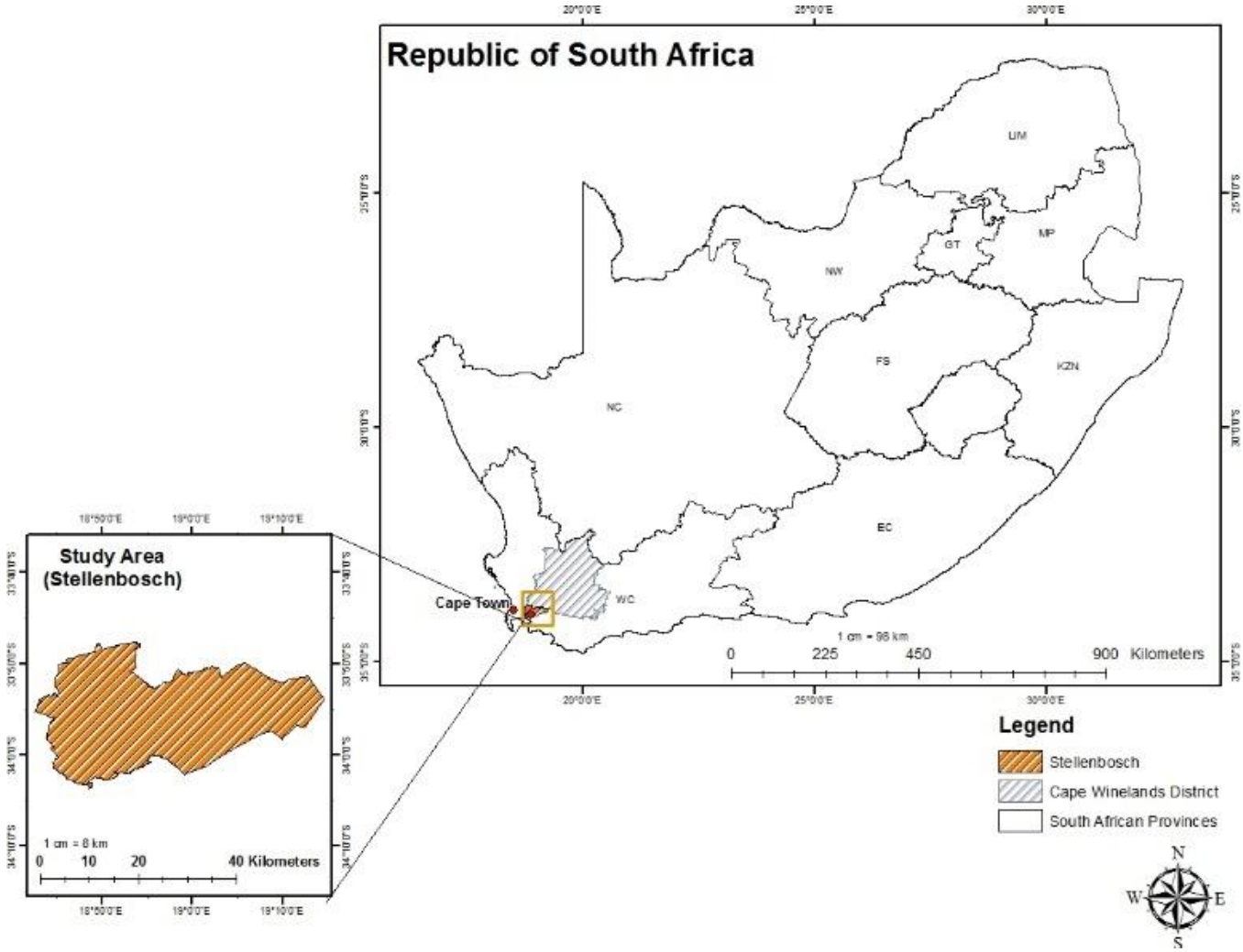

Fig. 1 Location of Stellenbosch Municipality in South Africa

[2] 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, petrol station fires or explosion [58], [59].

