



GIS as a tool for strategic risk reduction and decision making in Fire Services in the Mopani District Municipality

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Dissertation accepted in fulfilment of the requirements for the degree *Master of Science in Environmental Science with Disaster Risk Science* at the North-West University

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Graduation October 2022

32594313

There are many people who have encouraged and assisted me over the years. To each and every one who has supported me on this journey, especially my family, I am most grateful. My father, Bernard Altenroxel, sadly did not get to see me finish this journey. I dedicate this dissertation to his memory.

To all those in Fire and Rescue Services and Disaster Management who have provided me with the opportunity to test new ways of exploring spatial data, thank you for your patience and trust. Kobus Visser, Vincent van der Westhuizen, Beryl Monakisi, Ludwig Stemmett, Ntsako Lambane and Wynand Els, I'd like to extend a special word of thanks for all the valuable advice and support over the years.

In memory of Hannes Steyn, who encouraged my studies and with whom I could debate issues around disaster management for hours. His wisdom and passion for disaster management instilled a fire in me for the public service and his endless self-sacrifice and dedication served as an example to be followed.

To Kristel Fourie and Prof. Cilliers, thank you for all your advice and support. I could not have completed my journey without your guidance.

Last, but not least, a special thanks to Tony Long who set me on this journey of discovery and study many years ago. Your wisdom and encouragement have kept me motivated to keep learning and to keep moving forward.

Providing an effective and efficient fire and rescue service in rural South Africa is a daunting task. There are many aspects of service provision which must be considered as well as key legislation and standards which guide policy implementation. The use of incident data collected through the disaster management information management process provides the platform for this study on location and resource allocation planning for Mopani Fire and Rescue Services. GIS (Geographical Information System) is used as a tool to visualise demand, undertake network analysis and to understand other spatial characteristics which can be used to inform choices on station location and resource needs. The linkage to disaster risk management and the use of collaborative networks is also considered, with particular focus on improved capacity for disaster risk reduction in the Mopani District.

Key terms: Mopani District Municipality, fire and rescue services, disaster management, risk reduction, resource needs, incident response, network analysis, service delivery, information management

Om 'n doeltreffende en effektiewe brand- en reddingsdiens in landelike Suid-Afrika te verskaf, is 'n uitdagende taak. Daar is baie aspekte van diensverskaffing wat oorweeg moet word, asook sleutelwetgewing en standarde wat beleidsimplementering rig. Die gebruik van voorvaldata wat deur die rampbestuurinligtingbestuursproses ingesamel is, bied die platform vir hierdie studie oor ligging- en hulpbrontoewysingsbeplanning vir Mopani Brand- en Reddingsdienste. GIS (Geografiese Inligtingstelsel) word gebruik as 'n instrument om aanvraag te visualiseer, netwerkanalise te onderneem en om ander ruimtelike kenmerke te verstaan wat gebruik kan word om keuses oor stasieligging en hulpbronbehoefte in te lig. Die koppeling met ramprisikobestuur en die gebruik van samewerkende netwerke word ook oorweeg, met spesifieke fokus op verbeterde kapasiteit vir ramprisikovermindering in die Mopani-distrik.

Sleutel terme: Mopani-distriksmunisipaliteit, brand- en reddingsdienste, rampbestuur, risikovermindering, hulpbronbehoefte, insidentreaksie, netwerkontleding, dienslewering, inligtingbestuur

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CHAPTER 1: INTRODUCTION

1.1 Introduction

A wealth of research has been undertaken locally and internationally on emergency services, including fire and rescue services, as a means to identify gaps in service delivery or in planning for optimum station location (Oppong, *et al.*, 2018; Yao and Zhang, 2018; Aldabbas, *et al.*, 2018; Liman, *et al.*, 2016; Green, *et al.*, 2014). GIS (Geographical Information System) has been central in many of these studies, linking policy and industry standards with a visual representation of service provision for more informed decision-making and the application of strategic risk reduction (Green, *et al.*, 2014; Aldibbas, *et al.*, 2018; Oppong, 2017). This strategic risk reduction relates to the use of innovative tools to achieve disaster risk reduction. In business management, strategic risk reduction is used to manage change and its associated risks (Roberts, *et al.*, 2018:x). However, in the context of disaster management, strategic risk reduction through the innovative use of tools and technology aids in the mitigation of disaster risk (Izumi, *et al.*, 2019:1).

This chapter thus provides brief background information on the use of GIS for emergency services, with special focus on fire and rescue services (also colloquially known as 'fire services'), the Mopani District Municipality and the research design. The research question, key objectives, ethical considerations and limitations of the study are also set out.

1.2 Problem statement

GIS (Geographical Information System) is well recognised as a powerful tool for supporting decision-making process in emergency services. GIS not only aids in identifying spatial trends and patterns, but can also be used to answer questions related to the station location problem, including optimal fire station location planning (Heywood *et al.*, 2011:175). GIS enables visual representation of spatial data and the stimulation of spatial thinking in disaster management (Tomaszewski, 2020:18-19). GIS thus provides tools for the evaluation and analysis of data which are beneficial to all emergency services.

The South African National Standard (SANS) 10090:2018, which deals with community protection against fire, sets out standards against which fire and rescue services in South Africa can be evaluated on aspects such as response times and fire risk classification, amongst others (SANS, 2018). Coupling GIS with the requirements set out in the SANS (2018) provides a powerful means to analyse and visualise service delivery to develop strategic plans aimed at optimal fire station location planning and disaster risk management. Green *et al.* (2014:59-61) illustrated this fact

utilising GIS for accessibility analysis for the eThekweni Metro Fire and Rescue Services. Through their study, Green *et al.* (2014) could put forward recommendations on optimal fire station location planning for eThekweni Metro. Furthermore, a clear link was recognised between fire station placement and disaster risk management (Green *et al.*, 2014:53). Similarly, Baloyi (2019) applied an accessibility analysis technique for the evaluation of fire station location in Ekurhuleni Metro, while also considering the SANS (Baloyi, 2019:20). These two studies provide practical examples of how, in striving to meet national standards, actual service delivery can be measured and strategically adjusted for disaster risk reduction where necessary (Green *et al.*, 2014:55). There are however numerous other ways in which GIS can be applied strategically to inform decision-making related to fire and rescue services and related emergency services, as illustrated in some of the studies highlighted below.

The focus of prior research in the context of South African emergency services has generally only been on one aspect of the work, such as the provision of water for fire-fighting (Myburgh, 2012; Bean and Ilemohade, 2018) or road traffic accidents (Osidele, 2016). Others have used GIS to undertake accessibility analysis for ambulance services or investigated disaster risk reduction strategies related to informal settlement fires (Baloyi *et al.*, 2017; Dlodla, 2016). Internationally, GIS has been used in the spatial analysis of road traffic accidents in Serbia, location planning for fire stations in Switzerland and Nigeria, and accessibility analysis for ambulance services in Iran (Çela *et al.*, 2012:164; Aldabbas *et al.*, 2018:69; Isa *et al.*, 2016:42; Masoodi and Rahinzadeh, 2015:439).

In the context of this study, GIS is suggested as a tool which can be used to generate information and data in order to consider station location. By using historic fire and rescue service incident location data together with SANS 10090:2018 requirements in terms of response times and fire risk classification, decisions on better station placement, strategic decision making and disaster risk reduction are possible. The effectiveness of the relationship between information management and GIS was illustrated in the study undertaken by Isa *et al.* (2016) as they sought to analyse the spatial distribution of fire stations in Kano Metropolis, Nigeria, against actual fire incidents. Similar to the study by Green *et al.* (2014), the outcome of the study proved beneficial to fire and rescue services. In the South African context, the outcome of the study could be incorporated into disaster risk reduction planning (Green *et al.*, 2014:64).

Within the Mopani District Municipality, the provision of fire-fighting services is listed among the powers and functions of the municipality, and includes accident response and specialised rescue (MDM, 2018a:14;79). There are five fire stations located within the Mopani District, and a purpose-

built Disaster Management Centre in the town of Tzaneen (MDM, 2018a:79;154). Fire and rescue services in South Africa are frequently faced with challenges, including meeting service standards in terms of response times (Green *et al.*, 2014: 53; MDM, 2018a:79). In the more rural context, such as the Mopani District, the scattered spatial distribution of rural communities makes service delivery challenging and is also often hampered by poor access roads (MDM, 2018a:45;46). Without proper information management and detailed analysis, it is difficult to motivate for better, or more appropriate resources and station location, which can improve service delivery and reduce risk. Historically, in situations where the use of this data could have assisted in decision-making, it has been found that incident-related-data is incomplete or not available (Green *et al.*, 2014:53). In the context of Mopani however, the availability of full data through information management provides the opportunity to incorporate this aspect into the study. Unlike previous studies which only focused on one aspect of the work undertaken by Fire and Rescue Services, such as fire or rescue work, this study seeks to incorporate both aspects. This is aimed at generating a full understanding of the operating environment within which the service works for the development of appropriate, risk reduction measures and decision-making for improved service delivery.

1.3 Key research questions

- How can GIS and information management be used to support decision-making in developing disaster risk reduction strategies?
- How can GIS be used to support decision-making in station location planning and resource allocation for fire and rescue services?
- Can recommendations be made on the use of GIS for the development of disaster risk reduction strategies?
- How can information management be used to support decision-making in the Mopani District Municipality?

1.4 Research objectives

The research aimed to make use of historic incident data and GIS analysis techniques to strengthen decision-making on resource needs for fire and rescue services, fire station location planning and aid in the development of strategic disaster risk reduction strategies. The intention was to illustrate how information management could be used to strengthen decision-making for fire and rescue services while also bolstering disaster risk management activities.

The following research objectives were set:

- To explore the use of GIS coupled with information management as a tool for developing disaster risk reduction strategies;
- To explore the use of GIS as a tool for decision-making in service delivery, location and resource needs for fire and rescue services;
- To make recommendations for the use of GIS in the development of disaster risk reduction strategies;
- To consider how information management can support decision-making in the Mopani District Municipality.

1.5 Literature review

Literature for the study focused on the use of GIS and how it has been applied in studies on emergency services, both locally and internationally. Of particular interest is how GIS can serve as a tool through which a deeper understanding can be gained of the station location problem and the spatial significance of historic incident data for informed decision-making. Among those whose work was drawn upon in the study include Heywood *et al.* (2011), Baloyi *et al.* (2017), Green *et al.* (2014), Baloyi (2019), Isa *et al.* (2016), Osidele (2016) and Çela *et al.* (2012). Much of this work illustrated by these authors provides guidance on the different methods employed by researchers globally. One key study considered is the case study by Green, *et al.* (2014) on the siting of fire stations for eThekweni Metro using the National Standard on community protection against fire. SANS 10090:2018 was used as a guiding document for this study. Other studies in the South African context which compared services to the SANS 10090:2003 focused on different aspects of the SANS other than station location for improved response capability, but may also be used in the proposed study (Bean and Ilemobade, 2018:1; Myburgh, 2012:iii). To supplement background information on the application of different GIS analysis techniques and the use of GIS in disaster management, the books by Heywood *et al.* (2011) and Tomaszewski (2020) are specifically of note. The legal framework used in this study includes the National Disaster Management Act (57 of 2002), as amended, the National, Provincial and District Disaster Management Frameworks and Fire Brigade Services Act (99 of 1987), as amended.

Reference material from both South African National Roads Agency Limited (SANRAL) (2015) and international agreements, such as the United Nations Decade of Action for Road Safety (2011), are used in delving into aspects related to the link to Disaster Management. Jung and Song (2015) delve into the need for collaborative networks for improved disaster resilience, with their reasoning grounded in organisational behaviour theory (Jung and Song, 2015:1465-1467). Gaillard and Mercer (2013) also regard disaster risk reduction as an integrative process which requires collaboration at multiple scales and levels from a variety of stakeholders and stresses

the need for the integration of local knowledge with scientific knowledge within disaster risk reduction, moving away from a more rigid top-down approach (Gaillard and Mercer, 2013:95-96). Work from these scholars on the topic and further related literature is used for this study.

1.6 Research design

A mixed-methods approach was utilised as most appropriate for the study as the research objectives are best achieved by using qualitative and quantitative data. The mixed-methods approach, according to Creswell (2015) and Plano Clark (2016), employs the use of both philosophical assumptions and methods as part of the research design. In so doing, a better understanding of the matter at the centre of the study can be generated, building on the relative strengths of both qualitative and quantitative methods (cited by De Vos *et al.*, 2011:435). An explanatory sequential research design was used as this enabled a process in which quantitative data was collected and analysed first, explained and then further explored through qualitative data collection and analysis before final inferences were made (Creswell, 2015:37-38). The explanatory sequential research design connects data in a two-phased, sequential approach, with the intention of allowing one phase to build on the other (Ivankova, *et al.*, 2006:3; Cameron, 2009:145; Fetters, *et al.*, 2013:2134). In the context of the study, historic incident data collected from Mopani Fire and Rescue Services was first analysed quantitatively in order to understand the broader operating environment and to identify key themes. The analysis of the quantitative data, including the fire risk classification in terms of the SANS 10090:2018 and network analysis, were undertaken using open-source QGIS software and Microsoft Excel spreadsheets.

According to Creswell (2015), in an explanatory sequential research design, random sample selection of quantitative data and purposeful collection of qualitative data are required (Creswell, 2015:78). As suggested by Onwuegbuzie and Collins, considering the two, broad overall fire and rescue themes, a stratified random sampling approach was undertaken for the quantitative data (Onwuegbuzie and Collins, 2007:285). The historic incident data was also used to test the potential for improved response for a site already identified for future fire station development. For the purposeful qualitative data collection, senior managers from fire and rescue services were interviewed in key informant interviews (KIIs) to gain a deeper understanding of the quantitative data analysis results and the application of the SANS 10090:2018. The second phase could thus be used to build on the first phase, offering insights into the functioning of fire and rescue services before final inferences were made.

1.7 Justification for study

The provision of an effective Disaster Management and Fire and Rescue Service are requirements under legislation, which includes the National Disaster Management Act (57 of 2002), as amended, the National, Provincial and District Disaster Management Frameworks and Fire Brigade Services Act (99 of 1987), as amended. The SANS 10090:2018 provides guidance on the provision of fire and rescue services in South Africa. Economic and population characteristics undergo change over time, and fire and rescue services need to keep pace with these changes if service delivery is to be kept at an optimum. The study is required to evaluate needs based on this changing landscape and demand for service provision.

1.8 Limitations of study

While every effort has been made to verify and locate incident locations as accurately as possible, it should be acknowledged that there may be slight differences in actual location, especially where fires are concerned. Multiple sources were drawn upon to verify incident locations, including photographs, media articles, personal communication with people who were in attendance at the scenes, pin-drops shared over social media of incident locations, route marker boards, landmarks, stand numbers and street addresses in addition to the locations detailed in the incident forms. To compensate for any error, broader analysis techniques have been applied. However, where there has been uncertainty over an incident location, these incidents were not considered in the spatial analysis. The time calculations should also be viewed as an estimate. Every response to an incident will be unique, posing different challenges in terms of road condition, traffic congestion and driver behaviour. The time estimates do however provide a guideline which can be used in better understanding where service delivery can be improved.

1.9 Ethical considerations

In dealing with incidents dealt with by fire and rescue services, one must always remember that human lives are inevitably involved. In some cases, there may be one or more fatalities or people may have suffered the loss of their homes, means of income or means of transport. There is thus often significant trauma involved, whether physical or mental, for those who have been affected by fire, accidents or incidents which require specialised rescue. This study recognises this and every effort has been made not to divulge names or other details which may identify the people involved. At no stage were any victims or their families engaged or involved in any part of this study. While basic details of the fire-fighters who attended different scenes is captured from the incident forms completed by the fire stations, this has merely been done for reference purposes if more clarity on an incident should be required. These names, or abbreviations of the names

(different stations capture this differently) have not been used in the study to the extent that it would identify those involved. In collecting the individual fire station incident data from the incident books, the initials or surname of the fire fighters who responded to the reported incident were merely noted in one of the attribute columns. No information regarding the identity of other first responders is captured as this information is not typically captured on the incident forms. Ethics approval for the study was provided by North West University's Faculty of Natural and Agricultural Sciences Ethics Committee with the assigned ethics number being NWU-010420-20-A9. The risk category was deemed minimal.

1.10 Conclusion

The study was aimed at providing Mopani Fire and Rescue Service with carefully analysed data upon which sound decisions can be made on resource needs and possible station location. The expected increased capacity can in effect result in disaster risk reduction in the Mopani District. In Chapter 2 which follows, the theoretical component linking disaster management information management, GIS, collaborative networks and fire and rescue services will be explored in greater detail. Chapter 3 outlines the research methodology and the sequential steps undertaken in two phases in accordance with the explanatory sequential research design. The data presentation and analysis of the two phases are detailed in Chapter 4, with Chapter 5 presenting the findings and discussion of the study. The conclusion and recommendations are provided in Chapter 6.

CHAPTER 2: LINKS IN THE CHAIN – DISASTER MANAGEMENT, FIRE AND RESCUE SERVICES, GIS AND COLLABORATIVE NETWORKS

2.1 Introduction

The National Disaster Management Act (NDMA) (57 of 2002), the Disaster Management Amendment Act (DMAA) (16 of 2015) and the National Disaster Management Framework (NDMF) guide the implementation of disaster management in all three spheres of government in South Africa. The NDMF gives effect to the NDMA, and places a strong focus on disaster risk reduction (South Africa, 2005:2). The South African legislation on disaster management is proactive in nature, providing for an approach which is aimed at preventing losses (Bruwer, *et al.*, 2017:105). To achieve this, the NDMA (57 of 2002), as amended, requires, amongst others, the development of structures and collaborative efforts with disaster risk management role-players, including role-players such as fire and rescue services. Both the NDMA (57 of 2002) and the Fire Brigade Services Act (FBSA) (99 of 1987) are administered by the Department of Cooperative Governance and Traditional Affairs through the National Disaster Management Centre (South Africa, 2014:6; NDMC, 2016). In the sphere of local government, disaster management and fire and rescue services thus often work in tandem, giving effect to the respective legislative frameworks under which they operate. In so doing, the potential exists for working together to build capacity and participating in disaster risk reduction initiatives together.

Disaster management and fire and rescue services in South Africa are guided by key legislation. It is upon this legislative framework that activities are developed and coordinated, striving to meet a set national standard. Although the FBSA (99 of 1987), as amended, makes provision for the establishment and standardisation of fire brigades, the South African National Standard (SANS) 10090:2018 sets out guidelines on requirements which should be met by fire and rescue services in terms of community protection against fire (SANS, 2018:iv). Fire and rescue services are thus provided with a framework against which they can assess their service, including on aspects such as fire risk classification, the organisation of services, minimum response times according to risk category, and fire prevention (SANS, 2018:1). In applying the Standard, fire and rescue services not only ensure the provision of an efficient service, but are also provided with guidance which may aid in the identification of the most appropriate sites for future fire station placement for improved service delivery (SANS, 2018:iv;7). Community needs must be carefully considered in the development of new stations so as to guide optimal fire station placement. As will be discussed in this chapter, the disaster management information management cycle may aid in strategic decision-making in this regard, with the potential to create a link between disaster risk

management and fire and rescue service activities with the potential to inform decision-making for reduced disaster risk and focused planning.

The NDMF, which will be discussed in more detail in Section 2.4, consists of four Key Performance Areas (KPAs) and three Enablers, with Enabler 1 dealing with disaster management information management and communication needs (South Africa, 2005:1-2). As mandated through the NDMF, Enabler 1 provides a vital link in the achievement of strategic goals for disaster risk management since it is supportive of each of the KPAs and Enablers of which the NDMF is comprised (South Africa, 2005:2-3). GIS (geographical information system) is well-recognised as essential for decision-making in all aspects of disaster management (cited by Tomaszewski, 2020:1). GIS forms an integral link in the acquisition, storage, handling and analysis of data collected through the disaster management information management process (South Africa, 2005:63). Sourcing quality, relevant data for disaster risk management is thus a requirement in terms of Enabler 1 of the NDMF. This need is highlighted by many authors, including Kunguma (2020), Tomaszewski (2020) and Hernaiz (2020). The use of GIS emerges as a powerful tool with the potential to aid in decision-making not only related to different aspects of disaster management, but from which fire and rescue services may also derive benefit.

To explain the role of disaster management information management and the link to fire and rescue services an explanation of the different links in the process and how this can ultimately serve the needs of disaster risk reduction is required. An exploration of how information management and GIS can be used as tools for disaster risk reduction is undertaken, including on issues related to improved service delivery, location planning and the identification of resource needs. An understanding of international policy and South African legislation on disaster risk management is also generated which provides the framework upon which local government can act for better informed decision-making and the development of innovative risk reduction initiatives. In the sections which follow, key literature on these links will be examined and how, combined, they have the potential to create a new understanding of information / data for more informed decision-making for service provision. The link between disaster risk management / fire and rescue services through information management and GIS is made in Section 2.2. In Section 2.3, the characteristics of disaster risk, i.e. hazard, vulnerability and capacity, are discussed while in Section 2.4 the legislative and policy basis of disaster risk management and fire and rescue services are discussed. The use of GIS in service provision and resource allocation is detailed in Section 2.5 to highlight the need for the collection of historic incident data for spatial analysis and modelling. Finally, ways in which value can be added to historic incident data will be explored under section 2.6.

2.2 GIS in Disaster Risk Management and Fire and Rescue Services

GIS (Geographical Information Systems) is well recognised as a powerful tool for supporting the decision-making process, not only helping to identify spatial trends and patterns, but which can also be used to answer questions related to the location problem (Heywood, *et al.*, 2011:175). In the field of disaster management, GIS has not only become a critical decision support tool, but is also essential for information management in all aspects of disaster management (cited by Tomaszewski, 2020:2). The power of GIS in disaster management lies in its ability to contextualise disasters, to develop better insight into a problem and to enable quick access to information through querying, amongst others (Tomaszewski, 2020:2-3). In summarising various cited definitions, Heywood *et al.* (2011) propose that GIS can be considered to be composed of three main components which are: a computer system (which includes hardware, software and appropriate procedures), spatially referenced or geographic data and the capability to carry out management and analysis tasks on this data (Heywood, *et al.*, 2011:18).

Internationally, GIS has covered many topics related to emergency services, including the spatial analysis of road traffic accidents, location planning for fire stations and accessibility analysis for ambulance services (Çela *et al.*, 2012:164; Aldabbas *et al.*, 2018:69; Isa *et al.*, 2016:42; Masoodi and Rahinzadeh, 2015:439). The relationship between information management and GIS was illustrated in the study undertaken by Isa *et al.* (2016) as they sought to analyse the spatial distribution of fire stations in Kano Metropolis, Nigeria, against actual fire incidents. Similar to the study conducted by Green *et al.* (2014), the outcome of the study proved beneficial to fire and rescue services by identifying areas which were potentially underserved (Isa, *et al.*, 2016:42).

In the context of the South African emergency services, prior research has generally only focused on one aspect of the work, such as the analysis of road traffic accidents (Osidele, 2016) or the provision of water for fire-fighting (Myburgh, 2012; Bean and Ilemohade, 2018). Others have used GIS to undertake accessibility analysis for ambulance services or investigated disaster risk reduction strategies related to informal settlement fires (Baloyi *et al.*, 2017; Dlodla, 2016). Using qualitative descriptions, Anyumbar (2019) considered a hypothetical situation in the Thohoyandou central business district which would test the ability of local emergency services to respond effectively (Anyumbar, 2019:1996). The study found that there would likely be significant infrastructure, human and mobility constraints, such as physical barriers and traffic congestion, that would make an effective response difficult for the different first responders considered, including fire and rescue services (Anyumbar, 2019:1996). While it would be of interest in terms of the importance of carefully considered urban spatial planning, the Thohoyandou-based study

does not explore emergency services from the perspective of service standards. These studies are however good examples of 'spatial thinking', which makes use of space, visual representations and reasoning processes, to structure and find solutions for problems (Tomaszewski, 2020:22). Tomaszewski (2020) is of the view that disasters are inherently spatial problems and that the development of spatial thinking is an essential skill for those interested in applying GIS in disaster management (Tomaszewski, 2020:22).

Fire and rescue services in South Africa are frequently faced with challenges, including meeting service standards in terms of response times (Green, *et al.*, 2014: 53; MDM, 2019:80). Without proper information management and detailed analysis, it is difficult to motivate for better, or more appropriate resources and station location which can improve service delivery and reduce risk through institutional capacity development. Incident-related data is however often incomplete or not available (Green, *et al.*, 2014:53). Bruwer, *et al.* (2017) also note the importance of historical data and the insight this can bring in understanding disaster risk (Bruwer, *et al.*, 2017:107). Green, *et al.* (2014) point out the importance of evidence and quantitative measurement in the placement of facilities such as fire stations (Green, *et al.*, 2014:54). The South African National Standard (SANS) 10090:2018 sets out standards against which fire and rescue services in South Africa can be evaluated (SANS, 2018). The SANS 10090:2018 is aimed at providing guidance on the provision of an efficient fire service in South Africa as well as mechanisms through which performance can be measured (SANS, 2018:ii). While the SANS 10090:2018 covers a wide variety of aspects on the provision of a fire service, including fire risk categorisation, the organisation and classification of fire services, weight and speed of response, communication, fire prevention and water supply, amongst others, the main focus of this literature review is on effective response and the evaluation thereof. Coupling GIS with the requirements set out in the SANS provides a powerful means to visualise service delivery, as illustrated by Green *et al.* (2014) and Baloyi (2019) who used GIS for accessibility analysis for the eThekweni and Ekurhuleni Metro Fire and Rescue Services respectively (Green, *et al.*, 2014:59-61; Baloyi, 2019:12-20). Comparing the SANS 10090:2003 requirements against those offered by the Metro, Green, *et al.* (2014) were able to put forward recommendations on the placement of new Fire Stations and, with special reference to the Disaster Management Act 57 of 2002, recognised the link between fire station placement and disaster risk management (Green, *et al.*, 2014:53). In striving to meet national standards, a method is provided through the study against which service delivery can be measured (Green, *et al.*, 2014:55). There are however numerous other ways in which GIS can be applied to inform decision-making related to emergency services.