[3] 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" [60]

[4] Disaster Risk Reduction refers to "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" [60], [61].

[5] Risk analysis structured procedure to evaluate qualitatively and/or quantitatively the threat posed by hazards and vulnerability to their effects [61], [37].

III. Material and Methods

This research applied mixed research methods consisting of the collection and analysis of geo-spatial data and qualitative data (see Fig. 2). 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 [21]. This was complemented by geo-spatial data collection, which examines the distribution and location of geographical data over space and time [22].

Key reason to apply a mixed method was to combine the strengths of methods while at same time addressing the weakness of each. For example, geo-spatial data were used in this study to identify the location and distribution of geographical petrol stations. However, this did not provide insights into the reasons for their location. Qualitative method aided in soliciting useful supplementary data that sought to understand the rationale for the location and distribution of the petrol stations in Stellenbosch. It also aided in investigating the legislative environment, the institutional land-use planning decisions governing the development of petrol stations, and institutional capability to respond to petrol station fires. Observation of human behaviour at the petrol stations was conducted at site, where images in each were subsequently taken.

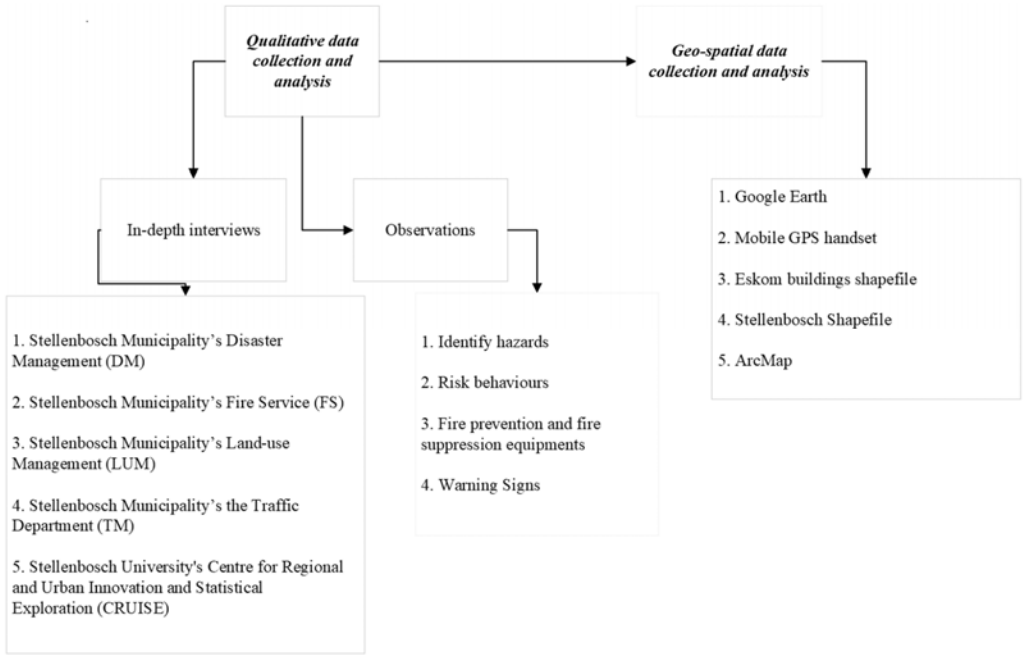

Fig. 2 Qualitative and geo-spatial data collection and analysis

A. 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.

a) 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 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 [23]. The in-depth interviews were transcribed by the researcher. Through the process of interviews and transcription, we 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

b) Data were also collected through observation. Observation is a data collection technique that can be either structured or unstructured [24]. The observation was structured using an adapted version of the South African Bureau of Standards (SABS) and 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 the supervisor and proof of ethical clearance. 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. SABS is an organisation lawfully established in terms of the Standards Act, 1945 (Act No. 24 of 1945) and works in terms of the recent Standards Act of 2008 (Act No.8 of 2008) [25]. As the national standardisation institution in South Africa, it is mandated to:

1. Develop, promote and maintain South African National Standards (SANS)
2. Promote quality in connection with commodities, products and services
3. Ensure conformity in assessment services and requirements established in terms of the Standard Act (SABS n.d). [25]

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 the following:

i. existing fire safety measures,
ii. control of ignition sources or sources of fuel,
iii. fire detection and warning, and
iv. means of escape (see Fig. 2). Photographs were also taken on sites.

B. Geo-Spatial Data Collection

The geo-spatial 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. Equation (1) extracted from an Introduction to GIS Handbook [26] was used:

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

(1)

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 town centre was determined using the Stellenbosch shapefile. A recently updated buildings shapefile compiled by Eskom was obtained from Umvoto Africa (Pty) (Ltd). Umvoto was identified through Internet search for GIS consulting companies. They provided the required data free of charge. The Eskom buildings layer covers the Western Cape. The Eskom buildings falling within the study area were extracted in ArcMap using a geo-processing tool.

IV. Results

Nine petrol stations were identified within six kilometres from Stellenbosch centre (see Fig. 3). Contrary to best practice, there is a significant development in close proximity to petrol stations.

Land-use development found in proximity to these petrol stations included (1) commercial activity such as convenience stores, restaurants, fast food stores and liquor stores, (2) dwellings such as residential apartments, university hostels and accommodation and (2) institutional buildings such as University of Stellenbosch Arts & Social Sciences building (see Fig. 4).

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. other than those set by SABS. However, the 2002 Environmental Impact Assessment 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 [27]. The research showed that petrol stations in Stellenbosch do not comply with the EIA guidelines [27]. More than 100 residential developments were found to be within 100 metres of the petrol stations (see Fig. 5).

Seven petrol stations were found within three kilometres of each other (see Fig. 6).