There are many applications for GIS in gaining a deeper understanding of the environment within which different emergency services operate. From analysing motor vehicle accidents (Osidele, 2016) to studying the spatial distribution of fire stations (Isa *et al.*, 2016), GIS has proven to be an effective tool for more informed decision-making locally and internationally. Among the spatial analysis techniques which can be used to delve into planning for station location for improved service delivery is network analysis. This and related spatial analysis techniques will be explored in Section 2.5. In Section 2.3 below, key disaster management terms are explained, while Section 2.4 delves into greater detail on information management and key legislation which guides disaster management and fire and rescue services in South Africa.

2.3 Disaster management context: Understanding key terms, risk, hazard, vulnerability and capacity

As outlined in Section 2.1 above, the NDMA (57 of 2002), used in combination with the NDMF, provides for a proactive approach to disaster risk management in South Africa, and effectively resulted in the integration of disaster risk reduction in South Africa's public sector (cited by Van Niekerk, 2014:858). While the NDMF places emphasis on disaster risk reduction through mitigation and disaster prevention, the NDMA (57 of 2002) also recognises that national government cannot fulfil the task of disaster management on its own, and requires cooperation from a wide range of role-players (South Africa, 2005:2; Bruwer, *et al.*, 2017:106-107). Although requiring multi-sectoral and multi-disciplinary involvement in disaster risk reduction at all three spheres of government, this has however been found to have been poorly implemented in the public sector in South Africa (Van Niekerk, 2014:859).

While often used interchangeably, the terms 'disaster risk reduction', 'disaster risk management' and 'hazards', have different meanings (Chakwizira, 2019:1). The NDMF also distinguishes between the terms 'disaster risk management' and 'disaster risk reduction', referring to disaster risk management as being an:

'integrated multi-sectoral and multidisciplinary administrative, organisational and operational planning processes and capacities aimed at lessening the impacts of natural hazards and related environmental, technical and biological disasters.' (South Africa, 2005:2)

This definition is closely mirrored by the definition of 'disaster management', as per the NDMA (57 of 2002), with 'disaster risk management' considered the more appropriate term since it is more strongly aligned with international thinking (South Africa, 2005:2). According to the United Nations Office for Disaster Risk Reduction (UNDRR):

“Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.” (UNDRR, 2017a)

The NDMF specifically indicates that disaster risk reduction includes core risk reduction principles, namely: prevention, mitigation and preparedness (South Africa, 2005:2). This addresses the need for capacity building and active risk reduction which is focused on known hazards, in line with the proactive approach advocated by the NDMA (57 of 2002) and NDMF.

To gain a holistic understanding of disaster risk requires generating an understanding of each of its different characteristics, namely hazard, vulnerability and capacity (NDMC, 2016:9). The NDMF acknowledges that there are a variety of methods for undertaking disaster risk assessments, but does not propose a standard format for assessing all of these characteristics (South Africa, 2005:28). In assessing risk, the NDMF rather suggests an approach to risk analysis in which hazards are analysed to determine and uncover historical information, probability, frequency, identity, intensity or scope, predictability / forewarning, exposure, impact, as well as associated forced and knock-on effects. The NDMF also suggests that vulnerability and capacity be determined through understanding the economic, social, physical and environmental aspects (South Africa, 2005:29). Once complete, the results of the risk assessment are integrated with disaster risk management planning (South Africa, 2005:30). If disaster risk management plans are to be successful however, they must form part of the Integrated Development Plan (IDP) of the municipality (Botha, *et al.*, 2011:9).

2.3.1 Capacity

The United Nations Office for Disaster Risk Reduction (UNDRR) defines capacity as:

‘The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.’ (UNDRR, 2017b)

It is noted that capacity may also include infrastructure, institutions, human knowledge and skills, amongst others (UNDRR, 2017b). Cvetković *et al.* (2021) indicate that capacity building has been central in disaster management practice and thinking since the mid-1990s, and is aimed at improving functioning ability, whether of individual, organisational or system level (Cvetković *et al.*, 2021:2). Coping capacity, on the other hand, is noted as contributing towards the reduction of disaster risks and includes the ability of people, organisations and systems, used in conjunction with skills and resources to:

'...manage adverse conditions, risks or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions.' (UNDRR, 2017b).

According to Wentink and Van Niekerk (2017), capacity development, whether at individual, institutional or community level, is required for disaster risk management to function effectively (Wentink and Van Niekerk, 2017:3). Cvetković *et al.* (2021) also note the importance of capacity building at different levels of society for proper disaster risk management functioning, and recognise that losses as a result of disasters can be reduced if sufficient capacity has been built (Cvetković *et al.*, 2021:1-2). There is thus a need to continuously evaluate and develop capacity at different levels. With the strong focus of the NDMA (57 of 2002) and NDMF on a proactive approach, the development of capacity is essential. This would include improving institutional capacity through the provision of better infrastructure and appropriate resources. There are however also various mechanisms which are put forward for broader capacity development for disaster risk reduction, including links with political forums and the establishment of a disaster management advisory forum (Wentink and Van Niekerk, 2017:4).

The role of capacity building in reducing vulnerability is also recognised by Yordanov *et al.* (2020), who investigated the role of capacity building through the development of participatory GIS and spatial data infrastructure in Mozambique. While focused specifically on climate change induced hazards and the development of education capacity, they highlight how vulnerability can be reduced through improved capacity (Yordanov *et al.*, 2020:151). GIS thus emerges as a tool through which better capacity can be achieved. GIS has already been identified as an integral component for effective disaster risk management in terms of the NDMF (South Africa, 2005:63). For GIS to function effectively requires the ready availability of data. Geographic information capacity (GIC) refers to the availability of quality spatial data, and is recognised by Tomaszewski (2020) as a critical component to support decision-making for disaster risk management (Tomaszewski, 2020:238). In striving for GIC, information and data needs can be met which can support decision-making and effective disaster risk management. The NDMF provides some guidance on the type of spatial data which is required to support and inform disaster risk management activities (South Africa, 2005:64). Additionally, various international policy frameworks are identified which can support the development of GIC, including the Sendai Framework, Sustainable Development Goals and Strategic Framework on Geospatial Information and Services for Disasters (Tomaszewski, *et al.*, 2020:2-3; UN-GGIM, 2021). It should thus be noted that, where geographical information and GIS skills are found to be lacking, reduced capacity exists to effectively implement disaster risk management activities (Tomaszewski, *et al.*, 2020:2). The link between fire station placement and disaster management is recognised by

Green *et al.* (2014) who point out that fire stations often provide the first-line response in a disaster situation (Green, *et al.*, 2014:53). Isa *et al.* (2016), also recognise the link between fire stations and response to emergencies and potential disasters in their study on fire station placement in the Kano Metropolis of Nigeria (Isa, *et al.*, 2016:42). These studies by Green *et al.* (2014) and Isa *et al.* (2016) illustrate how capacity can be improved, both through the use of appropriate data and harnessing the power of GIS to guide the placement of resources.

2.3.2 Hazard

The NDMC has made provision for a guideline document on hazard identification, analysis and prioritisation, which was published in 2016 by the Directorate: Policy Development and Regulatory Frameworks, with the term 'hazard' referred to as:

'a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage' (Cooperative Governance and Traditional Affairs, 2016:7).

A hazard is characterised by location, intensity and probability, and may also be single, sequential or combined in origin and effect (cited by Chakwizira, 2019:1). The NDMC guideline document puts forward a method of hazard analysis which scores the scale of the area affected, probability, frequency, and magnitude for hazard prioritisation (Cooperative Governance and Traditional Affairs, 2016:14-16). This process thus ranks hazards from highest to lowest, providing an informed approach in dealing with known hazards. The mapping of hazards, such as fire or flooding using GIS, has been well demonstrated by authors such as Kanga *et al.* (2017) and Gigovič *et al.* (2017). These studies indicate how GIS can be utilised for viewing the spatial extent of known hazards. As Gigovič *et al.* (2017) point out in their study on flooding, the development of flood hazard maps enables the generation of different outputs based on different conditions, indicating potential losses which may be suffered under different scenarios (Gigovič, *et al.*, 2017). Maps such as these would thus be essential for the guidance of disaster risk reduction activities and planning related to a particular hazard. Similarly, Kanga, *et al.* (2017) in their study on fire, propose that the mapped fire hazard can be used for future fire management (Kanga, *et al.*, 2017:38). These two studies indicate how generating an understanding of the spatial extent of the area affected by a hazard is essential for the development of disaster risk reduction measures for identified hazards.

2.3.3 Vulnerability

The UNDRR definition of vulnerability refers to the:

‘...conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.’ (UNDRR, 2017c).

The Disaster Management Amendment Act (16 of 2015) offers a similar definition, but with the focus more on the susceptibility of a community to the impacts of hazards (South Africa, 2015a:6). Ten Have (2018) indicates that the term ‘vulnerability’ is used by a number of disciplines and that the understanding of the term differs among them (Ten Have, 2018:160). In terms of disasters, Ten Have (2018) argues that there are different levels of vulnerability in different geographic regions, and that vulnerability should be assessed at national and sub-group level (Ten Have, 2018:162). This is perhaps what the UNDRR definition suggests in referring to ‘an individual, a community, assets or systems’. Chakwizira (2019) contends that there is a link between vulnerability, disaster risk reduction and disaster risk management (Chakwizira, 2019:1). He further argues that vulnerability should be co-considered in association with resilience, which relates to the ability to recover or cope with the impact of a hazardous event (Chakwizira, 2019:1-2).

There is a great deal of responsibility placed on the shoulders of decision-makers in the field of disaster management in terms of legal accountability. In trying to understand legal responsibilities in terms of disaster, Lautá (2018) argues that there has been a collective change in perceptions of what disasters are, and that often, modern disasters are less strongly linked to so-called “natural disasters”, bringing them into the legal sphere (Lautá, 2018:43). Ten Have (2018) also notes that sensitivity to exposure differs across society, making some more vulnerable than others (Ten Have, 2018:161). Understanding which sectors of society are vulnerable and addressing this vulnerability through appropriate projects and programmes is thus also essential to avoid legal liability. Differences in vulnerability need to be understood in context, since not all sectors of society are equally vulnerable, depending on differing social characteristics such as age, disability and income (Papathoma-Köhle *et al.*, 2019:2). Those responsible for disaster risk assessment and disaster risk reduction may thus be placed at the centre of legal challenges if they fail to execute their mandate properly. As Lautá (2018) notes, issues of accountability may arise where, even in the case of natural events, negligence may be found against those who did not respond appropriately in the face of known hazards (Lautá, 2018:46).

GIS is often used to develop a spatial index of vulnerability using variables such as social variables or physical variables (Tomaszewski, 2020:394). The development of such a spatial index can aid in focusing attention on specific geographic areas for intervention. Using a social vulnerability index and COVID-19 distribution data, for example, Karaye and Horney (2020) demonstrated a link between social vulnerability and COVID-19 infections on the global level. The same study however showed variances across different states within the United States (Karaye and Horney, 2020:317). Understanding how vulnerability varies across different sectors of society and geographic areas is essential for the development of appropriate responses. In the example of the COVID-19 study given above, the power of GIS to visualise vulnerability can better inform appropriate responses.

2.3.4 Risk characteristics in a nutshell

In the section above, the different key terms of disaster risk were discussed in detail. The meanings and definitions of the different terms, i.e. capacity, hazard and vulnerability were discussed. Based on this discussion, it can be seen how each characteristic has bearing on overall disaster risk. Furthermore, it becomes clear how leveraging one or more of these characteristics down, for example through capacity building or reducing vulnerability, has the potential to reduce disaster risk. Disaster risk is thus a function of hazard, vulnerability and capacity. In order to plan an effective disaster risk reduction programme, a disaster risk assessment must first be undertaken and should include a consultative process with all key stakeholders (South Africa, 2015a:25). According to the UNDRR, a disaster risk assessment can be undertaken using a qualitative or quantitative approach to consider hazard, exposure, vulnerability and capacity (UNDRR, 2017d). Jordaan notes the limited availability of reliable data which can be utilised in disaster risk assessments in the South African context (Jordaan, 2006:10). The NDMF however recognises the need for hazard and disaster risk information, providing a framework through which appropriate data can be gathered through proper information management (South Africa, 2005:63). The NDMF suggests a four-stage process in undertaking disaster risk assessments (South Africa, 2015a:28):

- Stage 1: Identification of disaster risks to be assessed.
- Stage 2: Analysis of the disaster risk.
- Stage 3: Evaluation of the disaster risk under assessment and the development of prioritised actions.
- Stage 4: Ongoing disaster risk assessment and planning which includes the monitoring of disaster risks and the effectiveness of projects aimed at risk reduction.

In disaster management, risk is often quantified using the mathematical formula: Risk = Hazard x Vulnerability. Wisner *et al.* (2011) however regard this formula as a mnemonic device rather than a mathematical equation (Wisner, *et al.*, 2011:19). The formula is a simple, effective tool used in assessing risk and is known as the pressure and release model (UNU-EHS, 2006:29). The model is based on a framework which views vulnerability and the development of a potential disaster situation as a process in which there is growing pressure, but also opportunities to reduce this pressure (UNU-EHS, 2006:29). The pressure and release model thus considers a disaster as a meeting of two opposing forces i.e. between vulnerability and hazards (Jordaan, 2006:3-4). The traditional pressure and release model formula has however been expanded to also consider capacity (Jordaan, 2006:7). Considering capacity provides the opportunity to counteract vulnerability through protective action (Wisner, *et al.*, 2011:21). Thus, by enhancing capacity, disaster risk can be reduced.

The NDMF calls for the development of a uniform approach to disaster risk management in South Africa and the development of a national standard which can guide the assessment of priority disaster risks (South Africa, 2005:32). The UNDRR definitions for 'risk', 'disaster risk' and 'capacity' are closely mirrored in the NDMC guideline document. The guideline calls for a standardised approach to risk assessment and understanding the different components of disaster risk (Cooperative Governance and Traditional Affairs, 2016:9). While recognising that there are many different methods for undertaking disaster risk assessments, it is the pressure and release model which is proposed as the preferred method across all spheres of government in South Africa (Cooperative Governance and Traditional Affairs, 2016:11;17):

$$\text{Disaster risk} = \frac{(\text{Hazard} \times \text{Vulnerability})}{\text{Capacity}}$$

The guideline document only focuses on hazard identification, analysis and prioritisation as the first step in conducting a risk assessment and does not elaborate further on vulnerability and capacity assessment (Cooperative Governance and Traditional Affairs, 2016:11).

Each of the different components of disaster risk were examined in Section 2.2.1 to 2.2.3 above. Furthermore, it was demonstrated how the spatial component of each can assist in bringing context and greater meaning in support of decision-making. Linkages with GIS and the availability of data were thus provided. With capacity identified as a method through which risk can be reduced, GIC emerges as a critical component that has a bearing on each of the identified components of disaster risk. Quality data provided through the strengthening of GIC can aid in better decision-making through the accurate visualisation of spatial data. With this understanding in mind, the following section seeks to explain the integral role of GIS in information management

for disaster risk management and the legislative and policy aspects thereof internationally and nationally. A brief overview on legislative aspects related to fire and rescue services is also considered in order to generate an understanding of the legal framework under which they operate and as well as the application of fire risk in terms of SANS 10090:2018.

2.4 The role of information management for disaster risk management

In this section, the role of information management for disaster risk management will be explored in more detail. International and local policies provide guidance on information needs, but also provide opportunities for collaborative efforts for improved capacity and reduced disaster risk.

2.4.1 Information management for disaster management: Legislative and international policy overview

In reviewing relevant literature, it is evident that information management provides the basis for decision-making in all aspects of disaster risk management, and will be discussed in more detail in this section (Li *et al.*, 2017; Hernaiz, 2020; Tomaszewski, 2020). This has been recognised locally and internationally in legislative and policy frameworks which provide guidance on the development of information management needs for disaster risk management (UN, 2015; South Africa 2005; UN-GGIM, 2021). Internationally, the role of effective information management in disaster risk management practice is well recognised. Li *et al.* (2017), Hernaiz (2020) and Tomaszewski (2020) are among those who highlight the importance of information management in disaster risk management. While considering this in the context of disaster events, Li *et al.* (2017) recognise the importance of data-driven disaster management for improved decision-making and reduced losses, indicating the use of advanced data collection and analysis technologies (Li *et al.*, 2017:3). While the study focuses more on disaster management systems, techniques for improved situational awareness, information retrieval, personalised information needs of users and data mining (Li *et al.*, 2017:5-34), much of what is put forward in the paper is mirrored by the requirements set out in South Africa's National Disaster Management Framework (discussed in more detail in Section 2.3.1.2 below). Similarly, Pamukçu *et al.* (2019) note that resource allocation in disaster situations can be challenging as authorities strive to provide for the needs of affected communities, and suggest a data-driven approach through which risks can be quantified to facilitate an appropriate response (Pamukçu *et al.*, 2019:151). These studies highlight the importance of the proposed data-driven approach in disaster risk management, which can be applied at a variety of different scales and situations, focusing attention on the need for proper information management. Moreover, it is also a clear indication that sufficient base data is required and needs to constantly be reviewed and updated if decision-making during disaster

events is to be properly supported. Tomaszewski (2020) emphasises the critical role GIS and information management play in all aspects of disaster risk management, detailing how mapping can aid in better understanding the geographic context of a situation when a disaster occurs (Tomaszewski, 2020:2-3). The development of meaningful maps during disaster situations will however only be effective if sufficient base data is available on communities, infrastructure and the environment so as to bring the disaster risk into context. Sufficient geospatial data through information management thus needs to be collected and made available before a disaster strikes, highlighting the need for this to be undertaken on a continuous basis (Hernaiz, 2020:1-2). This understanding can thus extend beyond information management just during disasters, to include other aspects of disaster risk management as well, such as efforts aimed at disaster risk reduction. The need for information management to occur on a continuous basis is thus clear.

Despite all these benefits related to the use of GIS for disaster risk management, it is acknowledged that there is room for improvement (Tomaszewski, 2020:7). Indeed, Hernaiz (2020) concedes that levels of geospatial preparedness to support disaster response differ vastly around the world (Hernaiz, 2020:1). The growing need at all levels of society for improved disaster risk management efforts gave rise to the development of a global framework for action.

2.4.1.1 International Policy

The Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted in March 2015 at the Third UN World Conference held in Sendai, Japan, and was developed with a stronger emphasis on disaster risk management (UN, 2015:5). The Sendai Framework, which builds on the Hyogo Framework for Action, focuses on four priority areas (UN, 2015:14):

- *“Understanding disaster risk;*
- *Strengthening disaster risk governance to manage disaster risk;*
- *Investing in disaster risk reduction for resilience; and*
- *Enhancing disaster preparedness for effective response and to ‘Build Back Better’ in recovery, rehabilitation and reconstruction.”*

In terms of Priority 1 (understanding disaster risk), the Sendai Framework calls for a process in which information management is undertaken to cater for all aspects of disaster risk management, including the use of GIS as a tool for the processing and analysis of collected data (UN, 2015:14-15). Despite this strong move towards disaster risk reduction globally, the implementation of the Sendai Framework at the local level has been muted (Busayo, *et al.*, 2020:1). Furthermore, there is a lack of consensus on how best the Sendai Framework should be implemented (Munene, *et*

al., 2018:653). However, Busayo *et al.* (2020) point out that there is still time for the Sendai Framework to be adopted if state and local capacity can be boosted (Busayo, *et al.*, 2020:6).

The United Nations Strategic Framework on Geospatial Information and Services for Disasters recognises the need for quality geospatial and statistical information to support sound decision-making in all aspects of disaster risk management (UN, 2017:5). This strategic framework, which builds on key documents, such as the Sendai Framework for Disaster Risk Reduction, was adopted by the UN Economic and Social Council under resolution 2018/14 in July 2018 and outlines five priority areas for action, namely (UN-GGIM, 2021) (UN, 2017:5;8):

- *“Governance and policies;*
- *Awareness raising and capacity building;*
- *Data management;*
- *Common infrastructure and services; and*
- *Resource mobilization.”*

This strategic framework, which is aimed at different levels of governance – from local to global - highlights the need for a coordinated, collaborative approach to achieving these priorities (UN, 2017:8). Recognising this need emphasises the requirement for proper information management to guide decision-making at all levels. The adoption of this policy can serve to streamline information management needs at different levels of governance globally. South Africa’s progressive disaster management legislation also recognised this need, and preceded the development of international guiding policies. This will be discussed in more detail below, with special emphasis on Enabler 1 of the National Disaster Management Framework, which primarily deals with information management.

2.4.1.2 National Legislation and Policy

Disaster management in South Africa is guided by the National Disaster Management Act (NDMA) (57 of 2002), the Disaster Management Amendment Act (DMAA) (16 of 2015) and the National Disaster Management Framework (NDMF). The NDMA (57 of 2002) provides for:

- *“an integrated and co-ordinated disaster risk management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, preparedness, rapid and effective response to disasters, and post-disaster recovery;*
- *the establishment of national, provincial and municipal disaster management centres;*

- *disaster management volunteers; and*
- *matters incidental thereto.”*

As outlined in the Section 2.3, the combined disaster management legislation has provided a decentralised approach to disaster management in South Africa and integrates disaster risk reduction at the three spheres of government (Van Niekerk, 2014:858). Until the promulgation of the NDMA (57 of 2002), disaster management in South Africa was typically reactive, until 1994 when significant flooding in the Western Cape gave rise to the realisation that an approach with a stronger focus on integrative risk reduction and alignment with international thinking was required (Reid and Van Niekerk, 2008:245). The process that led to the development of this legislation was progressive, and preceded the Hyogo Framework for Action (Van Niekerk, 2014:858). The South African disaster management legislation thus also preceded the development of the Strategic Framework on Geospatial Information and Services for Disasters, which was only developed in 2017.

The NDMF aims to give effect to the NDMA (57 of 2002), and comprises four key performance areas (KPA) and three enablers (South Africa, 2005:1-2). The NDMF provides guidance on the application of disaster risk management in South Africa, ensuring that a consistent approach is followed across multiple interest groups (South Africa, 2005:1). The NDMF is cross-cutting, with the Enablers providing support for the attainment of the four KPAs (Kunguma, 2020:6-7). The need for integrated institutional arrangements for disaster risk management across all three spheres of government is recognised by KPA 1, with emphasis placed on stakeholder involvement for the enhancement of capabilities for reduced likelihood and severity of disasters (South Africa, 2005:2). The need for a uniform approach to disaster risk assessment is addressed by KPA 2, and includes the need to monitor the effectiveness of risk reduction measures which have been implemented by organs of state and related role players (South Africa, 2005:25). KPA 3 deals with disaster risk management planning and implementation for disaster risk reduction and calls for the alignment of planning and disaster management frameworks through all three spheres of government. KPA 3 also places the focus on integration of prevention and mitigation principles in projects and initiatives for reduced disaster risk (South Africa, 2005:3). Disaster response, recovery and rehabilitation are covered by KPA 4, including the roles, responsibilities and procedures to be followed when a disaster occurs or threatens to occur, as required by the NDMA (57 of 2002). The need for an integrated and co-ordinated policy which ensures rapid and effective disaster response as well as post-disaster recovery are recognised by KPA 4 (South Africa, 2005:54).

Enabler 1, which is discussed in more detail below Table 2-1, is focused on information management and communication for disaster risk management, and provides support for each KPA and the other two Enablers (South Africa, 2005:3). Enabler 2 deals with capacitating stakeholders through scientifically based education, training, public awareness and research to promote risk avoidance (South Africa, 2005: 76). Finally, Enabler 3 outlines the mechanisms which need to be established for the funding of disaster risk management (South Africa, 2005:88). In summary, the KPAs and Enablers are as follows (Table 2-1):

Table 2-1: National Disaster Management Framework KPAs and Enablers (South Africa, 2005:2-3)

KEY PERFORMANCE AREA / ENABLER	DESCRIPTION
KPA 1	KPA 1 deals with integrated institutional arrangements and matters incidental thereto, with special focus on co-operative governance.
KPA 2	KPA 2 deals with disaster risk assessment.
KPA 3	KPA 3 deals with disaster risk management planning.
KPA 4	Disaster response, recovery and rehabilitation outlined by KPA 4.
Enabler 1	Enabler 1 deals with information management and communication needs for disaster risk management.
Enabler 2	This Enabler focuses on education, training, public awareness and research.
Enabler 3	Enabler 3 is aimed at funding arrangements and funding mechanisms for disaster risk management.

Of these different key performance areas and enablers of the NDMF, it is Enabler 1 that requires the development of information processes which can be used to support sound decision-making for disaster risk management. According to the NDMF, the objective of Enabler 1 is to:

'Guide the development of a comprehensive information management and communication system and establish integrated communication links with all disaster risk management role players' (South Africa, 2005:63).

Information management thus spans a broad range of activities to support disaster risk management activities within the different spheres of government. Enabler 1 serves to fulfil the information needs for disaster risk management, with the NDMF specifically identifying the need for GIS as an integral part of the development of an effective information management system (South Africa, 2005:63). Enabler 1 mostly relates to data acquisition and analysis, and how this can be linked to different processes for improved capacity, planning and disaster risk reduction. Ultimately, Enabler 1 reflects the information management needs identified in the Sendai Framework and the Strategic Framework on Geospatial Information and Services for Disasters, enabling a process in which alignment with international policy becomes possible. However, it should be noted that information management and communication systems for disaster risk management in South Africa have not yet been studied in depth (Kunguma, 2020:iii).

The collection of appropriate data, amongst others, is required to achieve the objectives of the NDMA (57 of 2002) and NDMF (South Africa, 2005:64). The collection of data for use in GIS thus forms part of the information management process. Hernaiz (2020) also recognises this need, indicating the importance of 'geospatial preparedness', referring to the ready availability of geographical data, tools for the display and manipulation of this data and people with the capacity to use these tools (Hernaiz, 2020:15). GIS emerges as a vital tool for improved coordination and which is supportive of decision-making through all phases of disaster management (Hernaiz, 2020:15). Tomaszewski (2020), distinguishes between 'data' and 'information', indicating that the former refers to raw facts or information, while the latter is data with context or which has been processed into a form from which meaningful deductions can be made (Tomaszewski, 2020:32). The acquisition of data is dealt with in Section 5.3 of the NDMF and recognises the need for the collection of data which includes base data, such as topographical maps and cadastral data, situational and field data, which includes historical incident data, data on hazards (such as floods and fire) and early warnings (South Africa, 2005:66). Ensuring the ready availability of this type of data and the ability to process it fulfils the 'geospatial preparedness' need referred to by Hernaiz (2020). The NDMF further stipulates that different sources of data need to be identified and uploaded to an integrated disaster risk management database in a standard format to ensure

uniformity (South Africa, 2005:66). In effect, by ensuring that a database of appropriate data is acquired, maintained and continuously updated, support can be provided to achieve the objectives of the other KPAs and Enablers, thus also fulfilling the requirements of the NDMA (57 of 2002). Disaster management centres must thus ensure that they source the appropriate type and quality of data on a continuous basis to meet these needs.

The NDMF recognises the importance of the establishment of systems and processes to enable information management for disaster risk management activities, noting the need for the receipt, dissemination and exchange of information (South Africa, 2005:63). However, according to Hoets no formal information management and communication system has yet been developed by the NDMC (cited by Storie, 2018:2). Most PDMCs have also failed to develop the information management and communication systems required by the NDMF (Kunguma, 2020:iv). In the absence of a nationally developed system, disaster management centres in the provincial and local government sphere must thus find ways of sourcing their own data for the purpose of information management. The Western Cape Provincial Disaster Management Centre, for example, has developed its own GIS capability which includes base data and hazard-specific data such as areas at high risk from floods and fires (Storie, 2018:6). The information management systems and processes proposed in the NDMF are supportive of each of the KPAs and Enablers, largely forming the basis upon which they operate. It is thus essential that disaster management centres have access to suitable data. As Kunguma (2020) notes, to cover all aspects of disaster risk management, quality data and information management is required (Kunguma, 2020:iii). Base data, such as data on roads, critical biodiversity areas and population statistics are easily accessible from data custodians such as the Chief Directorate: National Geospatial Information, Statistics South Africa and the South African National Biodiversity Institute (Storie, 6-8). There is however also a need to for the continuous gathering of historic data on incidents and disasters which have occurred. Over time, this enables the development of hazard-specific data, such as the cited example of the Western Cape PDMC which has developed data on fire- and flood-prone areas.

The public needs to be kept informed of disaster risks and how to reduce their vulnerability and exposure to known hazards through public awareness campaigns (South Africa, 2005:83). Information can be shared with the public through a variety of mediums, including the internet, print and broadcast media, schools and other innovative mediums (South Africa, 2005:83-84). Schools, in particular, are recognised as offering a practical approach to awareness programmes (South Africa, 2005:84). Information management can assist in this regard by helping to identify areas which can benefit most from awareness campaigns and which schools are located within these areas. According to Dlodla (2016), the eThekweni Metro makes use of the Public Information

Education and Relations (PIER) program for improved public awareness and indicates that the program has been shown to reduce fire disasters (Dludla, 2016:75). Internationally, public awareness in schools adopts a similar approach. In Portland in the United States, for example, schoolchildren are appointed as assistant marshals in fire prevention, since the influence a child has in his / her home is recognised as a way in which fire risk can be reduced. The initiative teaches children to undertake inspections in their homes to ensure candles are not left where they may cause a fire and that stoves which are on are not left unattended. It was found that children took the bestowed responsibility very seriously and contributed towards fire prevention (cited by Dludla, 2016:23-24). The effect of public awareness through schools is undeniable as an effective tool through which fire prevention and fire safety can be promoted. Linking disaster management awareness initiatives with the PIER program will be mutually beneficial and prevent duplication.

2.4.2 Legislative overview of fire services

In terms of the Municipal Structures Act (117 of 1998), the provision of fire-fighting services is listed among the powers and functions of district municipalities (South Africa, 1998:58). The establishment of fire brigade services is also a Constitutional requirement (South Africa, 2014:8). The FBSA (99 of 1987) however provides the basis upon which fire services are established, maintained and standardised, and was amended in 1990 and 2000 (South Africa, 1987:1). Among the provisions of the FBSA (99 of 1987) are the prevention of the outbreak or spread of fire, fire-fighting, and the protection of life and property against fire or other dangers (South Africa, 2014:8). Since the FBSA (99 of 1987) is the mandate of the Department of Cooperative Governance, the NDMC Fire Services Directorate administers the FBSA (99 of 1987) (NDMC, 2016). Among the responsibilities of the NDMC Fire Services Directorate are the coordination of the activities of fire services in South Africa and the development of Regulations in terms of the FBSA (NDMC, 2016). The FBSA (99 of 1987), as amended, is however recognised as being out-dated and is in the process of being reviewed (Forsyth, *et al.*, 2019:28). Same as in the case of the development of the DMA (57 of 2002), the proposed amendments to the FBSA (99 of 1987) are expected to introduce a shift from being more responsive or reactive in nature to a stronger focus on prevention (Forsyth, *et al.*, 2019:28). Fire brigades, which are also located within the realm of local government, are a valuable source of information and an important collaborator for disaster risk management.

The SANS 10090:2003 was replaced by SANS 10090:2018 in July 2018 and is aimed at providing guidance on the provision of an efficient fire service in South Africa as well as mechanisms through which performance can be measured (SANS, 2018:ii). The SANS 10090:2018 covers a

wide variety of aspects related to the provision of a fire service, including fire risk categorisation, the organisation and classification of fire services, weight and speed of response, communication, fire prevention and water supply, amongst others. The link between the Standard and the use of GIS to evaluate fire station response times was recognised by Baloyi (2019) who undertook an accessibility analysis study on fire stations in Ekurhuleni (Baloyi, 2019:18). The results of the study provided the opportunity for better development planning in relation to fire station placement (Baloyi, 2019:i). According to the SANS 10090:2018, response times in accordance with different risk categories are as follows (Table 2-2):

Table 2-2: Attendance times according to SANS 10090:2018 according to risk category (SANS, 2018:4-7)

Risk Category	Risk Category Description	Maximum Appliance Travel Time (Minutes)	Maximum Attendance Time (Minutes)
A	CBD and extensive commercial and industrial areas (mostly refers to cities and large towns)	5	8
B	Areas with limited CBDs and smaller commercial or industrial areas normally found in small towns	7	10
C	Residential areas of conventional type of construction	10	13
D	Rural or remote areas with limited buildings	20	23
E	Special risk areas, such as large shopping centres, informal settlements and petrochemical plants	Within the requirements of the appropriate risk category.	

The case study by Green *et al.* (2014) in the eThekweni Metro attempts to illustrate the link between optimal fire station placement and reduced disaster risk, the reasoning being that optimal fire station placement provides the opportunity for ease of response to incidents and disasters

(Green *et al.*, 2014:1). The study also illustrates how GIS can be used to gain a holistic understanding of response and resource capacity across a municipal area in the context of fire services through the use of accessibility analysis modelling. It has been acknowledged that while disaster preparedness under which response is facilitated is of vital importance, there needs to be stronger focus on prevention strategies which protect lives and property (Bruwer, *et al.*, 2017:106). It can thus be argued that the placement of fire stations at optimal locations can serve as a prevention strategy by enabling faster response to reported incidents, saving both lives and property. Linking the requirements of disaster management legislation with legislation under which fire and rescue services operate in South Africa provides the opportunity for collaboration towards improved capacity, and thus also reduced disaster risk. Sibanda (2016) notes the responsibility of government to provide a disaster management service, as well as the provision of fire-fighting at a local level of government (Sibanda, 2016:15). In addressing vulnerability, Sibanda also highlights the need for the introduction of relevant programmes and initiatives for risk reduction, predominantly guided by local government (Sibanda, 2016:16). This is an indication of the legal responsibility which has been entrusted to local government to provide efficient and effective disaster management and fire and rescue services to communities within their jurisdiction.

This section has sought to clarify the legislative mandate on information management for disaster risk management and the role of fire and rescue services in achieving this mandate. In Section 2.5 below, the role of GIS is considered and how this can be used as a link to achieve the disaster risk management mandate and improve on service delivery. Practical examples are provided on the application of GIS in the field of disaster risk management and fire and rescue services.

2.5 The use of GIS in service provision and resource allocation

Spatial analysis is a method used in GIS to investigate questions or problems which are of a spatially oriented nature, while spatial modelling is frequently used to simulate actual conditions in GIS (Tomaszewski, 2020:104;108). The application of spatial analysis and spatial modelling have many advantages, with both having been widely used in GIS-based studies on emergency services, as will be seen below. Open-source GIS software, such as QGIS, provides an alternative to more expensive commercial software and places a wide range of spatial tools in the hands of the user, including spatial modelling capabilities (Tomaszewski, 2020:130-131).

The evaluation of the ability of fire services to meet specified standards or deliver an efficient service has been highlighted in several studies globally (Oppong, *et al.*, 2018:253; Yao and Zhang, 2016:362; Aldabbas, *et al.*, 2018:69; Liman, *et al.*, 2016:43). In the South African context,

studies have largely been applied to only one aspect of the work undertaken by fire services or associated services such as the study by Baloyi *et al.* (2017) on ambulance services. Using the prior version of the SANS Community Protection Against Fire (SANS 10090:2003), Green *et al.* (2014) were successfully able to demonstrate the application of GIS in visualising the most appropriate siting of Fire Stations for the eThekweni Metro. Their approach made use of accessibility analysis and demonstrated the need for the establishment of additional fire stations to meet demand (Green, *et al.*, 2014:53). A similar study was undertaken by Baloyi, *et al.* (2017) on the placement of Emergency Medical Service (EMS) stations in the City of Tshwane, also making use of accessibility analysis. Among the parameters used in the study by Baloyi (2017) were population, demand for service and road speeds, and the findings of the study were used as input for strategic municipal documents, including the IDP (Baloyi, *et al.*, 2017:172;173). A study undertaken in Ekurhuleni on fire station location also made use of accessibility analysis in GIS and found that only 63% of the population within the metro could potentially be served, albeit under constraint, and suggestions were put forward for new fire station locations (Baloyi, 2019:21;50). Data used in the study included census data, road network, existing fire station location, land use and building count (Baloyi, 2019:21). In the study by Green *et al.* (2014), specific speed variables of a road network were used for modelling estimated response times for emergency services (Green, *et al.*, 2014:55). The ability to adapt different parameters of the model in this way offers the opportunity to consider different scenarios (Tomaszewski, 2020:109).

Other studies conducted in South Africa to assess services in terms of the SANS 10090:2003 focused on different aspects of the Standard other than station location. These included the evaluation of whether the prescribed provision of water for fire-fighting was adequate (Bean, *et al.*, 2018:1) and water flow for fire protection in the context of risk category (Myburgh, 2012:ii). While not strictly evaluating fire and rescue services, Osidele (2018) assessed spatial patterns and trends in the Vhembe District in terms of road traffic accidents (Osidele, 2018:ii). Using data from the Department of Transport, the largely GIS-based study enabled him to identify accident hotspots and to investigate factors contributing towards the problem (Osidele, 2016:79).

Internationally, similar studies have been undertaken to assess fire and rescue services in both the Global North and Global South. Similar to the study undertaken by Osidele (2016), Çela, *et al.* (2012) used GIS to undertake a spatial analysis of road traffic accidents in Serbia using network K-function and network kernel density estimation. The study was able to identify specific areas of concern, but also suggested that future research might consider the spatio-temporal aspect of road traffic accidents (Çela, *et al.*, 2012:13). This finding echoes those of Liman *et al.* (2016) in their study on fire and rescue services in Kano Metropolis, Nigeria. Pour and Moridpour (2015) also focused on road traffic accidents in their study in Khuzestan, Iran. Using historic

incident data as part of their study, they were able to demonstrate that emergency medical services were not able to meet demand. Furthermore, they identified five statistical models for use in identifying accident-prone sections of road. Several sources of information were used and network analysis undertaken to solve the access location problem, with the authors focusing on keeping response times to within 20 minutes (Pour and Moridpour, 2015:102;105;107). Sufficient evidence and quantitative measurement are critical in making these determinations (Green *et al.*, 2014:54). Indeed, Isa *et al.*, are of the opinion that a plan for fire station location should be used to show the efficiency and deficiency of fire station coverage as well as providing a model for future fire station location (Isa *et al.*, 2016:43). Road accessibility is another factor which must be considered in fire station placement, with Mahmud and Indriasari (2009) recognising this link and noting that station service areas are influenced by road accessibility (cited by Isa *et al.*, 2016:43).

In Fribourg, Switzerland, a multiple-criteria decision analysis was undertaken to determine suitable locations for fire stations following a merger due to local government restructuring and reduced personnel numbers (Aldibas, *et al.*, 2018:69). Electre I and Electre II matrix methods, which consider performance against weighted criteria, were also used (Aldibas, *et al.*, 2018:73). Different scenarios were considered, with the final recommendation being that an entirely new fire station be built in a different location to replace three existing stations (Aldibas, *et al.*, 2018:82). The study is useful in understanding how future changes may shape the structure of fire and rescue services and their respective catchment areas. In Ghana, a lack of understanding of fire services prompted a study to uncover the spatial significance of fire station location, catchment areas and gaps in service provision (Oppong, *et al.*, 2017:256). GIS was used to classify land into different land use types in relation to station locations, estimated response times within catchment areas and the requirements of Ghanaian national standards (Oppong, *et al.*, 2017:256). This study revealed that many areas were under-served, and that the national response time of four minutes was considered impossible to achieve (Oppong, *et al.*, 2017:256). In terms of the SANS 10090:2018, expected response times required of fire services in South Africa differ according to assigned risk categories (SANS, 2018:7). The application of expected response times is also incorporated into the study by Tali, *et al.* (2017) on the Mysore urban area in India, indicating that the Standard Fire Advisory Council norms require arrival time within five minutes (Tali, *et al.*, 2017:797). As in the case of the Ghanaian study, the Mysore study, which used a location-allocation model, also revealed that much of the urbanised area was under-served and could benefit from the establishment of additional fire stations (Tali, *et al.*, 2017:797). As in the study by Green *et al.* (2014), they also recognised that, in establishing sufficient fire stations to meet demand, risk could be reduced (Tali, *et al.*, 2017:795). In effect, the establishment of additional fire stations improved capacity to bring about a reduction in disaster risk.

In a study done in China in 2016, Yao and Zhang considered suitable sites for fire stations in Nanjing, China. Using coverage-based models, and taking past fire history and population into account, preliminary results showed that additional fire stations would be required to properly serve the area (Yao and Zhang, 2016:362). Also recognising the achievement of efficiency in response and service provision, the advantages of spatial optimisation of fire stations was demonstrated (Yao and Zhang, 2016:362). In seeking answers to fire service provision in a residential environment, Ardianto and Chhetri (2019) used a Markov chain method to determine fire probability, with the focus on Melbourne, Australia. Historic fire data was used in the study, once again recognising the spatial and temporal components of fire (Ardianto and Chhetri, 2019:57). As with the study done by Osidele (2016), historic data proved highly significant in the study.

The use of spatial analysis and spatial modelling techniques provides decision-makers with results which can better inform resource needs, including fire station location, as demonstrated in the studies discussed above. A variety of different techniques were applied to better understand the needs of communities and resource needs for emergency services, the results of which could be beneficial for disaster risk management and the emergency service under study. Historic incident data proved beneficial in some of these studies, for example studies done by Ardianto and Chhetri (2019), Yao and Zhang (2016) and Osidele (2016). The next section will thus explore ways in which greater certainty can be achieved in the collection of incident data.

2.6 Disaster Management, collaborative networks and remote sensing: adding value to incident data

In South Africa, no nationally-developed information management and communication system exists for disaster risk management, and few are developed provincially (Kunguma, 2020:ii). Disaster management centres at provincial and local level need to identify reliable sources of information in order to develop their own databases for information management purposes, as contemplated in the NDMF (South Africa, 2005:63). For local government, this not only means identifying sources of reliable base data from national geospatial data providers, but also developing their own data based on historic incidents (South Africa, 2005:65-66). This section will thus explore reliable methods through which historic incident data can be obtained.

2.6.1 Collaborative networks

The NDMF recognises that disaster risk management is a collaborative process (South Africa, 2005:63). As such, the application of disaster management in South Africa requires input and coordination across a wide range of groups and services. Jung and Song (2015) delve into the

need for collaborative networks for improved disaster resilience, with their reasoning grounded in organisational behaviour theory (Jung, *et al.*, 2015:1465-1467). The belief is that increased resilience, i.e. capacity, is able to enhance mitigation, response and recovery within the context of emergency management (Jung and Song, 2015:1465-1467). Gaillard and Mercer (2013) also regard disaster risk reduction as an integrative process which requires collaboration at multiple scales and levels from a variety of stakeholders and they stress the need for the integration of local knowledge with scientific knowledge within disaster risk reduction, moving away from a more rigid top-down approach (Gaillard, *et al.*, 2013:95-96). Issues around lack of trust between stakeholders are also discussed as well as tools that can be used to develop better dialogue (Gaillard, *et al.*, 2013:101). In considering collaborative decision-making in emergency situations, Kapucu and Garayev (2011) mention the use of GIS and other technological tools for decision support (Kapucu and Garayev, 2011:369). Kapucu *et al.* (2010) also recognise the need for information sharing to facilitate an effective response (Kapucu and Gurayev., 2010:461). The link between collaborative networks and information management thus becomes clearer. The development of effective collaborative networks may also aid in the flow of quality data to inform accurate incident location. Over time, historic incident data collected through collaborative networks becomes valuable for spatial modelling and disaster risk management.

In the context of disaster management and collaborative emergency management, Kapucu *et al.* (2010) recognise the need for horizontal as well as vertical communication and coordination among the departments and sectors involved in disaster management (Kapucu, *et al.*, 2010:452). The typically rigid nature of government response agency protocols can make such communication and coordination difficult (Kapucu, *et al.*, 2010:453). Failing to achieve collaboration has the potential for dire consequences, warns Noran (2014), who also argues for an approach that draws on interoperability, collaborative networks and enterprise architecture disciplines (Noran, 2014:1032). There are however parallels already evident between the concept of collaborative networks and the already-established Road Incident Management Systems (RIMS) networks, which encourages the exchanges of information and cooperation through the different spheres of government. As identified by Kapucu and Demiroz (2011), the development of these types of collaborative networks is in pursuit of improved service delivery (Kapucu and Demiroz, 2011:549). This point is also emphasised by Chakwizira (2019) in his study on the link between disaster risk reduction and transport in South Africa. Chakwizira's study found that, there was a need, amongst others, for coordinated and connected measures within the different spheres of government as well as collaboration and partnership for strengthened disaster risk reduction (Chakwizira, 2019:6). Crucially, while considering different aspects of the transportation

industry in South Africa, Chakwizira (2019) identified a link between disaster risk reduction and transport in South Africa (Chakwizira, 2019:6).

RIMS is an initiative that was introduced by the Department of Transport in 1991 (South Africa, 2015b:9) and implemented by the South African National Road Agency SOC (SANRAL, 2020). This collaborative effort has helped to facilitate rapid and uniform response to road-related incidents, involving all first responders in South Africa (South Africa, 2015b:9). Through RIMS, structures at municipal (district) and provincial level have been established to oversee the implementation of RIMS at these different levels (SANRAL, 2020; South Africa, 2015b:9). Valuable sources of information related to road-related incidents can be sourced through the association with the RIMS and, by extension, from community-based groups, such as community policing forums, which provide support to RIMS objectives. While Chakwizira's desktop study identified gaps within the different spheres of government in terms of operating policy, institutional and legislative frameworks which compromised disaster risk reduction, the study did not consider the positive effect of RIMS (Chakwizira, 2019:1).

A reporting system for communication flow between the different spheres of government, i.e. local, provincial and national, has been made possible through the establishment of RIMS committees at each level, involving all first responders from the different sectors (South Africa, 2015b:14-15). This in effect provides for the vertical and horizontal coordination and flow of information, as envisaged by Kapucu *et al.* (2010). RIMS has enabled the development of a common platform through which road-traffic-related incidents, including accidents, can be communicated to all first responders. While helping to facilitate a rapid, uniform response to reported incidents, the RIMS platform is also a valuable source of information which often includes accurate location data on road-related incidents. In addition to facilitating a uniform and unified response to road incidents, the RIMS initiative links with the United Nations Decade of Action for Road Safety 2011-2020, which aims to reduce morbidity and mortality as a result of road traffic accidents (SANRAL, 2020; United Nations, 2011:3). Achieving the aims of RIMS at local level in effect aids in the achievement of national and international objectives for improved road safety.

In applying the RIMS procedures as a matter of routine, vital communication links and teamwork are established, leading to the potential for a relatively easy shift during escalating incidents or large-magnitude events. This may be due to the fact that roles and responsibilities of the different departments / first responders involved in RIMS are clearly defined and applied from the start, and regular tests are undertaken through simulations or post-incident assessments. In these processes, disaster management has a very clear role to play in the activation and coordination of activities, while also assisting with maintaining communication flow. This is evident in the

National Disaster Management Framework which requires, under KPA 1, the establishment of a strategic emergency communication system to facilitate communication among first responders and between first responders and other essential services (South Africa, 2005:13). The NDMF also recognises the need for a common platform to enable emergency communication in terms of KPA 4 for 'the management of incidents, significant events and disasters (South Africa, 2005:60). Enabler 1 adds impetus to this critical need by encouraging the development of a system for the facilitation of information exchange between primary interest groups, amongst others (South Africa, 2005:63). There is thus a strong link between RIMS and disaster management in South Africa. Ultimately, information received through RIMS association aids in strengthening GIC.

RIMS has also provided the opportunity through which stronger links may be developed with community-based groups. The development of these links with communities may also aid in disaster risk reduction initiatives through which better flow of information is facilitated and capacity can be built from grassroots level. Wentink and Van Niekerk (2017) acknowledge the importance of community participation in disaster risk reduction and argue for greater community involvement for reduced vulnerability and improved capacity (Wentink and Van Niekerk, 2017:2-3). While it is not a specific RIMS objective, the establishment of communication links with local community policing forums (CPFs) or neighbourhood watches provides the potential for the rapid detection and reporting of incidents, including accidents, fires and disasters. Urlings (2016) distinguishes between CPFs and neighbourhood watches in the South African context, with the former being established in terms of policing legislation, while the latter is more commonly established by the public, sometimes with the support of NGOs (Urlings, 2016:47). While most neighbourhood watches are focused on crime prevention (Urlings, 2016:15), their broad network of people and regular patrols often mean that they detect accidents and fires very soon after they have occurred. The same applies to CPFs. By tapping into this resource, where groupings have already been established on a legitimate basis, the potential is provided for a rapid and efficient response which may not only save lives, but also prevent or reduce property losses. The benefits are mutual, with the public receiving improved service delivery through a rapid and appropriate response, and emergency services being able to react efficiently. The latter is due to only those resources which are required to deal with the incident being activated, reducing resources being wasted on unnecessarily heavy responses. Ultimately, there is greater unity in emergency response and the resulting quality of information generated over time can be incorporated into subsequent disaster risk assessments and disaster risk management planning. Once again, GIC is strengthened through this association.

The NDMF recognises that mutual assistance agreements can be used to strengthen capacity in dealing with disaster risk reduction, response and recovery (South Africa, 2005:22). These mutual assistance agreements include those with, amongst others, the private sector and communities (South Africa, 2005:22). This links back to information management and the need for a system which allows for data acquisition, support for the KPAs and Enablers, and the facilitation of the effective flow of information (South Africa, 2005:64-65). Much of the information gathered through the association with RIMS role-players, CPFs and neighbourhood watches may inform the capture of data in GIS. The guideline document from the NDMC on 'Concluding Cooperation and Mutual Assistance Agreements' suggests a cautious approach which recognises that such agreements may strengthen capacity, but also warns of the possibility of intended or unintended legal implications (South Africa, 2018:9-10).

The significance of the success of the RIMS structures to overcome traditional problems encountered in dealing with road traffic related incidents is that the same group of departments / first responders are typically involved in dealing with other types of incidents too, including incidents such as fires, flooding and specialised rescues. The advantage of this is that, the same structure can be extended to deal with other types of emergencies or incidents as well, piggy-backing off the already established RIMS network. In effect, much of what Kapucu, *et al.* (2010) argue is required for effective collaborative emergency management has already been achieved in RIMS. It is important to note how first responders are working together in the pursuit of a common goal through the RIMS program.