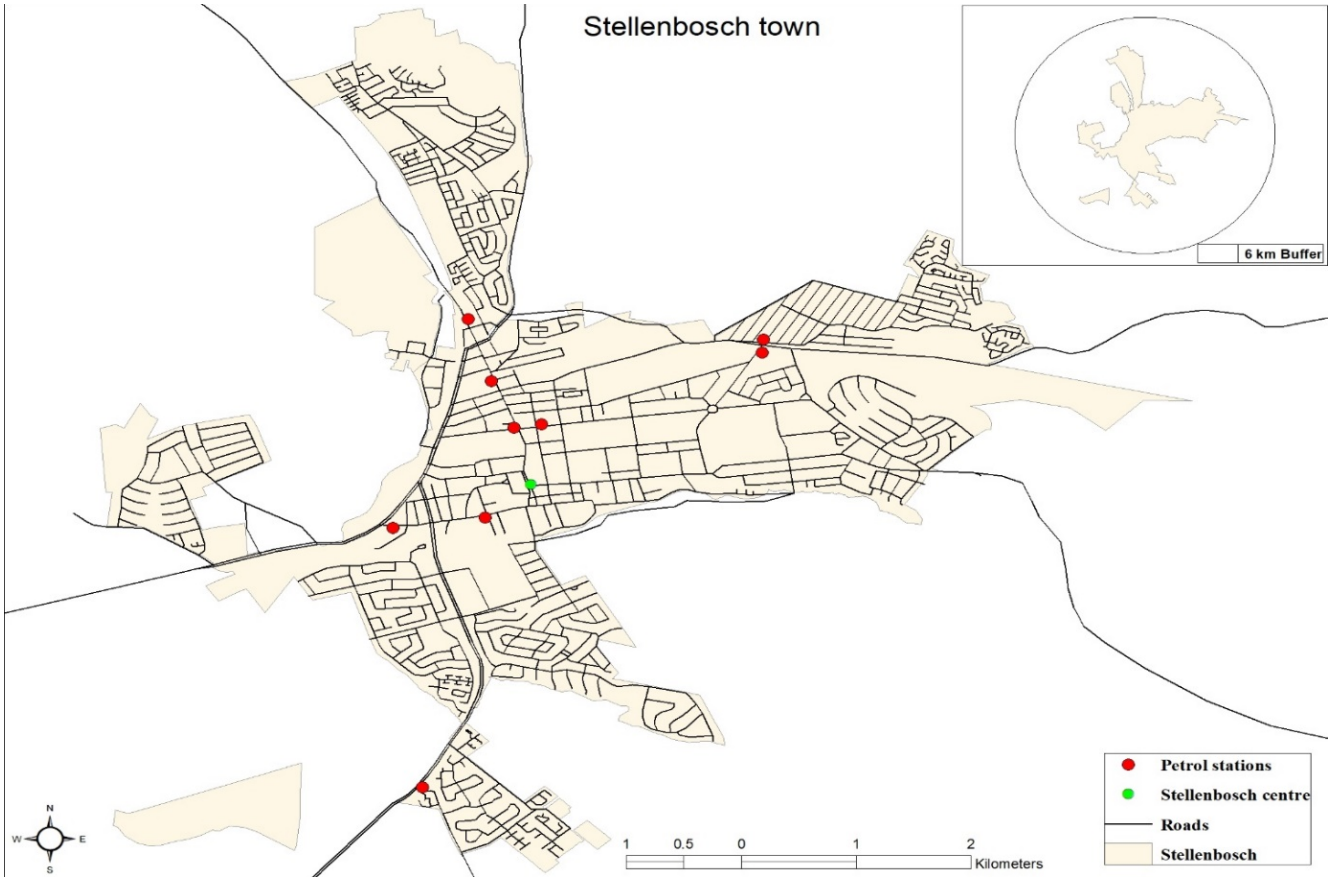

Fig. 3 Nine petrol stations within 6 km radius in Stellenbosch

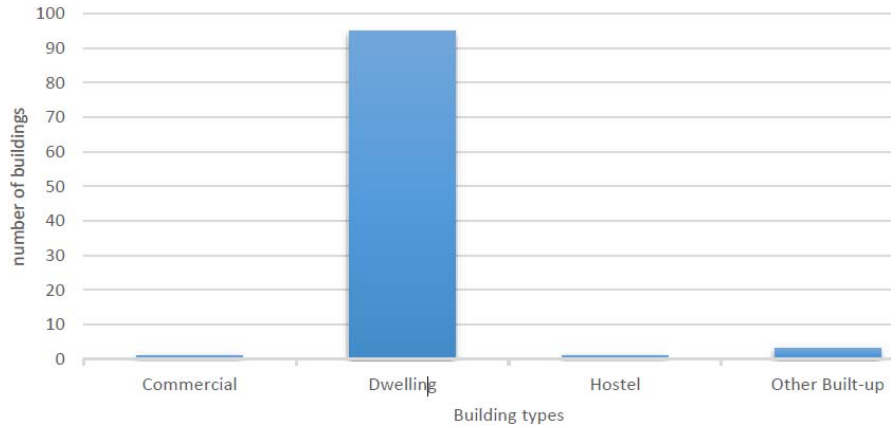

Fig. 4 Land-use developments within 100 m radius of petrol stations

Moreover, findings suggest the potential for fires at these petrol stations, as a result of risky behaviours by users. Risky behaviours observed in these petrol stations included customers leaving engines running while refilling their cars and smoking. Nevertheless, all the petrol stations had visible fire suppression equipment, and warning signs, but in some petrol stations fire extinguishers were unprotected from weather (see Fig. 11).

The Stellenbosch Municipality's level of preparedness to respond in the event of a fire at a petrol station appears low. The research established that petrol station fires were not considered a priority hazard by the Municipality. As a result, the Municipality has no plans in place to deal with such incidents. In addition, the municipality did not conduct emergency drills, indicating that the Municipality is less prepared for petrol station accidents should they occur (see Fig. 12).

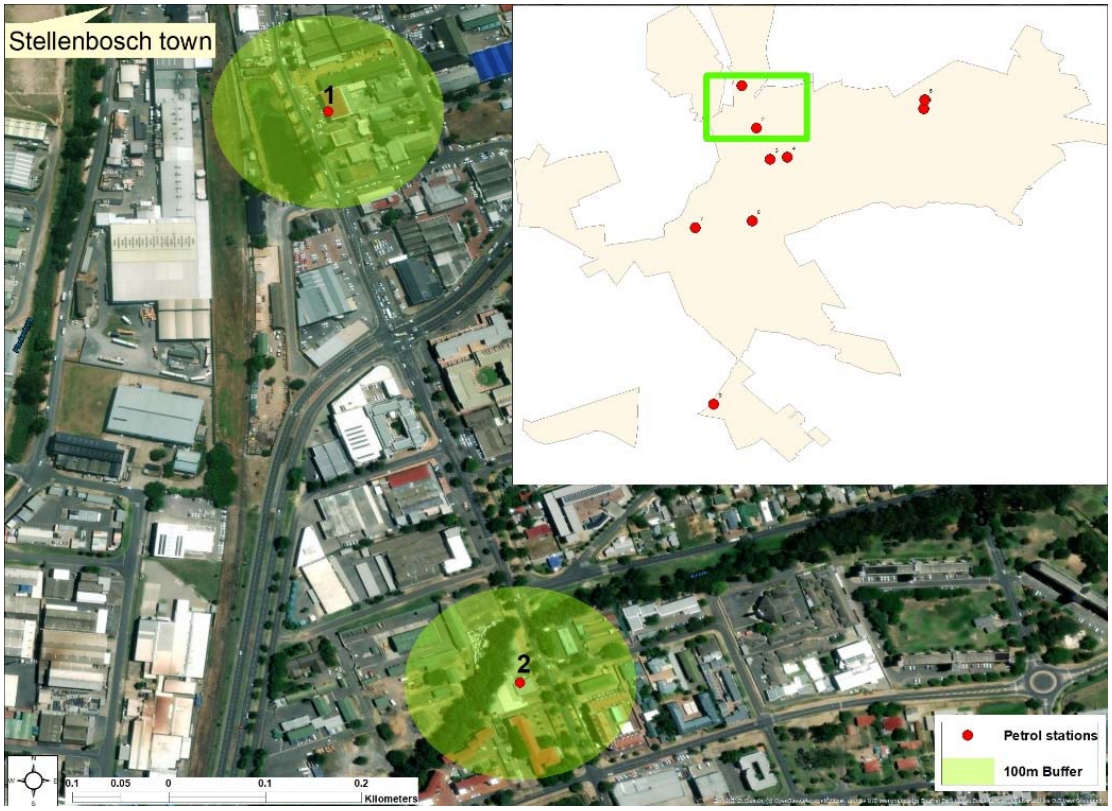

Fig. 5 Land-use development at 100 m radius of petrol stations 1 and 2 in Stellenbosch

Fig. 6 Land-use development at 100 m radius of petrol stations 3 and 4 in Stellenbosch