2.6.2 Remotely-sensed data

Remotely-sensed data has been acknowledged as having had a tremendously beneficial impact on disaster management activities, providing rapid, cost-effective access to data (Novellino, *et al.*, 2019:23-24). The integration of remote sensing technology with GIS provides the opportunity for the resolution of complex planning and management problems related to disaster management, as well as providing the basis for sound decision-making (Krishnamoorthi, 2016:144). There are many ways in which remotely-sensed data can be applied in disaster management, including risk modelling, the assessment of post-disaster damage, vulnerability analysis and early warnings (Krishnamoorthi, 2016:148-149). The Moderate Resolution Imaging Spectoradiometer (MODIS) is one of the instruments on board NASA's (National Aeronautics and Space Administration) Aqua and Terra satellites, and which acquires data in 36 spectral bands (Xiong, *et al.*, 2009:413). Aqua and Terra were launched in 1999 and 2002 respectively (Xiong, *et al.*, 2009:413). Terra was launched in December 1999 as part of NASA's Earth Observing System (EOS) and the MODIS instrument commenced with the collection of image data in

February 2000 (Justice, *et al.*, 2006:244). The purpose of MODIS was two-fold: firstly, to provide active fire products and, secondly, to provide a burnt area product for the calculation of the extent of burn scars (Justice, *et al.*, 2006:244). By 2002, MODIS was the only global daily fire product available (Justice, *et al.*, 2006:244). The launch of Aqua and Terra signified an important step forward and would result in a whole new era in terms of fire management and fire research globally.

A little more than a decade later, newer generation technology would become available which would ensure the continuity of remotely-sensed fire data. Following on from the success of MODIS, a new era in remote sensing for fire management was entered on 28 October 2011 with the launch of the Suomi National Polar-orbiting Partnership (NPP) satellite (Schroeder, *et al.*, 2014:85). One of the instruments on board the Suomi NPP satellite was the Visible Infrared Imaging Radiometer Suite (VIIRS) with the ability to, amongst other things, remotely sense fires, thus building on the MODIS legacy (Cao, *et al.*, 2014:1142). The superior mapping capabilities of VIIRS were soon noted, with a greater detection of fires compared to MODIS (Schroeder, *et al.*, 2014: 85). The value of these satellites lies not only in their ability to detect wildfires remotely in near real-time, but also their ability to provide fire managers and fire researchers with the type of data that can inform both proactive and reactive fire management planning.

As technology advanced, the quality and availability of fire-related data improved substantially, providing data on thermal anomalies in near-real time globally, as indicated above. Crucially, much of this data is readily available at no cost, making it accessible to fire managers and related fields around the world through platforms such as FIRMS (Fire Information and Resource Management System) (Davies, *et al.*, 2008:72). It is thus significant to note that, once remotely sensed fires could be viewed globally, one of the most striking features noted was the sheer number of fires which occur in Africa (Archibald, 2010:117). The availability of global remotely-sensed fire data also proved invaluable in providing a comprehensive look at fire patterns in different southern African landscapes (Archibald, 2010:117). Using a combination of fire detections from both MODIS and VIIRS, remotely-sensed fire points can be used as a source against which records maintained by fire and rescue services can be verified for more accurate incident location, or for risk assessment related to wildfires. The value of this remotely-sensed data relates to the contribution it makes towards GIC.

2.7 In summary

Information management for disaster risk management encompasses a wide variety of activities which help to guide and inform different sections of the NDMF and ensure implementation of the

National Disaster Management Act (57 of 2002), as amended. In the context of this study, information management can be seen as an on-going process which both drives and feeds into a usable system that informs resource needs and reduces risk. Collaborative networks aid in feeding this flow of information. There are mutual benefits for disaster management, fire and rescue services, communities and participating role players, as information-sharing is channelled into a method of analysis and visualisation that can be applied within context and to effect. The use of GIS and development of GIC are central in providing for these needs. GIS also offers the opportunity to study fire station location and, with the help of accurate historic incident data, make recommendations on the placement of new or satellite stations using guidance from the SANS 10090:2018. In providing new stations to meet demand, the improvement in institutional capacity can effectively leverage disaster risk down. This is in keeping with the proactive stance advocated by the NDMA, as amended, the NDMF and the international policy framework.

The use of GIS in disaster risk management and fire and rescue services was discussed in Section 2.2, while Section 2.3 explained capacity, hazard and vulnerability in the context of disaster management. In Section 2.3.1, the role of capacity in the context of disaster risk management was explained. Of note is that, when capacity to deal with certain hazards is improved, disaster risk is, in essence, reduced. One of the key points relates to the development of GIC (Geographical Information Capacity) and how this could contribute towards decision-making in disaster risk management. From this discussion, it was evident that the development of GIC can thus also aid in further capacity development in terms of improved infrastructure and allocation of resources. Section 2.4 outlined the international policy framework and local disaster management legislation which guide disaster risk management. The role of information management in this regard was discussed and provided insights into some of the information and geospatial data needs required to support sound decision-making. While some of the main geospatial data custodians were identified as sources of base data, the importance of the collection of historic incident data was also touched on, citing the example of the Western Cape PDMC. Leading on from this section, the link between the NDMC and fire and rescue services was explained, including the guiding legal framework which included the FBSA (99 of 1987) and the SANS 10090:2018. The way in which GIS can be utilised in fire and rescue services to test aspects of the SANS 10090:2018 in terms of response times was also briefly discussed. As argued in the referenced study by Green *et al.*, (2014), there is a link between fire station placement and disaster risk management. In these discussions, GIS emerged as a key tool in effective information management and which can be used to support decision-making.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology used in this research, as well as more information on the area under study.

3.1.1 Primary objectives

The study aimed to strengthen decision-making for both disaster management and fire and rescue services through the use of historic incident data and the application of GIS analysis techniques. The primary objectives of the study were to explore the use of GIS and disaster management information management as tools which could be used to support decision-making for the development of strategic disaster risk reduction strategies. For fire and rescue services, the objective was to explore the use of GIS as a tool for sound decision making for improved service delivery, location planning and identification of resource needs. Furthermore, recommendations on the use of GIS for the development of disaster risk reduction strategies were to be made, as well as how information management could be used to support decision-making. To achieve this, an understanding of the operating environment within which fire and rescue services work needed to be generated. Historic incident data and GIS analysis techniques were thus used to uncover the spatial significance of historic incidents and find solutions for the access location problem. The development of capacity can effectively reduce disaster risk, as illustrated in Section 2.3.1 of Chapter 2 above. The strategic development of new stations and provision of the most appropriate resources for individual fire stations serves to enhance capacity and thus reduce disaster risk through improved institutional capacity. The proper application of information management, mandated by the NDMF, provides spatial information which contributes towards the development of GIC, placing vital information and data in the hands of decision-makers. In analysing historic incident data in GIS, areas which can further benefit from targeted disaster risk reduction interventions, such as awareness campaigns, can also be more easily identified. This information and data serves to support the research objectives.

3.1.2 Area of study

The focus of the study was on the Mopani District Municipality's Fire and Rescue Service, seeking to address resource and service delivery needs, whilst also identifying opportunities for disaster risk reduction through information management and GIS. The Mopani District Municipality is one of five district municipalities located in Limpopo Province and is comprised of five local municipalities, namely Greater Tzaneen, Greater Giyani, Greater Letaba, Maruleng and Ba-

Phalaborwa Municipalities. The Mopani District is located on the north-eastern side of Limpopo Province and is bordered by Mozambique in the east, Vhembe District in the north, Capricorn and Sekhukhune Districts in the west and Ehlanzeni District (Mpumalanga Province) in the south (MDM, 2019:29). The Mopani District Municipality's management area also includes part of the Kruger National Park between the Olifants River in the south and the Shingwedzi River in the north. In terms of the NDMA (57 of 2002), as amended, municipal disaster management centres must be established within each district municipality. As such, the custom-built Mopani District Municipality Disaster Management Centre (MDM DMC) was officially opened in December 2008 (MDM, 2019:162). Since Mopani's Fire and Rescue Service is also a district function (MDM, 2019:80), there is close association with the MDM DMC.

Within the Mopani District Municipality, the provision of fire-fighting services is listed among the powers and functions of the municipality, and includes accident response and specialised rescue (MDM, 2019:80-81). There are currently five fire stations located within the Mopani District and a purpose-built MDM DMC in the town of Tzaneen (MDM, 2019:80;162). The fire stations are located in the towns of Tzaneen, Modjadjiskloof, Hoedspruit, Phalaborwa and Giyani. The MDM DMC and Tzaneen Fire Station are located on the same premises, but housed in different buildings. In the more rural context, such as the Mopani District, the scattered spatial distribution of rural communities makes service delivery challenging and is also often hampered by poor access roads (MDM, 2019:162).

In reviewing the literature, it was evident that the proper application of disaster management information management coupled with GIS can be beneficial in the development of strategic disaster risk reduction initiatives. Tomaszewski (2020), Green *et al.* (2014) and Hernaiz (2020) were among the authors who clearly illustrated how disaster management information management could be used in combination with GIS for improved decision-making. Scope was thus provided for the practical application of theoretical principles highlighted by these and other authors whose work was discussed in Chapter 2. Much of the research work discussed in Chapter 2 focused more on metropolitan areas (Green *et al.*, 2014; Baloyi, 2019; Isa *et al.*, 2016), leaving a gap to be explored in more rural contexts. The Mopani District Municipality was identified as a highly suitable area to address the research question of this study due to the extensive rural population, different land use types and vast distances between urban and rural areas. The study sought to make use of data collected through disaster management information management to inform fire station location and resource needs, as well as making recommendations for areas which can be targeted for disaster risk reduction initiatives. The study employed a mixed-methods approach and an explanatory sequential research design.

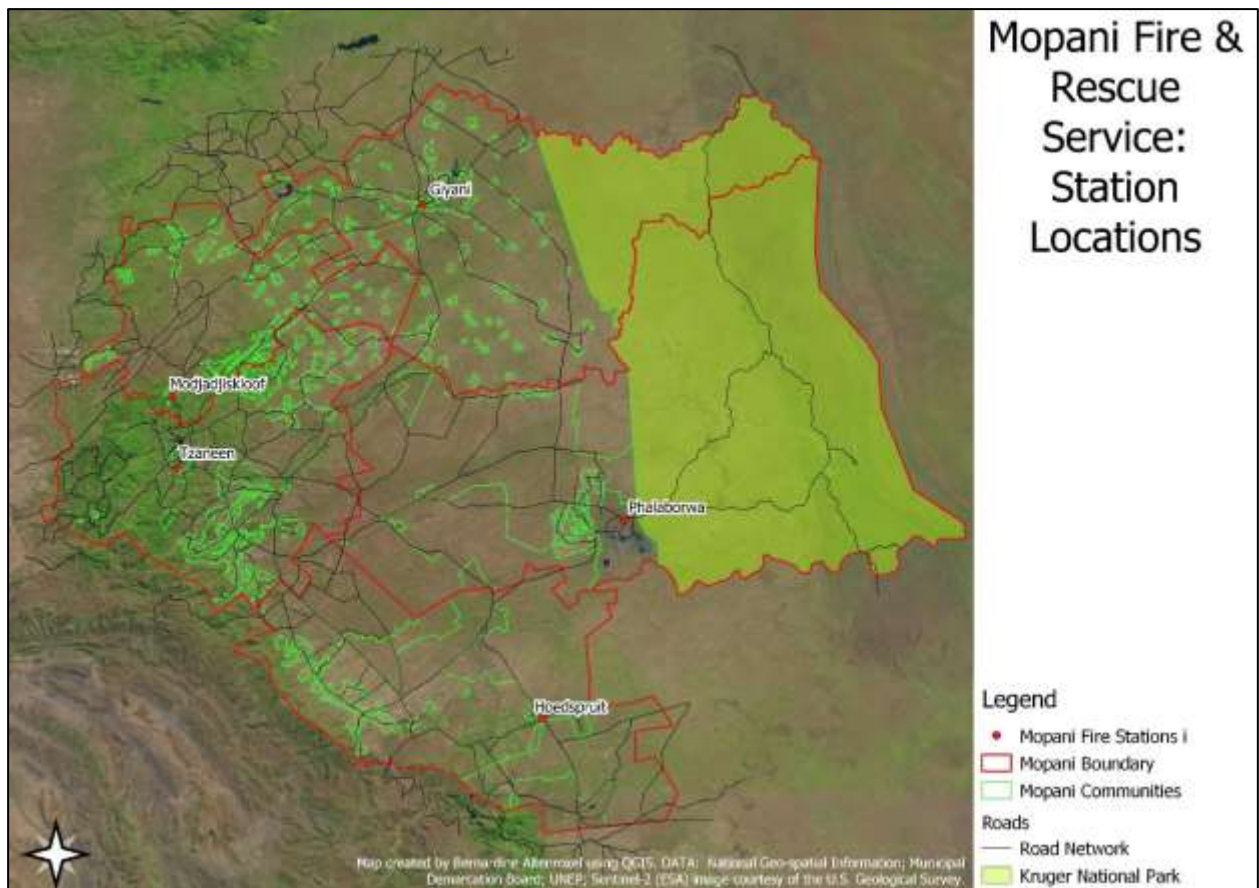


Figure 3-1: The location of the current fire stations in the Mopani District and their estimated reach within 20 minutes

3.2 Research design: An explanatory sequential research design

A mixed-methods approach was selected as the most appropriate for the study to answer the research questions and explore the research objectives. The mixed-methods approach, according to Creswell and Plano Clark (2007), employs the use of both philosophical assumptions and methods as part of the research design. In so doing, a better understanding of the matter at the centre of the study can be generated, building on the relative strengths of both qualitative and quantitative methods (cited by De Vos *et al.*, 2011:435; Creswell, 2015:Ch. 1). An explanatory sequential research design was selected to enable a process in which the data collected could first be quantitatively collected and analysed, and then further explained and explored through qualitative data collection and analysis before final inferences were made. The design thus seeks to connect data in a two-phased, sequential approach through which the topic can be explored (Cameron, 2009:145). This approach which uses sequential designs, is intended to allow one phase of the study to build on the other, with qualitative data being used to test the validity of the quantitative results (Fetters, *et al.*, 2013:2134-2135). In the first phase of an explanatory

sequential design, quantitative data collection, analysis and inferences are undertaken, and the second phase focuses on qualitative data collection (Cameron, 2009:145).

There is an advantage in the use of a mixed methods approach since this provides complementary strengths. However, there may be non-overlapping weaknesses in the analysis of textual data collected qualitatively (Haq, 2015:16). In using a sequential approach, data collected in the first phase was used to inform data collection and analysis in the second phase, as suggested by Haq (2015). While quantitative research tends to be more efficient in terms of the analysis of data and the investigation of relationships contained within this data, it provides a limited understanding of the perspectives of the participants (Creswell, 2015:Ch. 1). Both were necessary if full meaning was to be derived of fire and rescue services within the context of the Mopani District. The qualitative phase of the research, which followed the quantitative phase, provided the opportunity to explore the view of participants to understand their experiences within the context of the highly technical field of fire and rescue services, as suggested by Creswell (Creswell, 2015:Ch. 1). Thus, by making use of a mixed-methods approach, a deeper understanding could be gained within the broader context without overlooking the experiences and perspectives of the participants. The explanatory sequential research design typically places emphasis on the quantitative component (Bishop, 2015:8). The main emphasis of the Mopani-based study was thus on the quantitative phase which first thoroughly explored the collected incident data.

Analysis of the historic incident data was expedient in directing the interviews with fire and rescue service management while also creating a link to emphasise the use of GIS in relation to the requirements of SANS 10090:2018. This included the mapping of the area under study into different risk categories, and network analysis of current fire stations to estimate response times, similar to the study by Green *et al.* (2014) on the eThekweni Metro. In the study by Green *et al.* (2014), the eThekweni Metro was divided into different risk categories according to the SANS 10090:2003 before network analysis was undertaken using Flowmap to estimate response times from each of the fire stations within the Metro (Green, *et al.*, 2014:55). The authors in the Green *et al.* (2014) study point out the importance of evidence and quantitative measurement for sound decision-making in facility planning, with the findings of their study providing recommendations on fire station location planning (Green *et al.*, 2014:54). This is an indication of the importance of the quantitative element in the current study in making recommendations for improved decision-making.

3.3 Research methods

The sequential steps followed in the two-phased explanatory sequential research design are discussed in more detail below:

3.3.1 Phase 1: Data collection and analysis

In Phase 1, data was quantitatively collected and analysed. The process and sequential steps followed during Phase 1 of the study are detailed below.

3.3.1.1 Quantitative data collection from incident books and spatial analysis

Data for the research was collected from official incident record books held by Mopani Fire and Rescue Services for further analysis. The incident record books were accessed with the consent of the Mopani Fire and Rescue Services management and individual fire station managers from the Tzaneen, Phalaborwa, Maruleng, Modjadjiskloof and Giyani Fire Stations. Data was drawn from 40 incident record books. This collection of data forms part of the disaster management information management process. Although problems are frequently encountered in sourcing official documents (De Vos *et al.*, 2011:379), it is important to note that incident record books which contain information on incidents responded to are public documents. The data contained in the incident record books was developed into a digital format and content analysis was used as a systematic and enumerative method of uncovering underlying patterns (De Vos *et al.*, 2011:380). The incident books recorded information from various events, and details regarding the type of information and how it was recorded are explained in the next section. The analysis included spatial analysis, similar to that undertaken by Osidele (2018). This is most commonly associated with the positivist tradition (De Vos *et al.*, 2011:381) and it proved to be a useful approach in gaining a better understanding of spatial patterns and trends contained within the dataset. The analysis of the data also revealed key themes which could be further explored for example, the exploration of fire- and rescue-related issues in a broader context. These key themes could be further sub-divided to understand the proportion of incident types dealt with per fire station.

Before exploring the individual stations, a general overview of fire and rescue incidents was generated for the district so as to understand the distribution and trends of incidents. The large volume of incident data which had been collected first needed to be properly integrated and processed in Excel for the development of graphs to begin to understand the dynamics of fire and rescue services in the Mopani District. Incident data from the different fire stations was initially combined on one Excel worksheet with the two broad themes, namely fire and rescue incident

themes, and then separated for the individual stations. To start to develop profiles of each fire station, more graphs were developed for each fire station as well which would give an indication of typical incidents dealt with, as well as the time of day and day of the week when these incidents occurred. This was done with the cumulative data as well as on a year-on-year basis (2016 to 2019) to understand if changes had occurred over time. This process of data manipulation through the development of graphs could be used to understand and compare the different fire stations and it provided a clear indication of which stations were more heavily focused on fire-related incidents and which were more heavily focused on rescue-related incidents. This type of information is important to provide support for decision-makers who must ensure that each fire station is sufficiently resourced. The data was also imported into GIS and kernel density analysis was undertaken using the 'heatmap plugin' in open-source software QGIS over a 5km radius. This was intended to indicate areas of higher incident density within the Mopani District related to the two broad identified themes of fire and rescue incidents typically dealt with by fire and rescue services.

Tomaszewski (2020) recognises the value of open-source software, such as QGIS, in providing a wide range of spatial tools to users. This includes tools that provide spatial modelling capability (Tomaszewski, 2020:130-131). Network analysis was undertaken for each of the five fire stations in the Mopani District using the 'QNEAT plugin' in the open-source QGIS software. The end product provided a cost surface of 1 minute intervals indicating estimated response times from each station over the road network. Input parameters used in the calculation included each fire station as the start point, the vector road layer, the selection of the 'speed' field indicating road speed limits and a topology tolerance value of 50. In keeping with the study sampling design, representative samples were randomly selected from the vector point incident layer using the random selection tool in QGIS. The incident data was then combined with predetermined risk category and the cost surface layers before being exported from QGIS in CSV format. The CSV files were converted to Excel workbooks and graphs and tables were developed indicating historic incidents against estimated response times and risk category. This visualisation of incidents against estimated response times to incidents and risk category provided a clear indication of the ability to meet demand as well as the basis through which the potential for improved response times could be measured. To gain a proper understanding of the different types of incidents responded to per station, the incident data was then further sub-divided into sub-categories to indicate the proportion of different incident types responded to, such as house fires, grass fires and light motor vehicle accidents.

3.3.1.2 Methodology steps in Phase 1

During Phase 1 of the study, five sequential steps were followed, which will be discussed in more detail below.

3.3.1.2.1 Step 1 in Phase 1: Data collection and initial data analysis

Over the course of four years (2016-2019), incident data was collected from incident books maintained by each of Mopani's Fire and Rescue Service fire stations. These incident books are kept in each station's control room where incidents and updates are reported. The control room is staffed on a rotational basis by fire-fighters from the shift on duty. The incident books contain details on, amongst others, the time when an incident was received, the type of incident responded to, contact details of the caller, which personnel responded to the incident, resources used, incident location and additional details about the incident, such as patient priorities and scene description. A new incident form is opened upon the receipt of each call for assistance received, with details added as the response unfolds. The start and end kilometre readings for each of the vehicles used in the response are also captured. In this phase, the distance travelled was frequently used to determine the incident location and verified against Mopani RIMS collaborative network information and FIRMS fire data. Other placemarks, such as street addresses, stand numbers, farm names or nearby schools or clinics were also used as verification, where provided. Where there was too much uncertainty in actual incident location, such as response being cancelled before arrival, coordinates were omitted as no service was rendered. Only those incidents which included incident coordinates were considered during the sampling phase. The collection of incident data by the fire stations is still a manual process which requires the forms to be filled in by hand. The data collected from these incident books was converted to an electronic format for the purpose of display and analysis in GIS. The data contained within the incident books was captured as a spreadsheet using Microsoft Excel and converted to CSV (comma separated value) format under a series of columns corresponding to the variables captured in the form, which could be used for analysis. Incident locations were initially captured using the WGS84 datum and later converted to the Hartebeesthoek94 datum equivalent in QGIS. Once complete, the CSV was imported into QGIS for display and conversion to SHP (shapefile) format. This enabled a process through which different themes could emerge related to different incident types. The data formed the basis of the exploration of the use of GIS coupled with information management to be used as a tool for the development of disaster risk reduction strategies.

This historic incident data collected from Mopani Fire and Rescue Services was first analysed quantitatively using GIS and Excel spreadsheets to understand the broader operating environment and to identify key themes. Incidents were thus classified according to different themes (fire or rescue), incident types (house fires, grass fires, light motor vehicle accidents, etc), the time of the day and day of the week when they occurred, patient priorities and year of occurrence, amongst others. Themes which emerged during this process were then expressed as maps and graphs. Themes could broadly be divided into fire and rescue categories, and then further sub-divided into specific incident types, such as house fires, grass fires, light motor vehicle accidents or heavy motor vehicle accidents to indicate the proportion of these incident types per fire station. By separating the data into these different themes and categories, a clearer picture could be developed of these different incident types, their frequency of occurrence and spatial distribution. To better understand spatial significance, GIS analysis techniques such as kernel density using a 5km radius could be used to identify spatial patterns related to these different themes, which was among the techniques discussed by Osidele (2016), Isa *et al.* (2016) and Çela *et al.* (2013) in their respective studies on the spatial significance of incidents. Different parameters in radius were tested, with the 5km radius providing the clearest identification of incident clustering. The WGS84 datum was used in the heatmap analysis. In QGIS, the 'heatmap plug-in' can be used directly, or alternatively the 'kernel density' function geospatial algorithm can be performed through the QGIS processing toolbox. In the Mopani-based study, the 'heatmap plug-in' in QGIS was utilised.

3.3.1.2.2 Step 2 in Phase 1: Fire risk classification

In terms of SANS 10090:2018, the maximum appliance travel times for Category B and C risks are 7 and 10 minutes respectively, while a Category A risk is 5 minutes and a Category D risk is 20 minutes (SANS, 2018:7). The demarcation of the area served using these different risk categories was illustrated in the studies undertaken on fire station location planning by Green, *et al.* (2014) and Baloyi (2019), and the same process was thus applied to the Mopani District. Furthermore, according to Murray (2013), in the United States of America, National Fire Protection Association (NFPA) standards require that 90% of calls received must be reached within nine minutes from the fire station (cited by Green, *et al.*, 2014:54). Using this and the SANS 10090:2018 as a guideline, 90% of calls received by Mopani Fire and Rescue Services should thus be attended to within acceptable response times based on the different risk categories. In applying the SANS 10090:2018 in terms of recommended response times, the identification of different risk categories for each of the local municipalities located within the Mopani District Municipality was required. The Mopani District can broadly be designated as rural (Category D) based on the SANS-specified risk categories, although the more formal urban and industrial areas

of Tzaneen, Phalaborwa, Giyani, Hoedspruit and Modjadjiskloof can be considered as higher risk Category B and Category C areas (SANS, 2018:4-5). Other areas which have undergone extensive development and urbanisation were identified through a study of the IDPs of the Mopani District Municipality and the five local municipalities within its jurisdiction. These areas, which included Nkowankowa, Lenyenye, Ga-Kgapane and Namakgale, could thus also be categorised as Category B and Category C fire risk. This is due to the Category B fire-risk area being deemed as including areas with small central business districts and small industrial areas where fire risk is considered to be moderate, while Category C areas refer to residential areas of conventional type (SANS, 2018:4). A limited number of areas were designated as Category A and Category E fire risk. In the Mopani context, this mostly relates to informal settlements, such as Mokgoba outside Modjadjiskloof (Category E), or Tzaneen’s CBD area where several large shopping complexes are found (Category A). The SANS recommends special consideration in terms of the response time for the Category E fire risk category (SANS, 2018:5). In the eThekweni based study by Green *et al.* (2014), a response time of 5 minutes was suggested (Green, *et al.*, 2014:55). A 5-minute response time for the special fire risk category was thus also applied to the Mopani-based study. The remaining rural areas, including farms and rural communities, were categorised as Category D fire risk due to limited structures and their distance from urban areas (SANS, 2018:5). The application of this step in fire risk classification was an important component in exploring the use of GIS as a decision-making tool and formed the basis for bringing service delivery and fire station location needs into context. A summary of risk categories and maximum appliance (vehicle) travel times are indicated in Table 3-1 below.