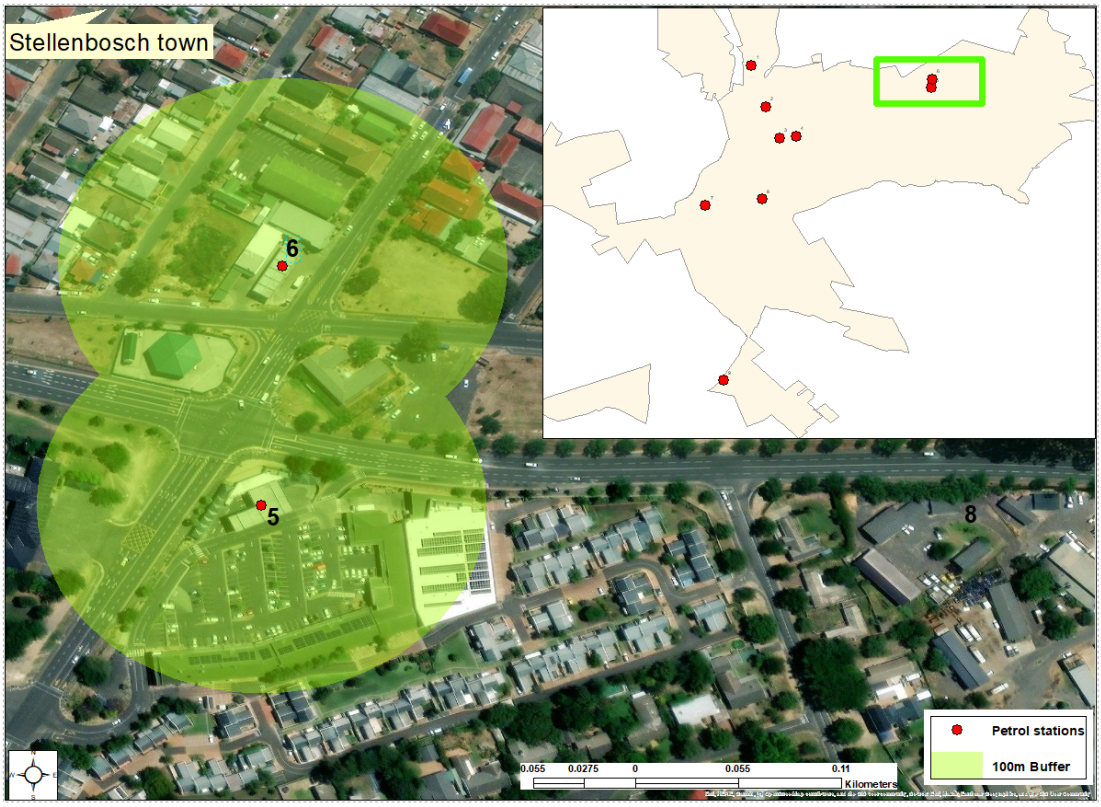

Fig. 7 Land-use development at 100 m radius of petrol stations 5 and 6 in Stellenbosch