Table 3-1: Risk categorisation according to SANS 10090:2018 (SANS, 2018:4-5)

RISK CATEGORY	TYPE	MAXIMUM APPLIANCE TRAVEL TIME (MINUTES)
Category A	High: CBDs and large commercial and industrial areas typically found in cities and large towns.	5
Category B	Moderate: Areas with small CBDs and small industrial areas, usually found in small towns	7
Category C	Low: Residential areas of conventional type	10

Category D	Rural: Areas with limited structures and far from urban areas	20
Category E	Special: Areas which require pre-determined attendance times over and above the predominant risk category e.g. informal settlements, large airports and major hazardous installations.	Within requirement of appropriate risk category. A time of 5-minutes was applied to the Mopani District.

In Figure 3-2 below, a map of the Mopani District Municipality divided into the different fire risk categories according the SANS 10090:2018 is displayed.

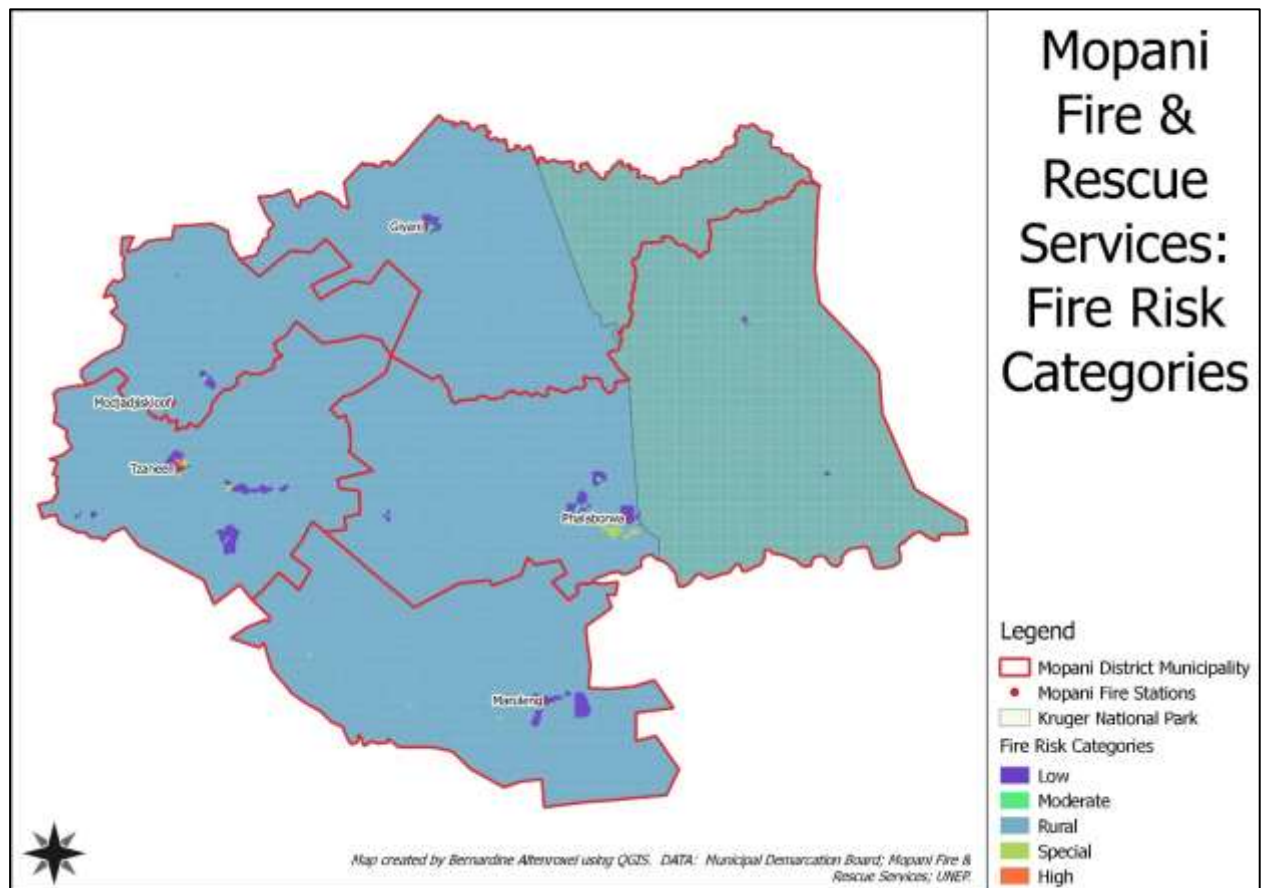


Figure 3-2: Fire risk categorisation of the Mopani District Municipality according to SANS 10090:2018

3.3.1.2.3 Step 3 in Phase 1: Quantitative sampling

According to Creswell (2015), sampling in an explanatory sequential design requires random sample selection of quantitative data and purposeful qualitative data collection (Creswell, 2015:78). Random sampling is typically associated with quantitative sampling (Onwuegbuzie and Collins, 2007:83). Since it is noted that the data collected on incidents can be broadly divided into fire and rescue categories, stratified random sampling was used for quantitative sampling. This is a sampling technique applied when clear sub-sections can be identified which have relatively homogeneous characteristics (Onwuegbuzie and Collins, 2007:285). To achieve a 95% confidence level, with a 5% margin of error would require samples per fire station and per strata as indicated in Table 3-2 below:

Table 3-2: A stratified random sampling method was used to identify sample size for each identified strata and individual fire station

	FIRE POPULATION	CONFIDENCE LEVEL	MARGIN OF ERROR	SAMPLE SIZE		RESCUE POPULATION	CONFIDENCE LEVEL	MARGIN OF ERROR	SAMPLE SIZE
Giyani Fire Station	198	95%	5%	132		361	95%	5%	187
Maruleng Fire Station	145	95%	5%	106		354	95%	5%	185
Modjadjiskloof Fire Station	308	95%	5%	172		324	95%	5%	177
Phalaborwa Fire Station	333	95%	5%	275		959	95%	5%	180
Tzaneen Fire Station	777	95%	5%	258		627	95%	5%	139

Random samples were selected by loading the layers in QGIS and then using the 'random selection' tool for vector layers. Key themes which emerged through the quantitative process were purposely identified and broadly categorised as either 'fire' or 'rescue'. As suggested by Creswell (2015), the results of the quantitative phase can be used to inform questions to be asked in the qualitative phase (Creswell, 2015:79). To satisfy the needs of the proposed study, in order to develop disaster risk reduction strategies and better inform decision-making, the quantitative and qualitative samples differed in size and population used. The qualitative phase sampling will be discussed in more detail in the discussion on Phase 2 of the study.

3.3.1.2.4 Step 4 in Phase 1: Network analysis, joining of layers and data analysis

To estimate the travelling time from each of the current and proposed fire stations located within the Mopani District, network analysis was undertaken in QGIS using the 'QNEAT plug-in' to generate a cost surface of estimated response time. QNEAT offers users different output options for network analysis, including the development of iso-area as polygon from point or layer (Github, 2018). Using the road network layer (1:50000 vector layer) provided by the Chief Directorate: National Geo-spatial Information under the Department of Rural Development and Land Reform, the travelling time from each station was measured based on the set speed limits for each road. The location of the different speed zones was mostly collected using a handheld Garmin Oregon GPS. Where the collection of these speed zones presented a safety issue, speed zones were collected using knowledge of the area and Google Street View. Once collected, the points of different speed demarcations were imported into QGIS and sections of the road layer were adjusted accordingly. All data used was converted to the Hartebeesthoek94 datum equivalent in QGIS. Due to rendering issues in QGIS with the south-oriented Hartebeesthoek94 datum, a north-oriented EPSG code (ZANGI) was developed to render data correctly (Github, 2013). On running the 'QNEAT plug-in', iso-areas as polygons (from layer) was run. This algorithm option provides filled polygons as output as well as an interpolated distance raster (Github, 2018). The use of this option is noted as well suited for the investigation of spatial objects located within a specified time range (Github, 2018). To run QNEAT required the preparation of a road network layer which had been demarcated into different speed zones as well as start points representing each of the fire stations. Input time values of 60 minutes (3600 seconds in the plug-in) with a contour interval of 1 minute (60 seconds in the plug-in) were used. 'Fastest path' was selected as the path type to calculate and the road speed field was selected from the road network layer. Topology tolerance was set at 50. Once run, both vector (polygon) and raster layers were produced, thus indicating estimated travel time. The raster layer was however not used. The vector polygon layer then required further work to first split the polygons into individual layers using the 'split vector layer' function in QGIS. Once this task was complete, the 'symmetrical difference' function was run as a batch process before the resulting polygon layers were re-joined. As discussed, incident location data was developed based on the records maintained by the five fire stations in the Mopani District and, where possible, verified from information received via the RIMS collaborative networks and FIRMS fire data. To compile the risk category layer, a 500m hexagon grid was rendered for the Mopani District in QGIS using the Hartebeesthoek94 datum equivalent, similar to the hexagon grid developed by Green *et al.* (2014:56) in their study on eThekweni Metro. The grid was then divided into the different fire risk categories according to the descriptions in the SANS 10090:2018 (SANS, 2018:4-5).

3.3.1.1.5 Step 5 in Phase 1: Extract joined layer from GIS to Excel

The sampled historic incident data, captured in point form, was then joined with the corresponding time layer polygons and risk category layer. The result was then exported as a series of Excel spreadsheets for the development of graphs and tables that would provide a clear illustration of demand for different incident types against estimated response times. The sequential steps undertaken up to this point formed a large part of the exploration of GIS as a tool which could be used to support decision-making in fire and rescue services on issues pertaining to service delivery and individual fire station resource needs.

3.3.2 Phase 2: Qualitative collection of data through interviews

Key Informant Interviews (KIIs) with senior managers from fire and rescue services were conducted to supplement the collection of the incident data. According to Creswell (2015), the purposeful collection of qualitative data is required during sampling in an explanatory sequential research design (Creswell, 2015:78). For this reason, only a small number of people with operational and management experience were targeted for interviews. Due to Covid-19-related precautionary measures, the interviews with the two main respondents were held individually, with questions structured around understanding the quantitative phase results as well as how information management and GIS could be linked to operational activities and legislative requirements for improved decision-making. Semi-structured one-to-one interviews were thus undertaken. The semi-structured interview provides the opportunity to gain a detailed understanding of the perceptions, beliefs and accounts of a participant around a particular topic and provides for greater flexibility (De Vos *et al.*, 2011:351). Using a semi-structured one-to-one interview offers an additional advantage of allowing for follow-up questions on interesting avenues which emerge during the interview (De Vos *et al.*, 2011:351). Predetermined questions were set for meaningful engagement with the participants and responses were recorded as field notes. All respondents were purposefully selected on the basis of their deep understanding of key challenges and constraints within their area of operation within fire and rescue services. They were able to provide information that is not found within the IDP or other official documentation, such as the availability of specific resources to meet demand and the unique challenges faced in road accessibility in the rural context. This proved useful in gaining a more holistic understanding of the matter at the centre of the study from an operational level, including the use of GIS, operational activities and forward planning to cope with growing development. The results of the interviews were then linked to the quantitative results.

3.3.2.1 Methodology steps in Phase 2

The four sequential steps followed in Phase 2 of the study are discussed in more detail below.

3.3.2.1.1 Step 1 in Phase 2: Interviews with senior managers (qualitative sampling)

To gain a better understanding of the perspective of fire and rescue services, individual, semi-structured, one-to-one interviews were undertaken with the three senior members of fire and rescue services. The individual and telephonic interviews were required in consideration of Covid-19 protocols. The qualitative data collected through these interviews were used to further expand on, and gain deeper insight into, the perspective of the operation of fire and rescue services, including the application and relevance of the SANS 10090:2018. The application of disaster management information management was also discussed to understand its role in management's decision-making. These discussions also helped to generate a deeper understanding of the quantitative phase results. As pointed out by De Vos *et al.* (2011), since semi-structured interviews offer flexibility, the knowledge and experiences of participants could be probed to gain a deeper understanding of their perspectives with regard to the delivery of a fire and rescue service (De Vos *et al.*, 2011:351).

3.3.2.1.2 Step 2 in Phase 2: Testing potential for improved response

For the proposed fire station, a similar process of network and data analysis, as described in Phase 1, was undertaken. With one site (Gavaza) already identified and having received Council approval for the future development of a fire station, estimated response time was calculated from this site in combination with the existing sister fire station (Tzaneen). Cost surface generation of estimated response times considering both the current and proposed fire station was thus undertaken.

3.3.2.1.3 Step 3 in Phase 2: Joining attributes by location and development of graphs

Using the sampled historic incident data, the point and polygon layers were also combined using the same process used for the current stations and then extracted from GIS in CSV format for further processing and development of graphs and tables for analysis. A comparison was then made of the potential benefits of the new station in terms of gains in respect of reduced response times. This step highlighted additional ways in which GIS can be applied to support decision-making in fire and rescue service fire station location planning. The step also contributed towards illustrating how disaster management information management can be applied to support decision-making in the Mopani District Municipality.

3.3.2.1.4 Step 4 in Phase 2: Combine results from qualitative and quantitative phases

Once the steps discussed above had been completed, the results from the quantitative and qualitative phases were combined for inferences to be drawn.

The tabulated summary of the different steps and research phases are indicated in Table 3-3 below:

Table 3-3: Steps taken during each research phase

STEP	DESCRIPTION	RESEARCH PHASE
Step 1	Collection, verification and processing of incident data, including development of themes and heatmap analysis of different incident types	Phase 1
Step 2	Classification of fire risk according to SANS 10090:2018	
Step 3	Quantitative sampling	
Step 4	Undertake network analysis per fire station and join attributes by location (join incident data, risk category and estimated response times per fire station)	
Step 5	Extract joined layer from GIS to Excel and graphs indicating incidents responded to against estimated response times and risk category.	
Step 1	Interviews with senior managers (qualitative sampling)	Phase 2
Step 2	Test potential improvement in response times by considering a current fire station in conjunction with the proposed satellite station	
Step 3	Join attributes by location by joining incident data, risk categories and estimated response times per fire station and proposed satellite station. Develop graphs and tables indicating incidents responded to against estimated	

	response times and risk category to indicate potential improvements in response time.	
Step 4	Combine results from the quantitative and qualitative phases.	

3.4 Conclusion

The two-phased approach of the explanatory sequential research design enabled a process in which the objectives of the study on the use of GIS as a tool for strategic risk reduction and decision-making for fire and rescue services could be fully explored. Data was first explored quantitatively followed by a qualitative phase. Using this two-phased mixed methods approach, several sequential steps were followed to explore the data and gain a deeper understanding of fire and rescue services needs and constraints. In following these sequential steps, which included spatial data analysis and spatial modelling, and interviews with senior fire and rescue services management, GIS and information management were central in generating a deeper understanding of the operating environment within which fire and rescue services work. The deeper understanding of fire and rescue service generated through this two-phased approach could be used to guide strategic decision-making on issues related to fire station location planning, potential improvement in response times and identifying resource needs for individual stations. At the same time, opportunities were highlighted through which institutional capacity could be enhanced, contributing towards the development of disaster risk reduction.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

In Chapter 2, the intricate role of information management in disaster risk management and fire and rescue services was explained, as well as how GIS, collaborative networks and remote sensing can aid in this process of information flow. The chapter included an overview of different legislation which guides disaster management and fire and rescue services in South Africa. The use of the SANS 10090:2018 guides community protection against fire and will be used in this chapter in combination with sampled historic incident data collected from Mopani Fire and Rescue Services to generate an understanding of needs relating to future fire station placement in the Mopani District, estimating response times against different fire risk categories using GIS and identifying resource needs. In so doing, the use of GIS as a tool for supporting decision-making for improved service delivery, fire station location planning and the identification of resource needs for fire and rescue services could be explored. The use of information management to support decision-making in the Mopani District Municipality is also illustrated.

The research methodology was discussed in Chapter 3, and outlined the use of an explanatory sequential research design and an appropriate sampling approach.

In this chapter (Chapter 4), the research methodology discussed in Chapter 3 was applied in a two-phased approach. Phase one involved the quantitative collection and analysis of data using content analysis, based on which inferences were made, while the second phase involved the qualitative collection of data to explain the quantitative results. Chapter 4 will thus consider a broad analysis of the Mopani Fire and Rescue Service following which a more detailed analysis of individual fire stations is presented. The results of interviews with senior management of Mopani Fire and Rescue Service is also discussed to provide an explanation of the results of the quantitative analysis.

4.2 Mopani District Municipality Fire and Rescue Services data analysis and overview

In order to gain a deeper understanding of the environment within which the five fire stations located within the Mopani District Municipality operate, a broad analysis of historic incident data was applied in Section 4.2.1 to Section 4.2.4 for the entire District. Kernel density mapping and network analysis were among the GIS analysis techniques applied. Following the broad analysis of fire and rescue services in the Mopani District, a more detailed analysis was undertaken on Mopani Fire and Rescue Services' individual fire stations in Section 4.2.5 to Section 4.2.9 where

fire risk classification according to SANS 10090:2018 was also considered in conjunction with network analysis.

4.2.1 The location of the current fire stations in the Mopani District and their estimated reach within 20 minutes

There are currently five fire stations in the Mopani District, which are located in the administrative centres of each of the five local municipalities, i.e. Tzaneen, Modjadjiskloof, Giyani, Hoedspruit and Phalaborwa. Fire and rescue service management were concerned not just about poor road conditions, but also the lack of house numbers and road names, factors which make locating incident addresses more difficult. These factors hamper response and increase response times. In rural communities, fire and rescue services management also indicated that spatial planning needs to be better in terms of residential road access. Each fire station is however also guided in its development and resource allocation by specific needs within the community served. As such, each of the local municipalities in which the fire stations are located will be discussed in order to provide sufficient background information on challenges faced, which have bearing on the provision of fire and rescue services. Using the IDP documents of each local municipality as well as the district municipality as a basis, the specific context of each local municipality can be better understood. The analysis of historic incident data per fire station is also undertaken and represents the quantitative phase of the research design.

While in-depth focus group interviews with respondents had initially been planned for this section of the study (qualitative phase), the Covid-19 outbreak and restrictions imposed around the pandemic made it impossible to carry out the interview as originally planned. Respondents were thus interviewed individually when restrictions were eased and their perceptions were subsequently consolidated. The use of information management, as mandated through Enabler 1 of the NDMF, and how this has been applied in the Mopani District Municipality were also discussed with respondents. In these interviews, the potential of proper disaster management information management coupled with GIS were discussed, including ways in which fire and rescue services could derive benefit. These include the reduction of risk through capacity building by informing fire station location according to demand, and the allocation of resource needs specific to each fire station. Respondent 1 noted that when viewing historic incident data in GIS, the: “..concentration of incidents provides visualisation to address problems...”, and that this provides the opportunity to develop proper facilities and build infrastructure which can serve community needs. The use of appropriate spatial data in GIS contributes towards Geographic Information Capacity (GIC), as highlighted by Tomaszewski (2020), who indicates GIC as a critical

component which supports decision-making in disaster risk management (Tomaszewski, 2020:238).

While the risk classification is discussed in more detail in the section on individual fire stations (Section 4.2.5 to Section 4.2.9), a broad overview of current estimated capacity to reach areas within a 20-minute response time can be seen in Figure 4-1 below. This is intended to provide an indication of potential footprint before more detailed analysis is applied.

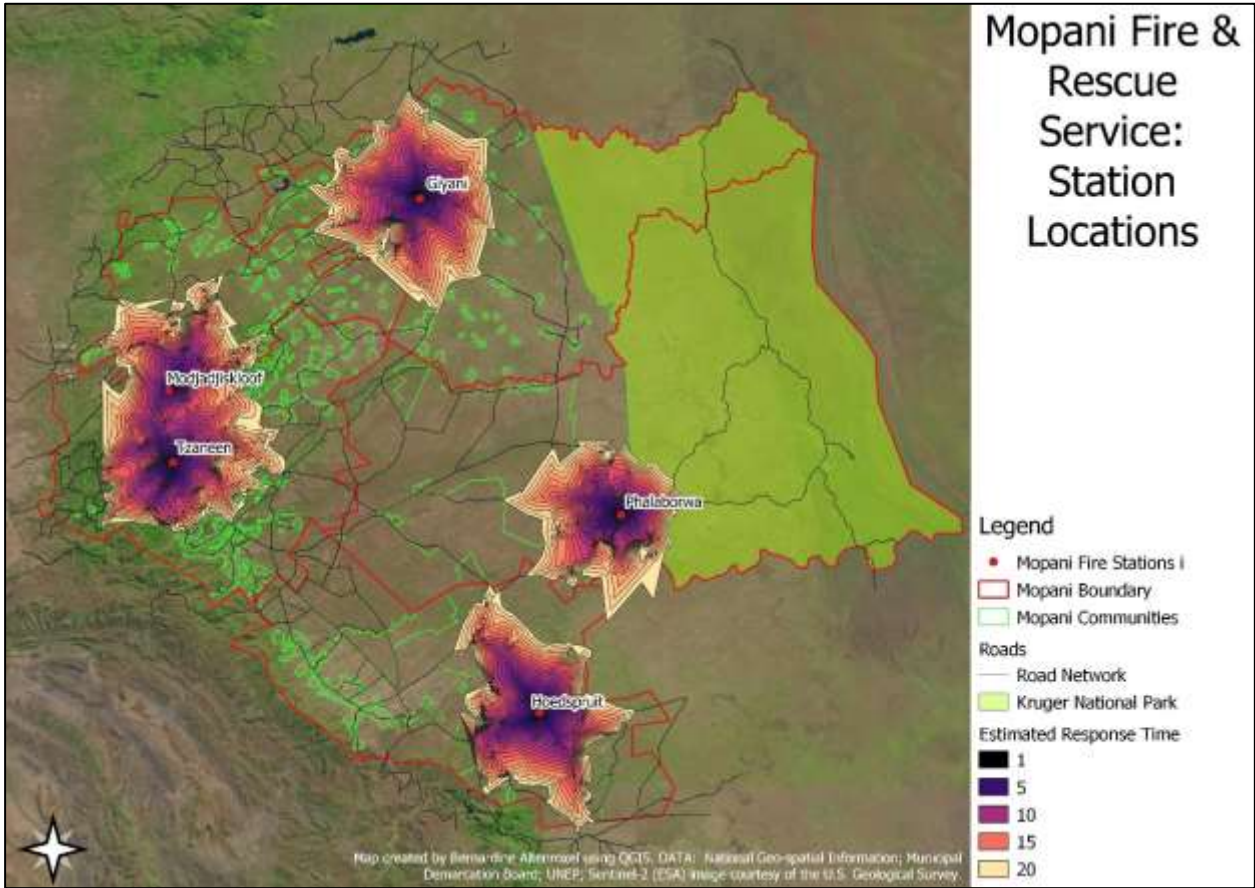


Figure 4-1: The location of the current fire stations in the Mopani District and their estimated reach within 20 minutes

In Section 4.2.2, Section 4.2.3 and Section 4.2.4 which follow, a process of kernel density mapping was undertaken to uncover spatial patterns in terms of historic fires and rescue (mostly consisting of light motor vehicle accidents, truck accidents and bus/taxi accidents) attended to by Mopani Fire and Rescue Services, since these emerged as major themes during the analysis. Graphs to indicate trends were also developed based on the historic incident data collected from Mopani Fire and Rescue Services. Of the five fire stations in the Mopani District, it is the Tzaneen Fire Station that deals with the most fires in the district (Section 4.2.2). However, it is the Phalaborwa Fire Station that deals with the most rescue-related incidents (Section 4.2.4). The

development of kernel-density maps and graphs to indicate trends is intended to guide decision-making in terms of specific resource needs per fire station.

4.2.2 The frequency of calls for fire

There are a number of different types of fires typically responded to, but each requires the use of different set of vehicles. For example, small grass fires can easily be extinguished using just a single skid unit (utility vehicle / pick-up truck with small water tank, pump and hose mounted on the back), but house and structural fires typically require a much bigger response, which will include one or more skid units being dispatched as a first-line rapid attack, with the larger, slower vehicles such as water tankers or major pumpers following to boost water supply capability, according to respondent 1 and respondent 2. Due to the differences in size and weight of each of these vehicles, different response times can be expected from each. Unlike urban areas, respondent 1 and respondent 2 indicated that rural areas do not have fire hydrants and bulk water needs to be driven to, or as close to, the site of the fire as possible.

The day of the week (Figure 4-2) and time of the day (Figure 4-3) when fire calls were received are displayed as graphs. These graphs were generated based on the incident data collected from the Mopani Fire and Rescue Service incident record books and processed for use in GIS. The graphs indicate that the Tzaneen Fire Station deals with far more fire calls than the other four fire stations. Days of the week when fires are typically reported vary slightly by station. Fires by time of the day show a stronger inclination for these calls to be received later in the day, when human activity is greater and daytime temperatures are at the highest. These aspects provide managers with information which can aid in decisions aimed at ensuring that sufficient personnel are available at these crucial times to meet demand. All fire incidents dealt with by Mopani Fire and Rescue Services can be seen in Figure 4-4 below. This indicates that the greatest clustering of fire-related incidents is located in and around Tzaneen, Modjadjiskloof, Phalaborwa and Giyani, as well as some communities adjacent to these main towns. Considering where these fires occur and their frequency helps to reduce disaster risk by ensuring that sufficient capacity is maintained to deal with the higher likelihood of fires on these days of the week and times of the day. The information can also be carried over to communities during community disaster awareness events aimed at disaster risk reduction to prompt greater vigilance on specific days and times of the day.