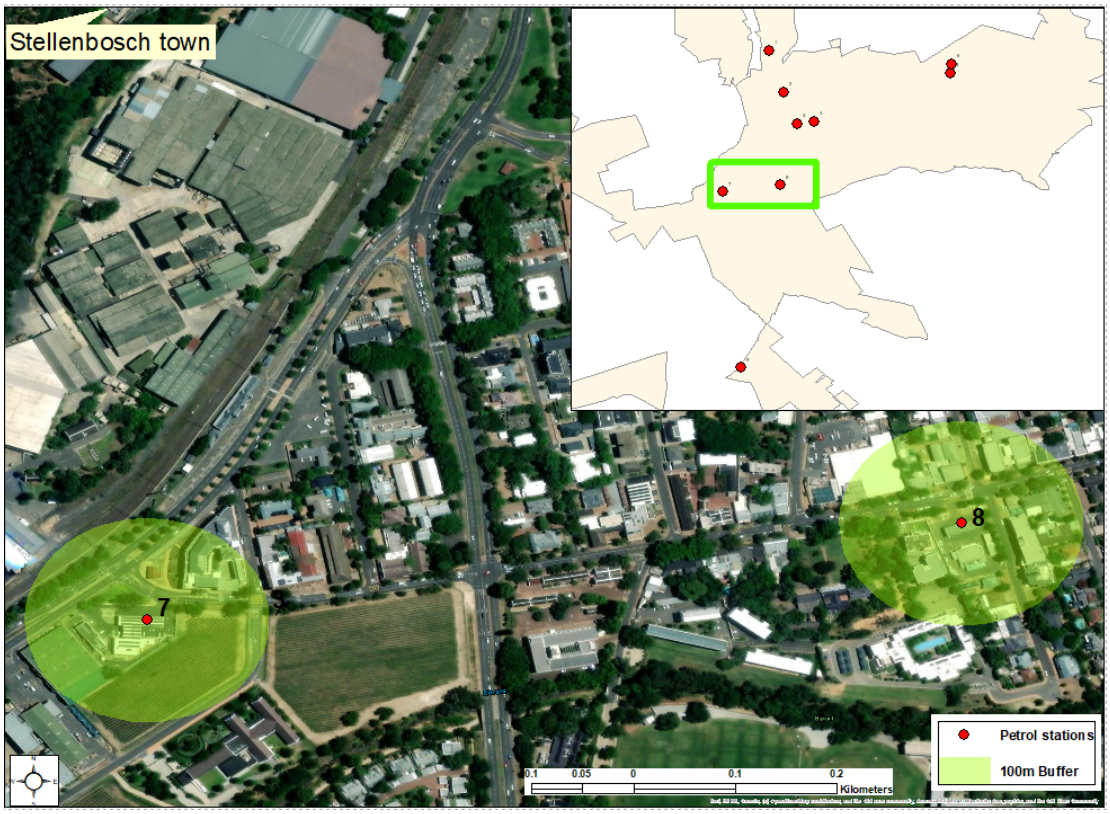

Fig. 8 Land-use development at 100 m radius of petrol stations 7 and 8 in Stellenbosch

Fig. 9 Land-use development at 100 m radius of petrol station 9 in Stellenbosch

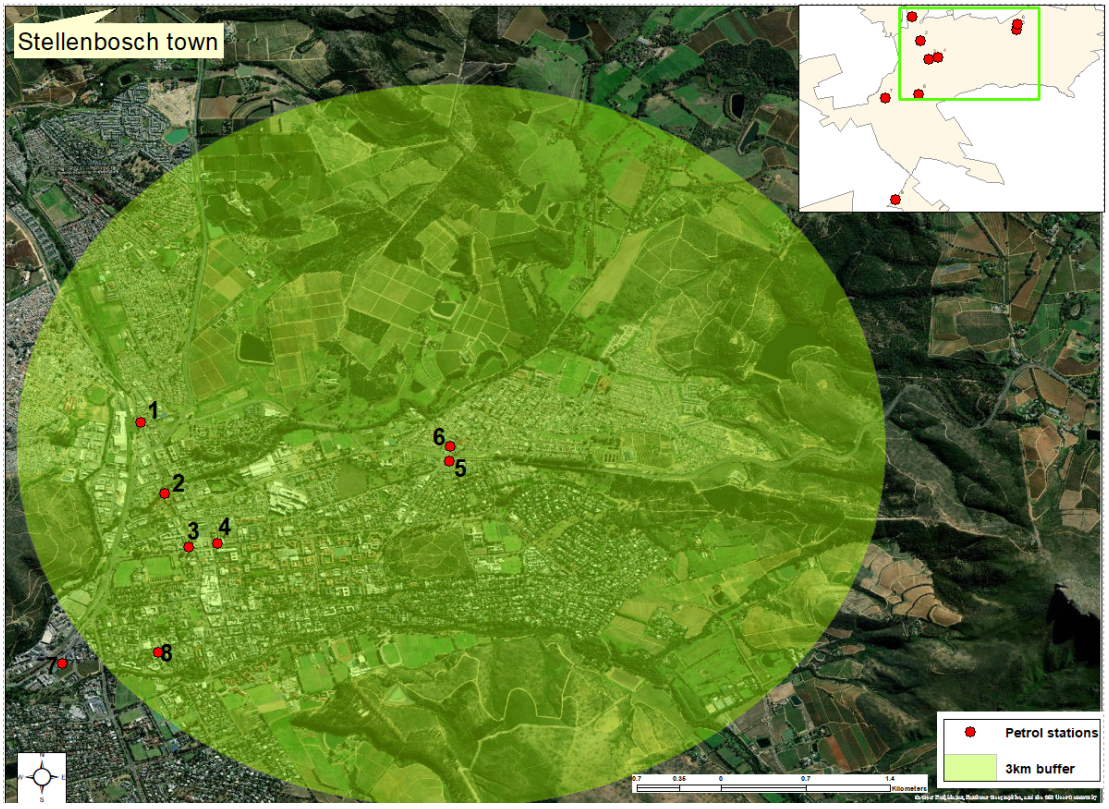

Fig. 10 Petrol stations at 3 km radius in Stellenbosch

Fig. 11 Unprotected Fire Extinguisher at petrol station #6 in Stellenbosch

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

Fig. 12 Priority hazards in Stellenbosch Municipality

V. Discussion

Technological hazards are well documented historically [28]-[31] 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 [19], [31]-[34]. As a result, DRR measures, enacted through policy intervention and legislation, were introduced in many countries and contexts [35]. 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 [36], and often resulting in disasters [28]. Contemporary society has advanced technologically and become so complex that the successful management and amelioration of technological disasters requires a holistic approach.