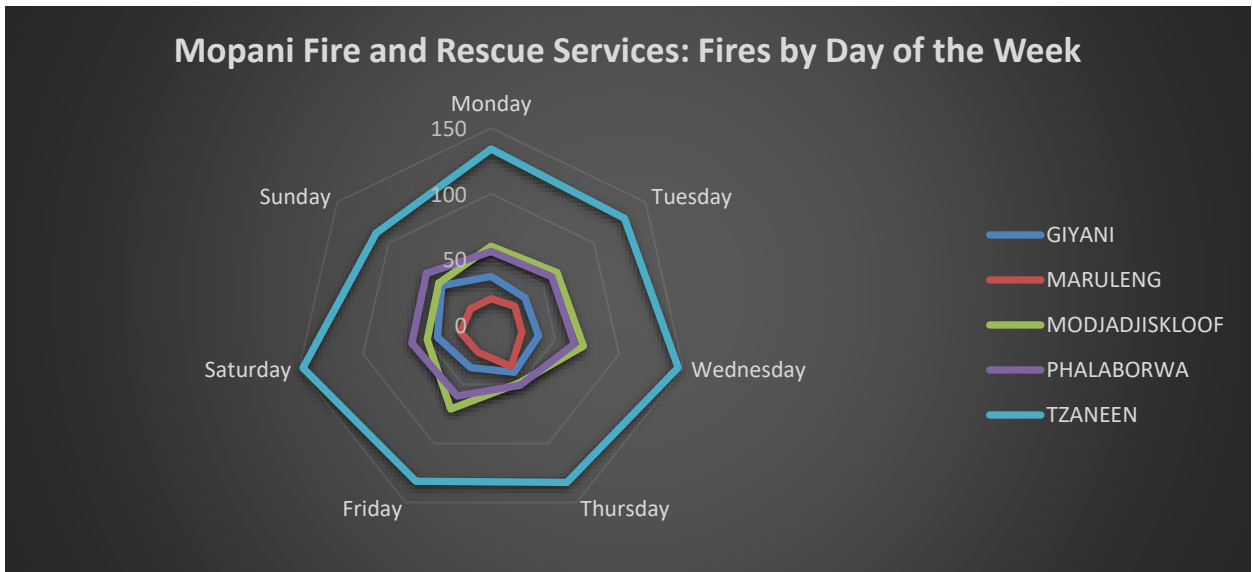


Figure 4-2: The day of the week when fire calls were received for each fire station between 2016 and 2019

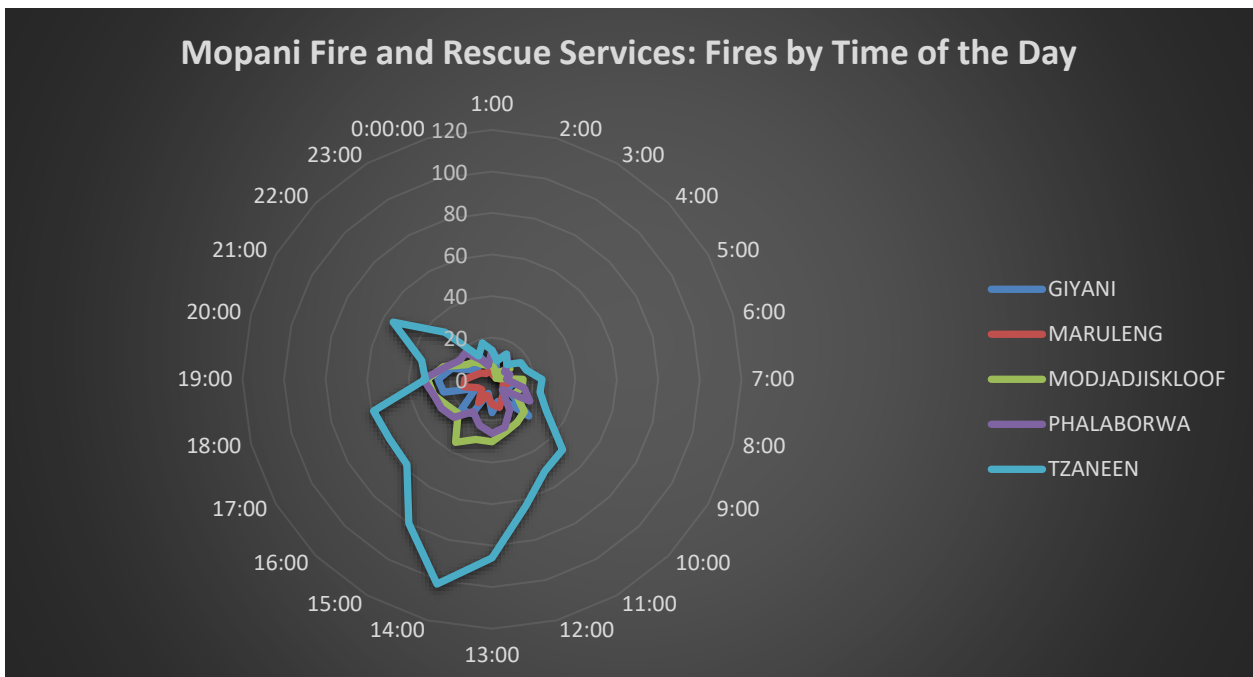


Figure 4-3: The time of the day when fire calls were received for each fire station between 2016 and 2019

4.2.3 Influences on fire occurrence

During the interview respondents indicated known problems related to the fire hazard in the Mopani District include plantation fires, alien invasive plant species, orchards that are not well maintained and different fire management approaches on communal land. These factors all influence fire occurrence, fire spread and may even affect fire behaviour. Furthermore,

respondents identified non-compliance of public buildings and lack of enforcement by local municipality building control officers as additional challenges they must face. These constraints place additional pressure on the delivery of a fire and rescue service. The presence of alien invasive plant species was recognised in the GLM IDP as posing an increased fire risk (GLM, 2020:59-60). This has implications for the Modjadjiskloof Fire Station, which must be suitably resourced for the enhanced fire risk in areas where alien invasive plant species grow in proliferation. Since the GTM and GLM are home to a large number of high-value pine and eucalyptus plantations, as described in the MDM IDP, this needs to be considered as well (MDM, 2019:77). Resources suitable for dealing with plantation fires are thus also required for the Tzaneen and Modjadjiskloof Fire Stations. The impact of these factors may also help to explain the higher number of fires attended to by the Tzaneen Fire Station and provides additional information which can inform where additional strategic disaster risk reduction activities can be directed.

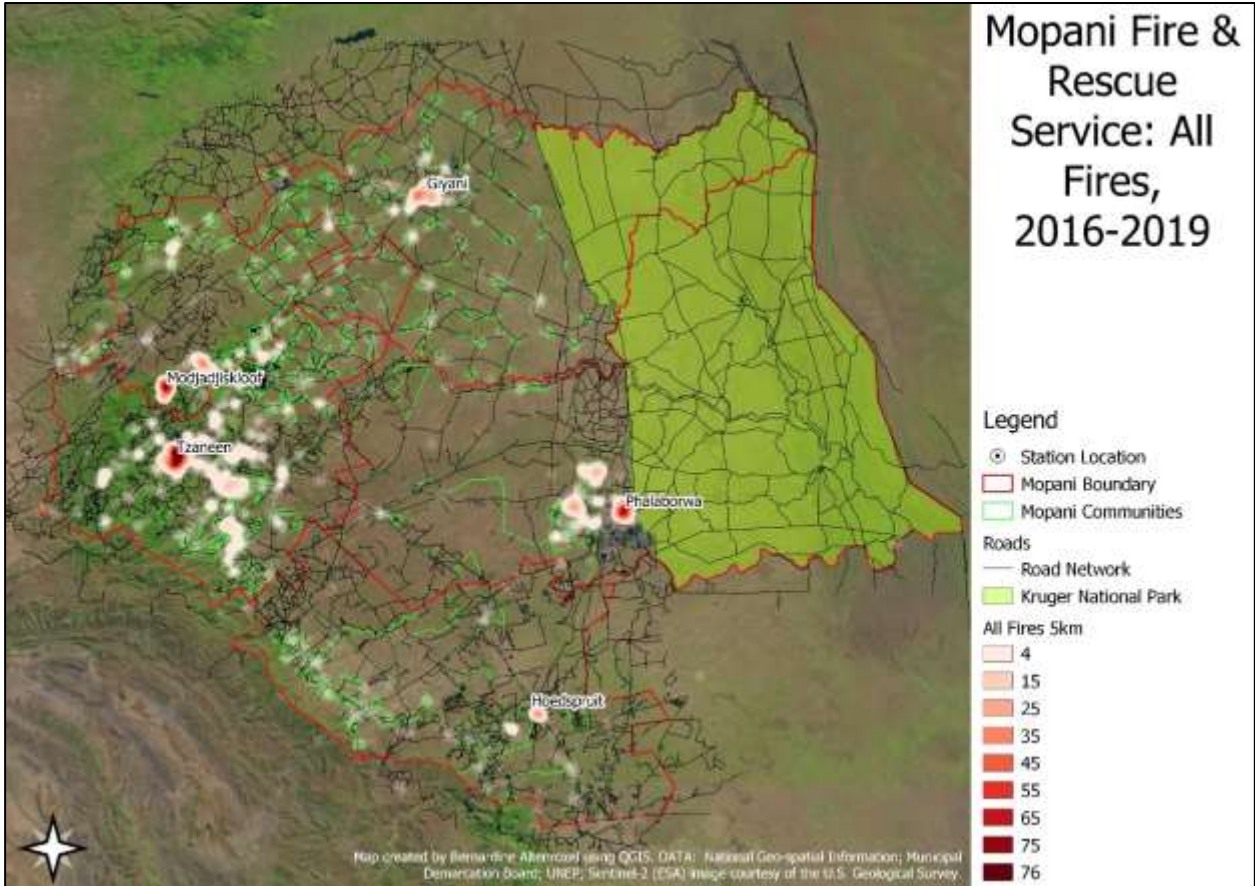


Figure 4-4: A kernel density map of fires attended to over the last four years by Mopani Fire and Rescue Services

4.2.4 Location and frequency of rescue-related incidents

The kernel density map of rescue incidents attended to, seen in Figure 4-5 reveals interesting patterns in the distribution across the Mopani road network, with key hot-spots which can be identified in places around Phalaborwa (most notably the R71 and R40), the R36 from Tzaneen to Ofcolaco, the R81 outside Giyani and along the Buffelsberg Pass near Ga-Sekgopo, the R71 Magoebaskloof road, the R528 George's Valley road and places along the R40 between Phalaborwa and Klaserie. In terms of rescue incidents, which are mostly made up of light motor vehicle accidents, truck accidents and some bus / taxi accidents, fire and rescue services in South Africa are required for the extrication of people trapped in vehicles, to extinguish or prevent fires from occurring and to provide scene safety (South Africa, 2020:290-291). Time is frequently of the essence to reach accident scenes as quickly as possible, prevent accident victims from suffering death or permanent disability and to protect life and property from any fire which can occur following an accident.

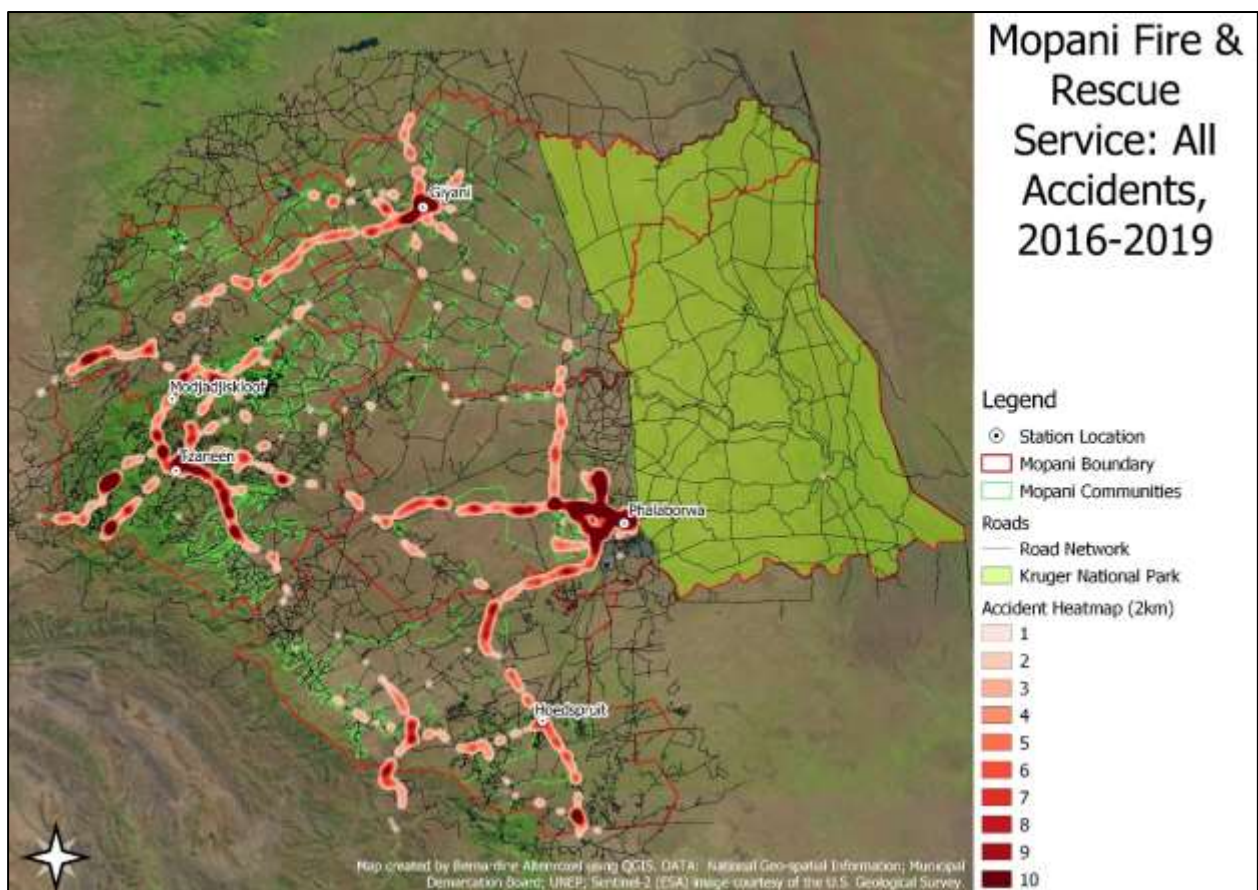


Figure 4-5: A kernel density map of accidents attended to over the last four years by Mopani Fire and Rescue Services

Determining areas of high incident concentration in terms of rescue incidents, can assist those involved with road safety to identify problem areas, according to respondent 2. Visualising accident location using kernel density mapping enables a focused approach, which can aid in decisions for improved road safety, particularly through collaborative networks such as the Road Incident Management System (RIMS). Within the RIMS structure, these high accident density areas can be targeted for intervention from a road safety or engineering perspective, as well as from a law enforcement perspective. This could involve the inspection of roads in identified high accident density areas to determine whether road signage, road markings and road surface are adequate or if any interventions are required, which could reduce or eliminate the risk of future accidents in identified problem areas. From the perspective of fire and rescue services, this information also aids in ensuring that each fire station is adequately equipped with sufficient and appropriate rescue equipment, according to respondent 1. More than one rescue vehicle may be required per station to ensure that multiple rescue incidents can be handled at the same time. The kernel density analysis can aid in making these decisions by visualising known problem areas, indicating which areas experience the most accidents and the relative distance of these from each fire station. Further analysis of the data using graphs reveals that Tzaneen Fire Station has dealt with the most fatalities over the last four years, while the Giyani Fire Station dealt with the most critically-injured patients (Figure 4-6). It is, however, the Phalaborwa Fire Station which has dealt with the most accidents compared to the other fire stations (Figure 4-7). The time of the day when accidents tended to occur differed slightly by station, but there is a general trend during the morning, noon and late afternoons (Figure 4-7). There is also a general trend for more accidents to occur over the weekends for all five fire stations (Figure 4-8).

Mopani Fire and Rescue Services: Injuries

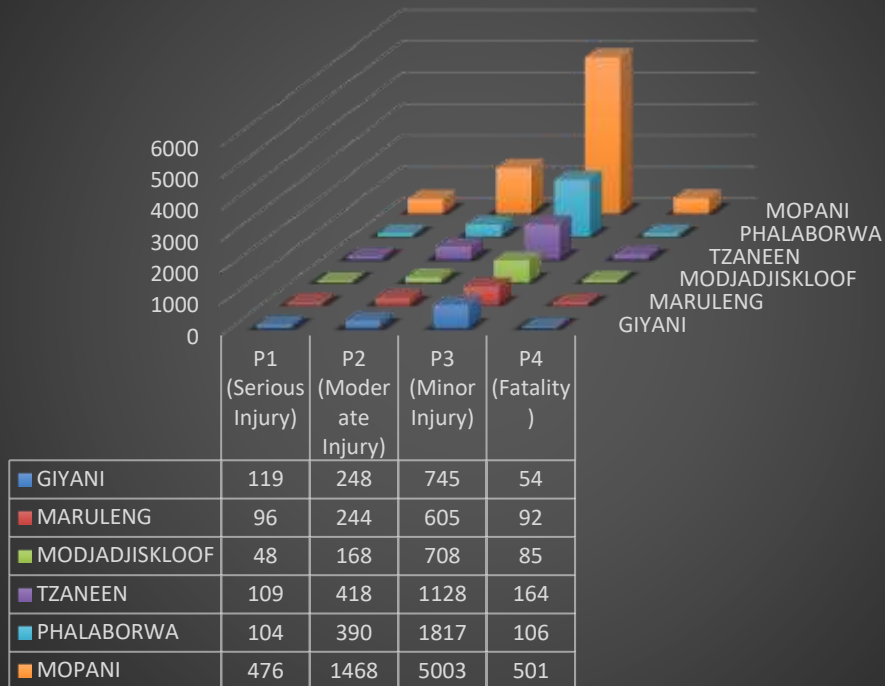


Figure 4-6: The total number of injuries and fatalities recorded over the period between 2016 and 2019 per fire station

Mopani Fire and Rescue Services: Accidents by Time of the Day

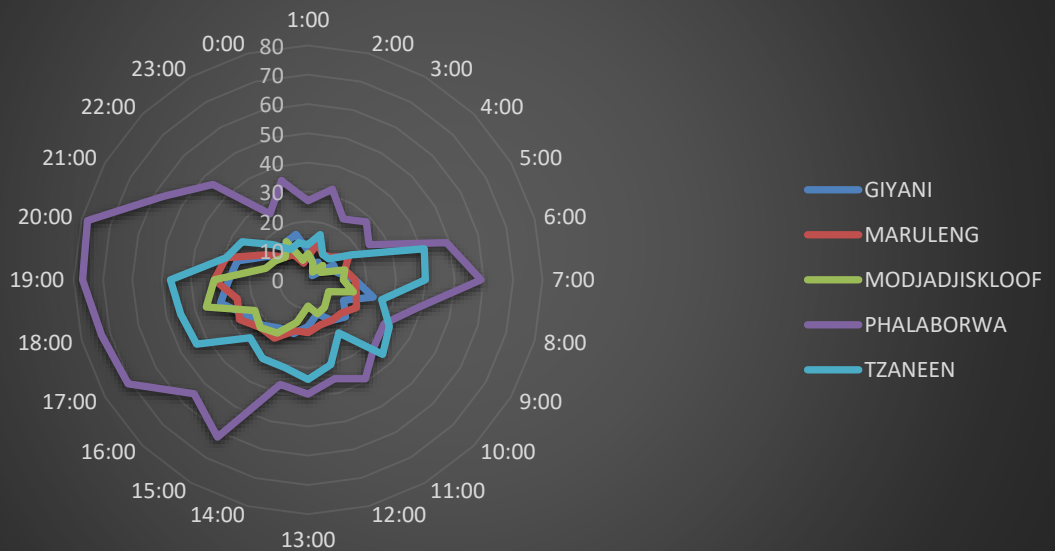


Figure 4-7: The time of day when accidents were attended to per fire station between 2016 and 2019

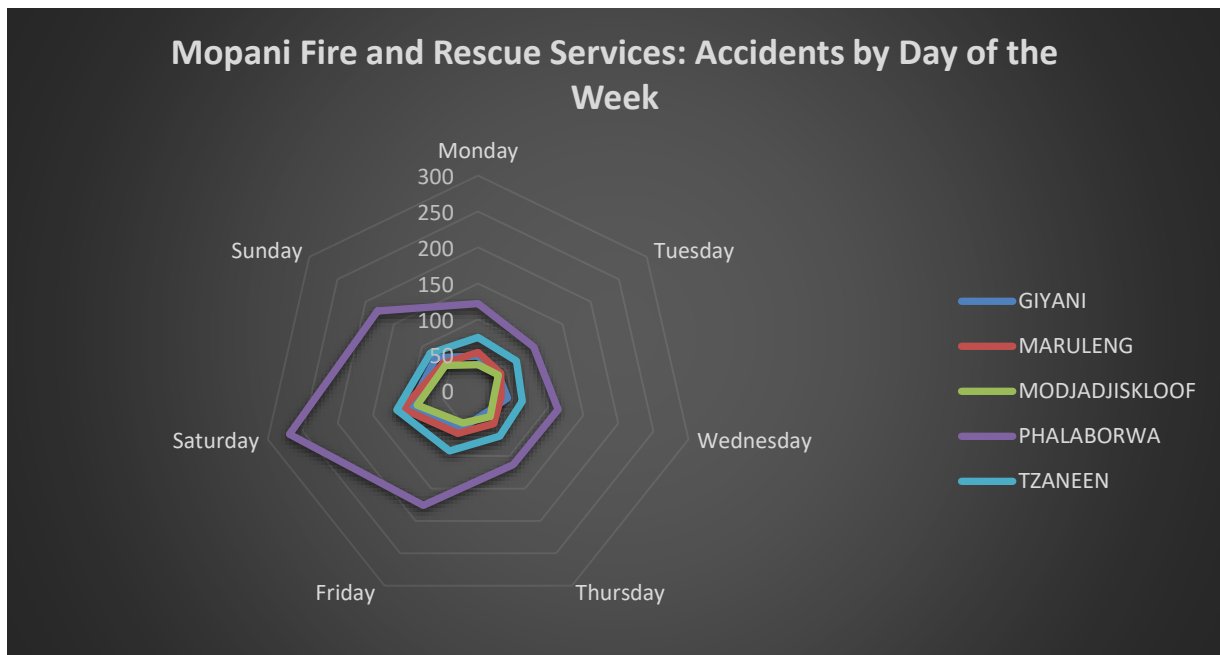


Figure 4-8: Day of the week when accidents were attended to per fire station between 2016 and 2019

The following section aims to highlight the link between data collected and how this can be used in decision-making to guide infrastructure development and resource needs. An overview of the characteristics of the area that each fire station must provide a service to is also revealed through the analysis of the IDPs of the local and district municipalities. An explanation of the fire risk classification for the local municipality within which each fire station is located is also explained.

4.2.5 Tzaneen Fire Station overview

The Tzaneen Fire Station and Mopani Disaster Management Centre are located on the same premises within a new residential extension on the outskirts of Tzaneen. The station is well-located, providing rapid access to major routes, including the R71, the R36 and the R528. There are five proclaimed towns within the Greater Tzaneen Municipality, these being Tzaneen, Nkowankowa, Letsitele, Lenyenye and Haenertsburg (GTM, 2020:146). Of these, it is Tzaneen which is the most extensively developed, with the most residential, industrial and business development concentrated in the town (GTM, 2020:147). There are four main shopping malls and three smaller centres located in Tzaneen, as well as two industrial sites. Haenertsburg and Letsitele have comparatively fewer businesses and much smaller residential areas, while Nkowankowa and Lenyenye have seen greater commercial and residential development in recent years. Nkowankowa and Lenyenye are located among more rural communities and are less well developed than Tzaneen. In addition to these proclaimed towns, there are some 125 rural communities that are mostly found within the eastern and south-eastern areas of the municipality

and are of a scattered spatial nature, with nearly 80% of the population living in these rural communities (GTM, 2020:146; MDM, 2019:43). There are also nine informal settlements located within the Greater Tzaneen Municipality (GTM, 2020:39), most of which are located within the Maake and Ritavi areas.

In terms of fire risk in accordance with the SANS 10090:2018, most of the rural areas of the GTM can be considered to be Category D (rural) fire risk, while the more formal residential areas can be considered to be Category C (low) fire risk. The two industrial areas in the town can be classified as Category B (moderate) fire risk. The residential, commercial and industrial areas within the town of Tzaneen can be easily reached within the recommended response time of 7 minutes for Category B (moderate) and 10 minutes for Category C (low) fire risks, as prescribed in the SANS 10090:2018 (SANS 2018:4-5;7). Table 4-1 below offers a summary of the different areas, risk categories and recommended response times as an example of how the Standard was applied. Figure 4-9 provides a spatial visualisation of the risk categorisation and the estimated 5-, 7-, 10-, 20- and 30-minute response times from the Tzaneen Fire Station. While Nkowankowa can be reached in an estimated 20 minutes or less, Letsitele, Lenyenye and Haenertsburg (including the luxury security estate alongside Ebenezer Dam) can be reached within 30 minutes or less, but all fall outside the recommended response time according to risk category.