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. [37] 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 [37]. The study findings correspond with observations by Christou et al. [37] 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 [38]-[40]. In countries where there are planning regulations, they were often ignored [37]. While the reasons may vary, the most common relates to the economic benefits of the petrol stations to the local community and municipality [39], [41]. Abdullahi and Dawha [39] argue 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 [42] 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 [43].

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 [27], [43]-[45]. 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 [27]. 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.

A. Results Implications 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 ensure that petrol stations are located a safe distance from one another.

B. Fire-Safety at Petrol Stations

A potential for a fire/explosion breaking out exists in petrol stations. The National Examination Board in Occupational Safety and Health (NEBOSH) [46] 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 [47], [48] indicate that petrol station accidents are most often due to human failures and negligence, with Cutter [31] and Crichton [19] identifying technological disasters as human induced events. In keeping with the literature on technological hazards, the observation data suggest 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 [31] argument that the public and customers often do not appreciate the dangers of technological fire hazards. In this respect, Coppola [49] 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 [49]. However, Stellenbosch Municipality indicated that they have not extensively engaged in public awareness programmes in developments around petrol stations. Those 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 [49].

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 (see Fig. 13) [50]. This is identified in the HFA 2005-15, under priority five, as a critical component of effective emergency response [51]. 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.

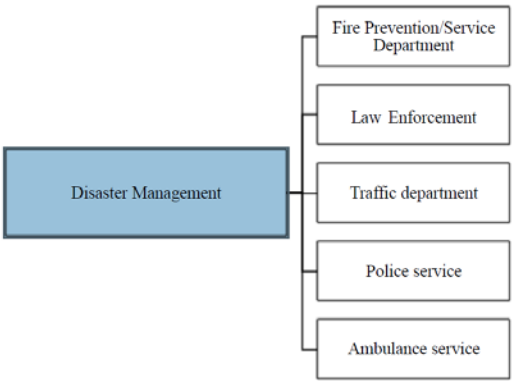

Fig. 13 Stellenbosch Municipality's Standard Operating Procedures to respond to disasters

Therefore, as Coppola [49] 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 [49]. Rehearsing response procedures also provides opportunities for the evaluation and improvement of preparedness plans [49], [52]. 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.

In addition, Coppola [49] 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 [50]. However, petrol stations are not considered as potential priority hazards, because in Stellenbosch they remain hypothetical and unrealised events. Coppola [49] 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 [49]. All nine petrol stations appear to have understood fire could possibly occur. As a result, they have posted conspicuous warning signs at pumps, which customers and petrol attendants can see clearly. Furthermore, Coppola [49] 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 [49]. 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. Alsina and Team [53] caution that prolonged sun exposure can cause parts to fail and the chemical agents in fire extinguishers to clump 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 [49] 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 [49]. 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 procedures and evaluate preparedness options [49], [52]. This could help the municipality determine the approximate time it would practically take for firefighters to reach each petrol station under different traffic conditions.

VI. Conclusion

Literature on technological hazards and records of fires and explosions 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 an 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 Province 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

VII. Recommendations

This research aids in policy making at various levels of government in relation to disaster risk management at petrol stations. It also contributes and fills the gap in the literature on technological hazards in South Africa, particularly the threat posed by petrol stations, and implications for land-use planning. The research assists 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 supports effective DRR with respect to petrol stations. The method applied in this research is useful in advancing further research to fire risk analysis elsewhere in South Africa.

Acknowledgments

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