Table 4-1: Risk categories in the Greater Tzaneen Municipality per area and corresponding recommended response times

Area	Risk Category	Expected Response Time
CBD, commercial development	A (High)	5 Minutes
Industrial areas	B (Moderate Risk)	7 minutes
Formal residential areas (Tzaneen, Nkowankowa, Lenyenye, Letsitele and Hanertsburg)	C (Low Risk)	10 minutes
Farms and rural settlements	D (Rural Risk)	20 minutes

Industrial areas, Informal Settlements (Talana Hostel)	E (Special)	Not specified, but within an acceptable response time according to risk
--------------------------------------------------------	-------------	-------------------------------------------------------------------------

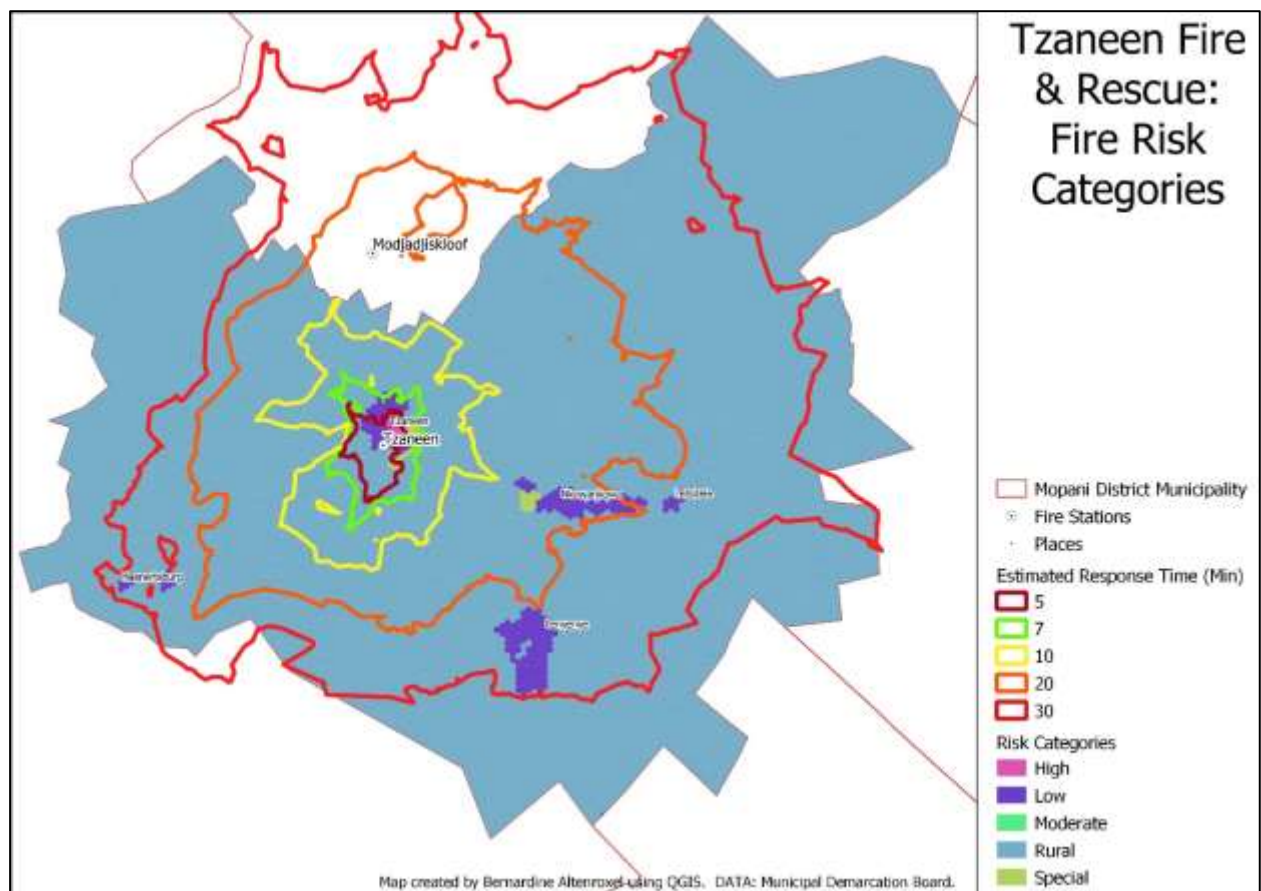


Figure 4-9: Risk categorisation of the Greater Tzaneen Municipality and estimated 5-, 7-, 10-, 20- and 30-minute reach from the Tzaneen Fire Station

Settlement patterns which are deeply rural, unequal service distribution and poor infrastructure are among the challenges listed in the Greater Tzaneen Municipality (GTM) draft IDP for 2020/2021 in terms of human settlement and development (GTM, 2020:38-39). These service delivery challenges not only mean rural communities are subjected to a lower standard of living, but are also impediments to the delivery of an efficient emergency service. The GTM IDP indicates this by identifying challenges with regards to the fire station being located within Tzaneen, as this creates difficulties in reaching outlying areas on time when there are fires (GTM, 2020:154). In the sections which follow below, this assertion will be explored.

Integrated human settlements are planned in and around Tzaneen (GTM, 2020:41), which will further expand the town's urban footprint. Rapid urbanisation is recognised as a factor which is driving the need for new infrastructure, but it is also acknowledged that there are challenges in providing sufficient infrastructure as well as maintaining ageing infrastructure (GTM, 2020:53). Perhaps the most telling aspect of the challenges related to the road infrastructure is that, of the 3091.36km road network that the Greater Tzaneen Municipality is responsible for, only 256.49km is tarred, with the remaining 2834.87km being gravel or dirt (GTM, 2020:80). This is a considerable problem in offering an efficient emergency response during times of need. The remaining road network, i.e. national, provincial and district roads, are maintained and / or managed by the Department of Public Works, Roads and Infrastructure, Roads Agency Limpopo (RAL) and the South African National Roads Agency (SANRAL), depending on road classification i.e. district, provincial or national roads (GTM, 2020:80-81). It is furthermore indicated that many of those gravel and tar roads which fall under the responsibility of RAL are in poor condition and in need of rehabilitation (GTM, 2020:82). These access problems relating to road condition are not only encountered by local residents, but by emergency services as well. Despite pressure from the public to maintain the road network in the main urbanised areas, the municipality concedes that this is an impossibility due to lack of funding (GTM, 2020:81). A programme for the maintenance and upgrade of rural gravel roads is on-going, but lack of resources hampers the expansion thereof (GTM, 2020:81). This should be noted as creating a challenge in the delivery of an emergency service.

The poor road network and road access challenges in some places must be considered in resource allocation. For the Tzaneen Fire Station, which deals with the most fires, there are additional challenges to face in terms of steep terrain and numerous high-value plantations. This means that they require vehicles which can access different types of terrain. A fire truck typically used for structural fires will not be able to access a road within a plantation. Small vehicles with 4x4 capability and a water supply mounted on the back (skid unit) would be the most appropriate, with a backup supply of water from water tankers. The Tzaneen Fire Station also deals with a large number of truck accidents, which means that they require sufficient heavy duty rescue equipment over-and-above the standard rescue equipment typically used for light motor vehicle accidents. The mountainous area in which the Tzaneen Fire Station operates also implies that they will require sufficient rope rescue and related rescue equipment to reach patients who have fallen down cliffs or whose vehicles have rolled down the mountainside.

In places such as Mokgolobotho (Greater Tzaneen Municipality), for example, it was indicated during the interviews with Mopani Fire and Rescue Services senior management that there is no access for large fire vehicles. This is a particular problem in dealing with house fires effectively

and means that only the smaller skid units (utility vehicle with small water tank, hose and pump mounted on the back) can reach the affected house. This supplies a minimal amount of water and therefore skid units must continuously return to where the water tanker is parked (as close to the fire as road access allows) to re-fill with water. Upgrades to the road network will undoubtedly facilitate a quicker emergency response, and thus also a reduced disaster risk by reducing or preventing damage when a fire occurs. In other words, the sooner a fire can be contained and extinguished, the lower the potential loss or damage. Until this happens, however, the poor road network and poor maintenance thereof will continue to act as impediments to the delivery of an efficient emergency service. This thus means a reduced capacity to respond in terms of acceptable response times as long as the roads remain in a state of disrepair. Through the analysis of the historic incident data however, decisions on appropriate resource allocation for the fire station, particularly in terms of vehicles, can be guided so as to provide the best possible service under the circumstances.

With mines located in Phalaborwa and Gravelotte, dangerous goods are also transported by road via Tzaneen to these mines. This means that the Tzaneen Fire Station must have equipment and resources at its disposal for handling dangerous goods incidents, including the containment of spills.

The town of Tzaneen, including both industrial areas, residential areas and commercial business areas, are within easy access of the Tzaneen Fire Station, as illustrated in Figure 4-10 below. As the main town with the greatest mix of different risk categories, and as administrative centre in the GTM, Tzaneen was considered separately to determine access to different parts of the town. In Figure 4-11, a broader approach is applied to determine which areas fall within an estimated 60 minutes of the station. This indicates that the entire Greater Tzaneen Municipality can easily be reached as well as Greater Letaba Municipality and parts of Greater Giyani, Ba-Phalaborwa and Maruleng Municipalities. However, appropriate response times differ by risk category. The different risk categories and corresponding estimated response times of historic incidents are considered in the sections below.

Tzaneen is the most extensively developed of the five proclaimed towns in the municipal area. The CBD, two industrial areas and residential areas can be reached with ease from the Tzaneen Fire Station within the recommended times for Category B and Category C fire risks. Further residential expansion in and around Tzaneen, as outlined in the GTM IDP, can still be comfortably reached within recommended response times. While Nkowankowa can be reached in 20 minutes or less, it can take up to an estimated 30 minutes to reach all residential areas of Lenyenyene, Letsitele and Haenertsburg since they are remote from Tzaneen. The pack houses around

Letsitele would fall within an estimated response time of 20-30 minutes. This is an indication that a new or satellite fire station is required to reduce response times and improve on service delivery, particularly through Lenyenye and Letsitele where the demand for service is higher. Some overlap in jurisdiction occurs with the Capricorn District, particularly in terms of accident-related incidents on the R71 road between Haenertsburg and Boyne. In this regard, signing a memorandum of understanding (MOU) with the Capricorn District Municipality can help to facilitate a faster response to accidents or fires in this area through the Mankweng Fire Station.

In terms of resource needs for the Tzaneen Fire Station, which deals with the most fires in the Mopani District, it is important that sufficient resources are provided to effectively deal with fire. Given that more than half of all fires sampled were grass fires, this means that emphasis should be placed on resource provision, including vehicles and equipment, which can adequately meet community needs in terms of response to grass fires.

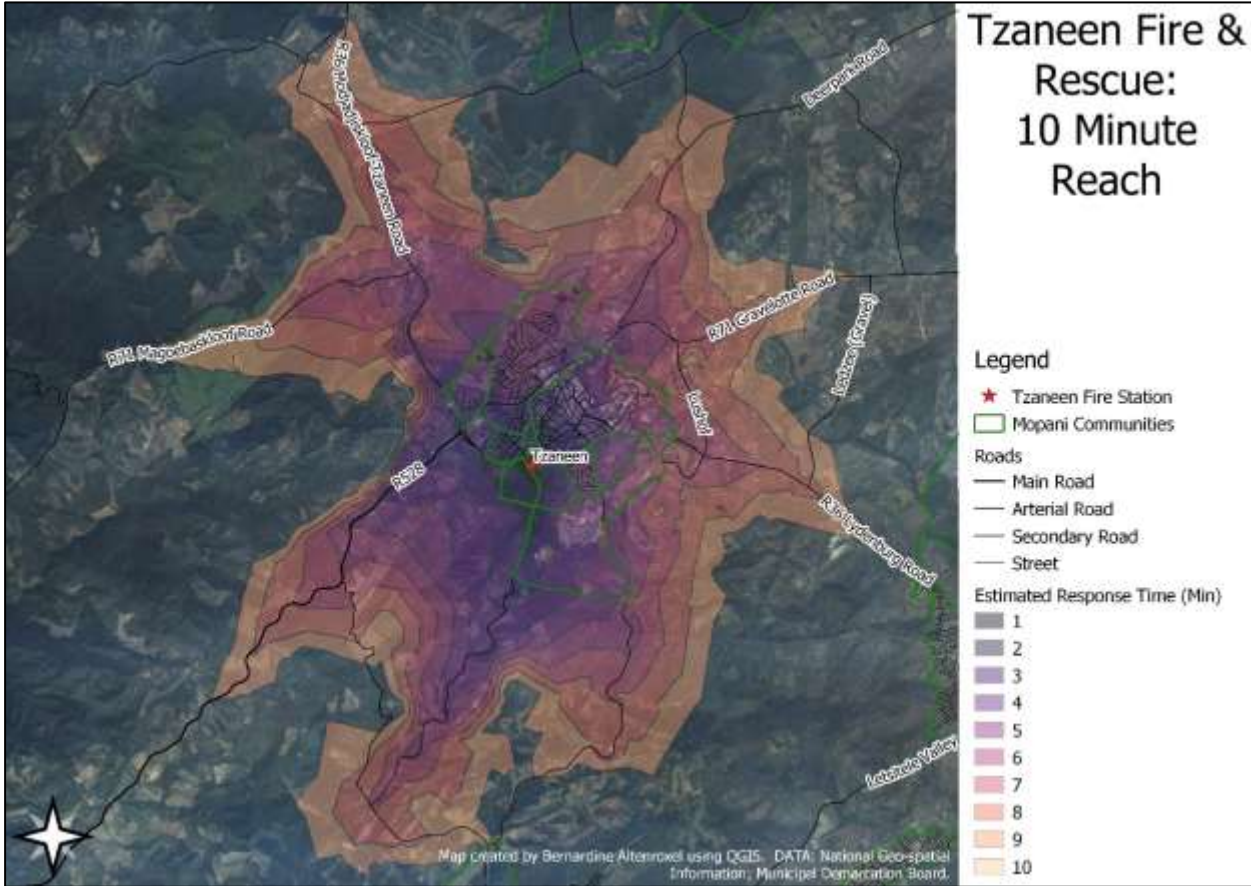


Figure 4-10: Areas within the estimated 10-minute reach of the Tzaneen Fire Station

Fire-fighting vehicles with off-road capabilities would be most suitable, and can double as rapid-response vehicles for different types of fires, including house fires, in more rural settings. Since multiple fire incidents may occur simultaneously, or the possibility exists that a large fire must be fought from multiple fronts, sufficient vehicles with off-road capability should be provided. Consideration should also be given to possible mechanical failure of vehicles and the development / procurement of a maintenance plan which streamlines the repair of vehicles. This should ensure that adequate vehicles are kept in service. The Tzaneen Fire Station also deals with a large number of accidents, including truck accidents. Sufficient rescue equipment, including heavy duty rescue equipment (such as cutters and spreaders), is thus required. Being located in a mountainous area also requires the provision of rope rescue equipment and personnel who are sufficiently trained in rope rescue techniques.

Considering the commercial development and residential expansion in the Ritavi and Maake areas, as well as large pack houses in the Letsitele area, an additional fire station in the Maake area would facilitate a quicker response to future fire and rescue incidents. The development of a station at Gavaza has already received council approval, according to Respondents. The potential benefit of this site will be discussed in more detail in Section 4.3.

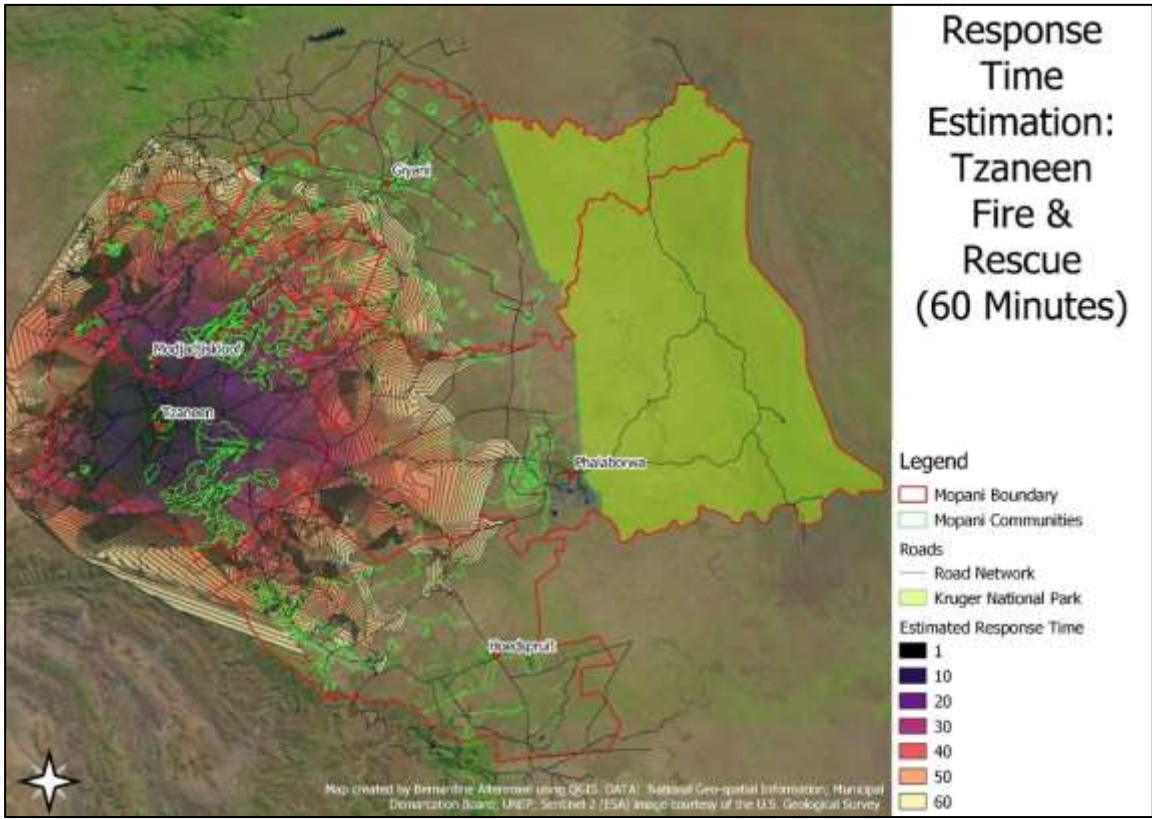


Figure 4-11: Areas within the estimated 60-minute reach of the Tzaneen Fire Station

4.2.5.1 Fire occurrence in the Greater Tzaneen Municipality

Table 4-2 below indicates the proportion of each fire type contained within the sampled data. Based on this, the majority of that the Tzaneen Fire Station responded to were grass fires (51.16%), followed by house fires (18.99%) and structural fires (10.85%). This fits with the rural-urban interface and rapidly growing urban and commercial developments described in the GTM IDP. Also, since the GTM falls within a high rainfall area with greater biomass production, the annual fire season typically brings a high number of grass fires. This is well reflected in the high proportion of grass fires contained within the sampled fire data. Those fires attended to that involved informal structures were mostly scattered in the areas described within the IDP.

Table 4-2: The proportion of fire types within the sampled data for the Tzaneen Fire Station

FIRE TYPE	NUMBER	% OF TOTAL
Electrical Fires	7	2.71%
House Fires	49	18.99%
Structural Fires	28	10.85%
Grass Fires	132	51.16%
Vehicle Fires	22	8.53%
Informal Settlement Fires	10	3.88%
Other Fires	8	3.10%
Rubbish Fires	2	0.78%
TOTAL	258	

The estimated number of fires reached within and outside recommended response times are tabulated in Table 4-3 below. This indicates that only fires within the high-risk category were all estimated to have been reached within the recommended response time. As described in the literature review (Chapter 2), in accordance with NFPA standards, 90% of calls received should be reached within the prescribed response time. The spatial distribution of rural communities and other proclaimed towns within the GTM however makes this very difficult to achieve. Only an estimated 68.42% of fires in the low risk category and an estimated 68.71% of fires in the rural risk category could thus be reached in accordance with the NFPA standard. Within the special risk category, only an estimated 29.41% of fires could be reached within the stipulated time. This is largely due to parts of the ‘old industrial area’ in Tzaneen not quite being covered either within an estimated 5-minute response time or the industrial area of Nkowankowa. In Figure 4-12, sampled fires attended to over the last four years are visualised against estimated response time. This map indicates that grass fires tended to occur more commonly in and around Tzaneen, while

other fire types, such as house fires, were more common in the surrounding rural communities, including Ritavi and Maake.

Table 4-3: The estimated number of fires reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	7 Min	68.42%	31.58%
Moderate	10 Min	0.00%	100.00%
Rural	20 Min	68.71%	31.29%
Special	5 Min	29.41%	70.59%
High	5 Min	100%	0.00%

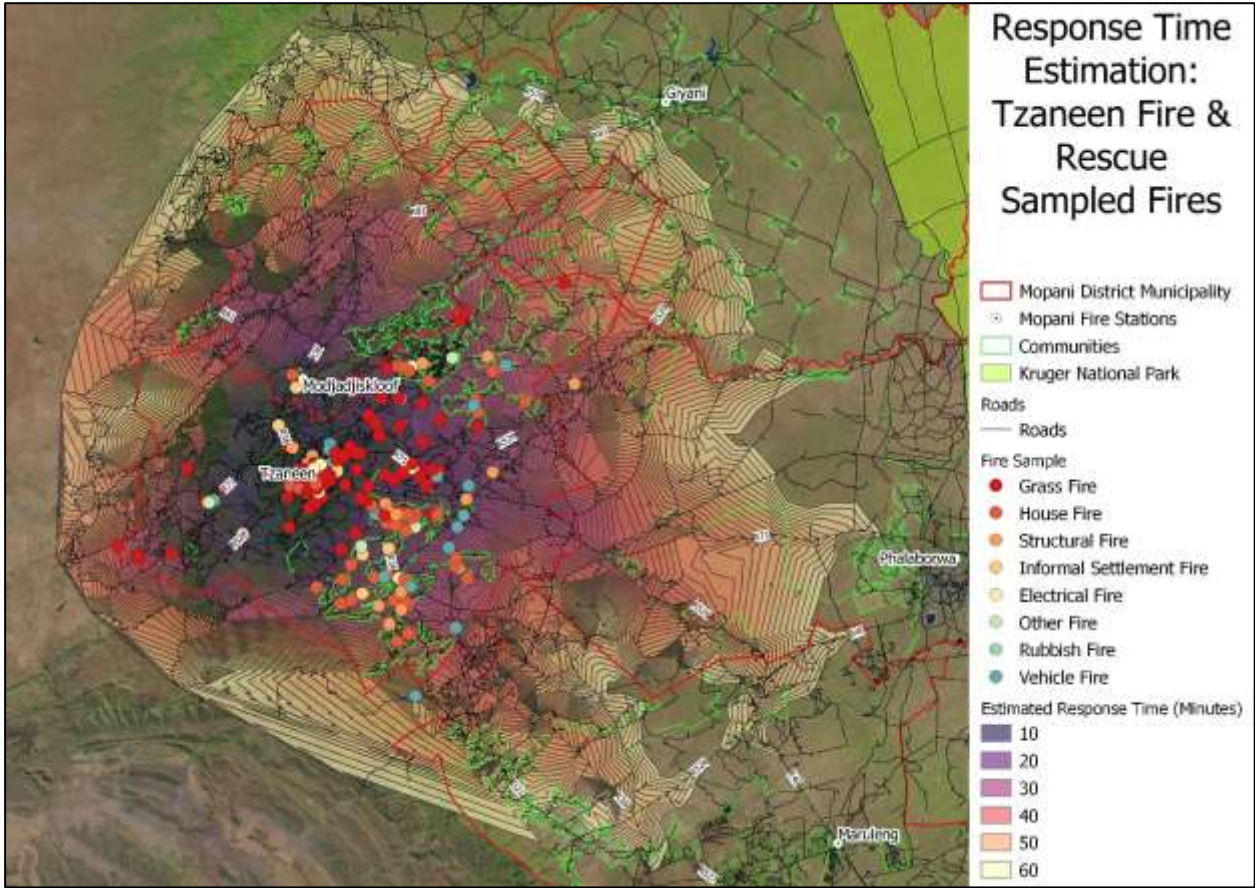


Figure 4-12: Areas within the estimated 60-minute reach of the Tzaneen Fire Station and sampled fires dealt with between 2016 and 2019

In order to understand possible time constraints, the results of the estimated response time, risk categories and fire sample are represented in the graph in Figure 4-13 below. This provides an indication of the distribution of the historic sampled fire incidents per risk category and typical estimated response times. To further contextualise this, each risk category is considered

individually. Figure 4-14 indicates that typical low risk fires responded to within and around Tzaneen could be reached within the allotted time of 10 minutes or less. However, the more formal residential areas of Nkowankowa, Letsitele, Lenyenye and Haenertsburg are not located within 10 minutes from the Tzaneen Fire Station, and are indicated after the gap in the graph. Only one of the sampled fires occurred within an area of moderate risk, however, (Figure 4-15) and it was located in Haenertsburg. With the GTM municipal area largely being of a rural fire risk, the majority of sampled fires occurred within the rural risk classification. Fires in the rural risk classification could mostly be reached within the recommended response time of 20 minutes (68.71%) (Figure 4-16). Although there were few fires within the high-risk classification (Figure 4-17), 100% could be reached within the recommended response time of 5 minutes. However, within the special risk classification (Figure 4-18), only 29.41% of fires could be reached within the recommended response time. Fires in this risk category included grass fires and some structural fires. The difference in estimated response times between the Tzaneen industrial areas and the industrial area of Nkowankowa are illustrated by two separate peaks in the graph.

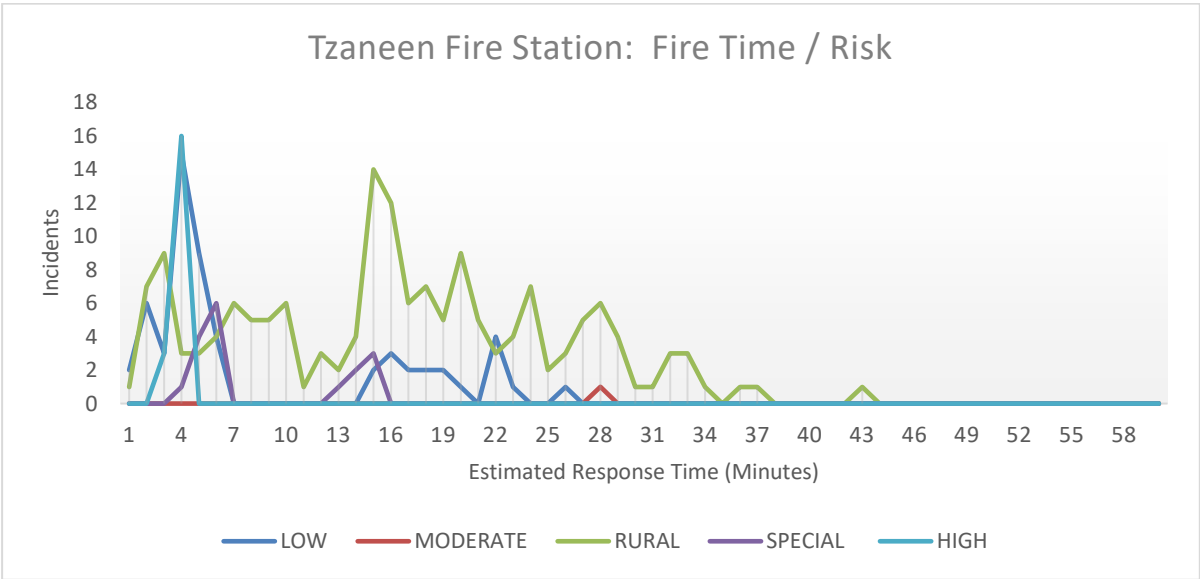


Figure 4-13: Sampled fires plotted per time interval and fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

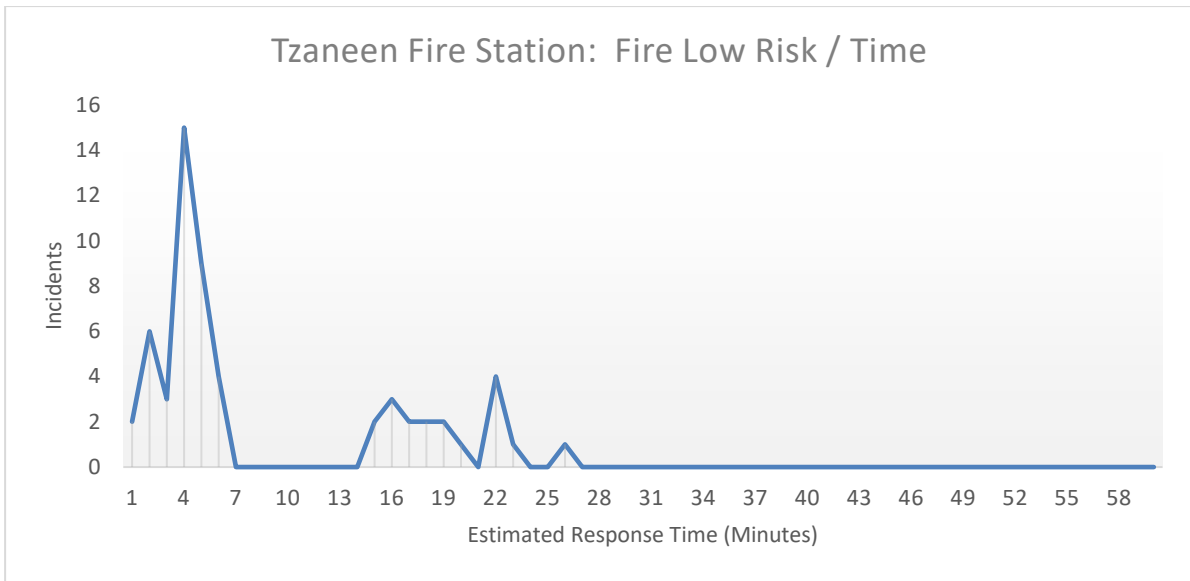


Figure 4-14: Sampled fires plotted per time interval and low fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

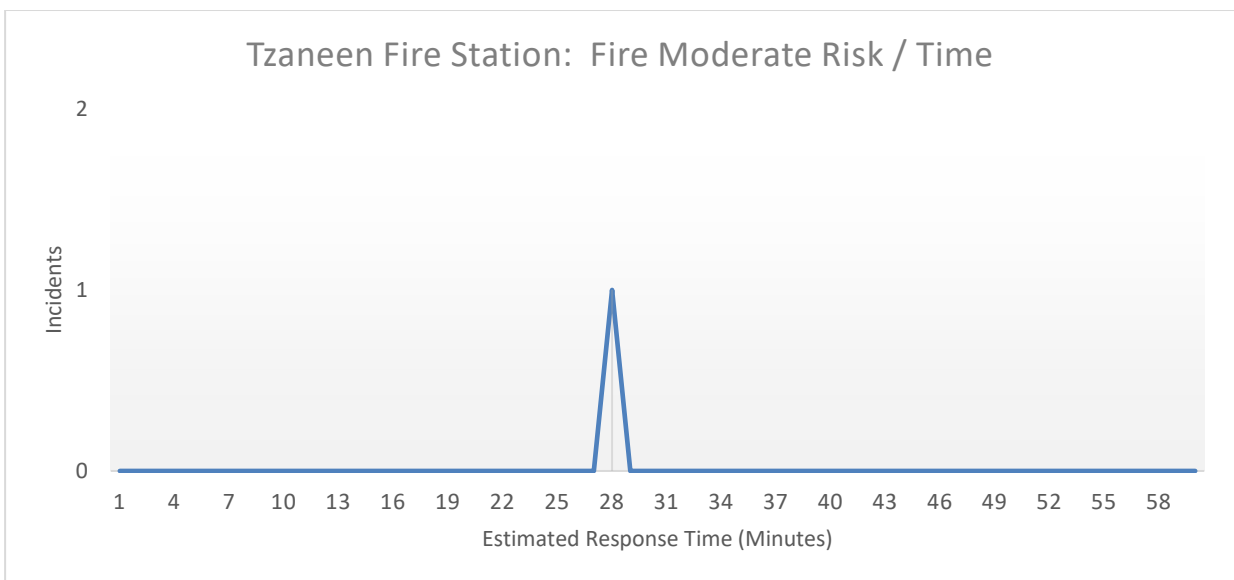


Figure 4-15: Sampled fires plotted per time interval and moderate fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

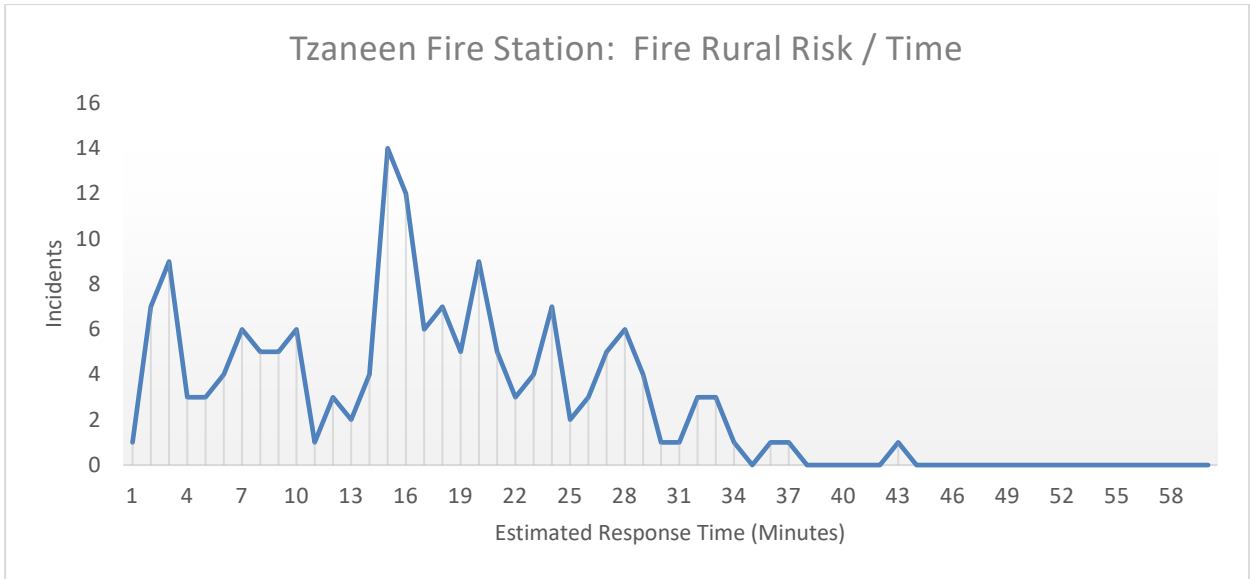


Figure 4-16: Sampled fires plotted per time interval and rural fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

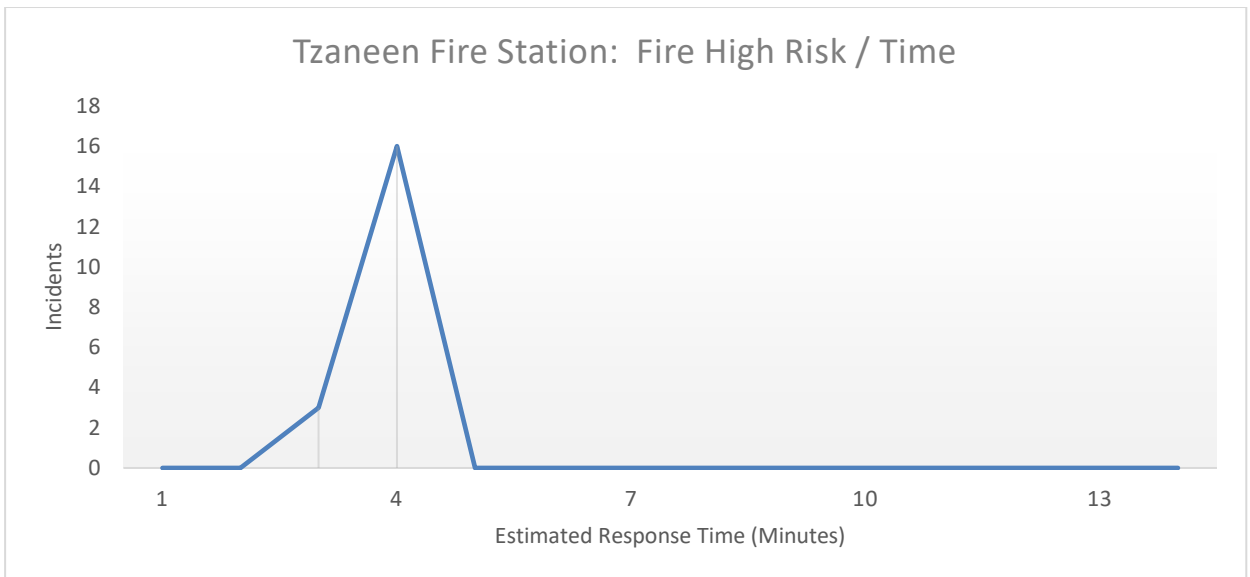


Figure 4-17: Sampled fires plotted per time interval and high fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

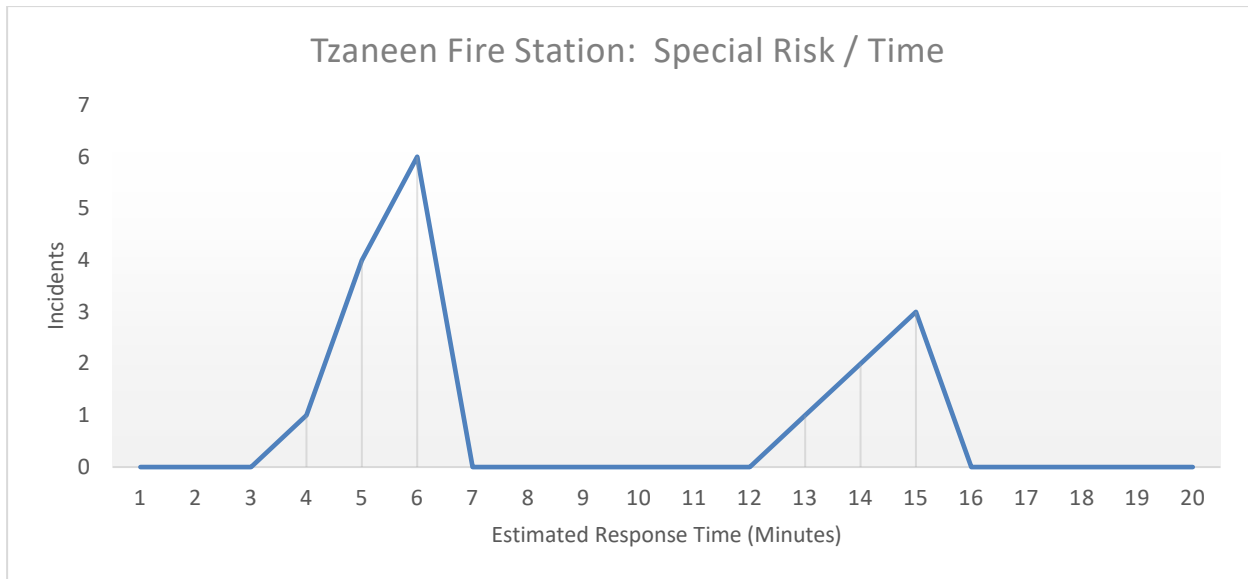


Figure 4-18: Sampled fires plotted per time interval and special fire risk type for sampled fires attended to by the Tzaneen Fire Station between 2016 and 2019

4.2.5.2 Rescue incidents attended to by the Tzaneen Fire Station

All rescue-related incidents analysed involved different types of accidents, ranging from light motor vehicles to taxi and bus accidents. Table 4-4 below contains a summary of the proportion of different rescue types contained within the sample. Based on this, it can be seen that the vast majority of rescue-related incidents were for light motor vehicle accidents (79.92%), followed by truck accidents (12.97%) and taxi accidents (5.44%). There were relatively few bus and pedestrian accidents (1.26% and 0.42% respectively). The number of truck accidents comes as no surprise considering the two mountain passes entering the Mopani District through GTM from the west, i.e. the R71 Magoebaskloof and R528 George’s Valley roads.

Figure 4-19 provides an overview of the spatial distribution of the rescue sample, also indicating different incident types. In terms of the proportion of rescues attended to according to the different risk categories, the Tzaneen Fire Station fares relatively well, being able to reach 78.14% of rescues in the rural risk category, and 76% of rescues within the low risk category within the recommended response times (Table 4-6). Although there were not many rescues located in high risk classification, they could all be reached within recommended response times. There was only one rescue incident which occurred within the special risk classification, but this was outside the recommended response time of 5 minutes.

Table 4-4: The proportion of rescue types within the sampled data for the Tzaneen Fire Station

RESCUE TYPE	NUMBER	% OF TOTAL
MVA	191	79.92%
Truck Accidents	31	12.97%
Pedestrian Accidents	1	0.42%
Taxi Accidents	13	5.44%
Bus Accidents	3	1.26%
TOTAL	239	

Table 4-5: The estimated number of rescues reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	7 Min	76%	24%
Moderate	10 Min	0.00%	0.00%
Rural	20 Min	78.14%	21.86%
Special	5 Min	0%	100%
High	5 Min	100%	0.00%

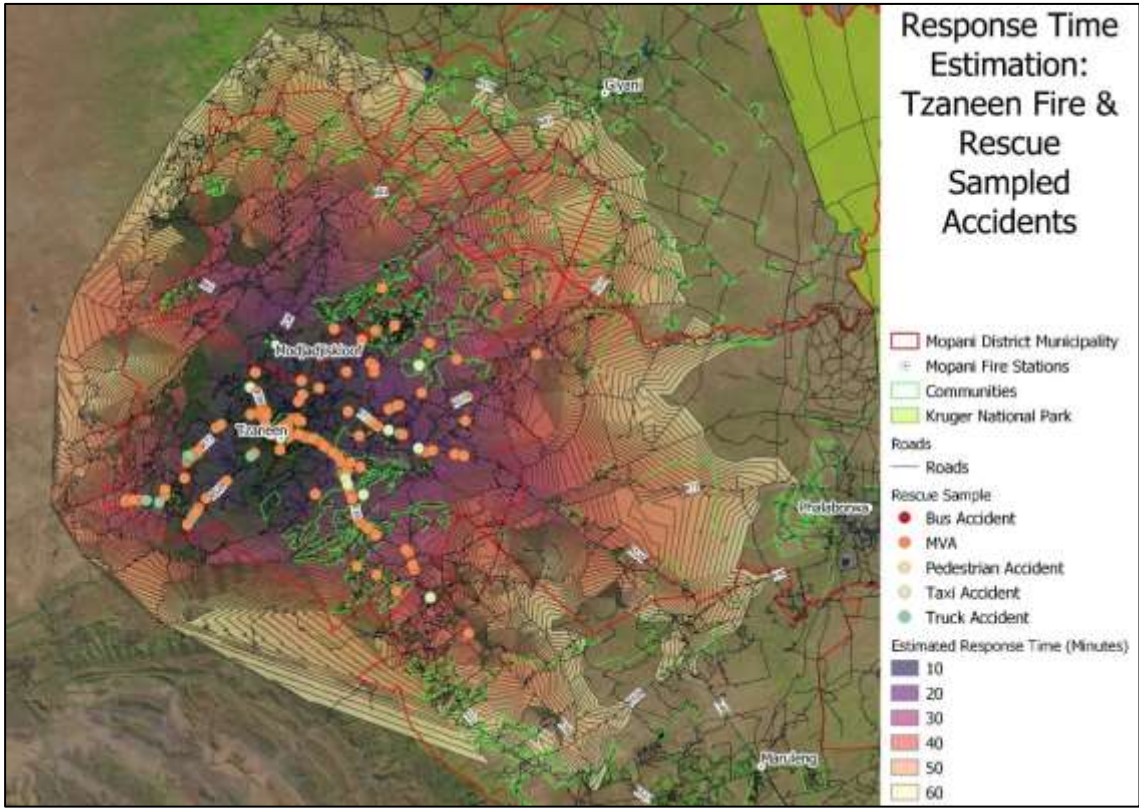


Figure 4-19: Areas within the estimated 60-minute reach of the Tzaneen Fire Station and sampled accidents (rescue) dealt with between 2016 and 2019

The distribution of rescue-related incidents was plotted against risk classification and estimated response time, as seen in Figure 4-20 below. This provides a good indication that the majority of rescue-related incidents occur within the rural risk category. There were comparatively fewer rescue-related incidents in the low risk category (Figure 4-21), with the majority (76%) estimated to have been reached within the recommended response time. Although the remaining 24% fell outside the recommended response times, these in actual fact only related to five incidents. As already indicated above, the majority of rescue-related incidents occurred within the rural risk category. In Figure 4-22 below, the distribution of these incidents can be seen plotted against estimated response time. A large peak can be seen in this distribution within the range of 12- to 22-minute estimated response time. The total number of incidents reduces after this, with only a few smaller peaks. Even though the number of incidents taper off after the main peak, it may still take a considerable amount of time to reach incidents in more remote locations. Given the size of the area and extent of the road network (including gravel roads), this may be unavoidable to some extent. Figure 4-23 indicates that all incidents in the high-risk category could be reached within the recommended response time, while Figure 4-24 indicates that the only incident to occur within the special risk classification was located outside the recommended response time.

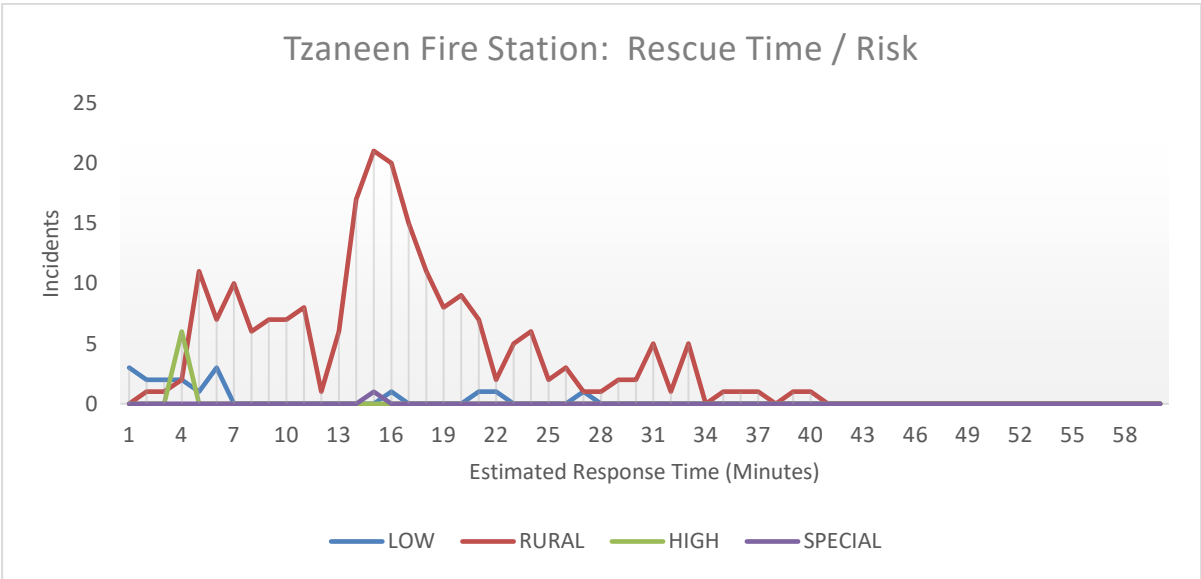


Figure 4-20: Sampled rescues plotted per time interval and risk type attended to by the Tzaneen Fire Station between 2016 and 2019

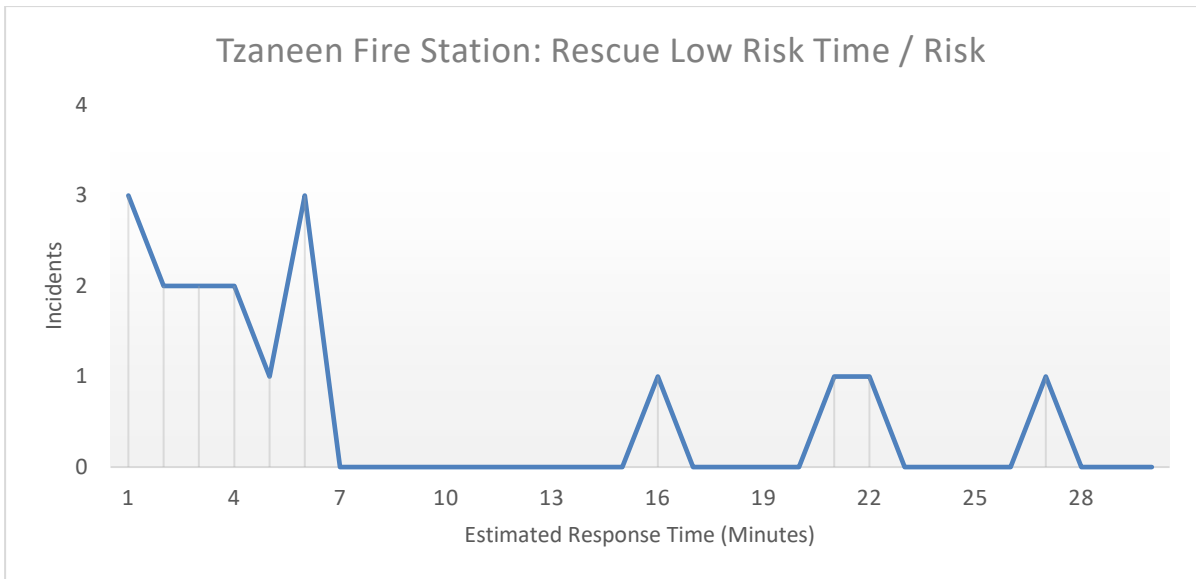


Figure 4-21: Sampled rescues plotted per time interval and low risk type attended to by the Tzaneen Fire Station

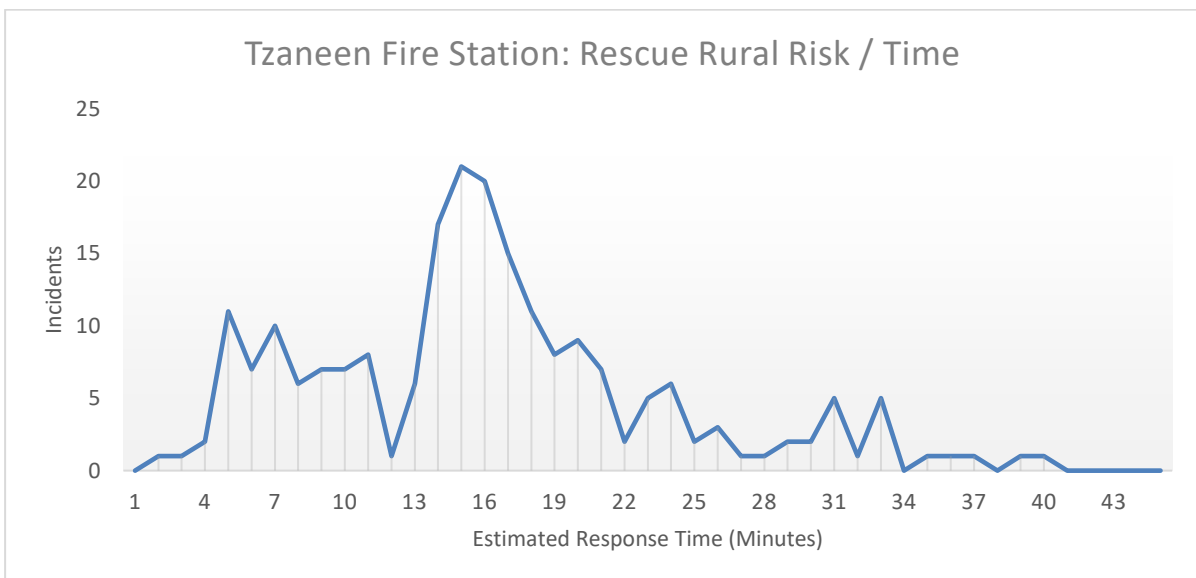


Figure 4-22: Sampled rescues plotted per time interval and rural risk type attended to by the Tzaneen Fire Station

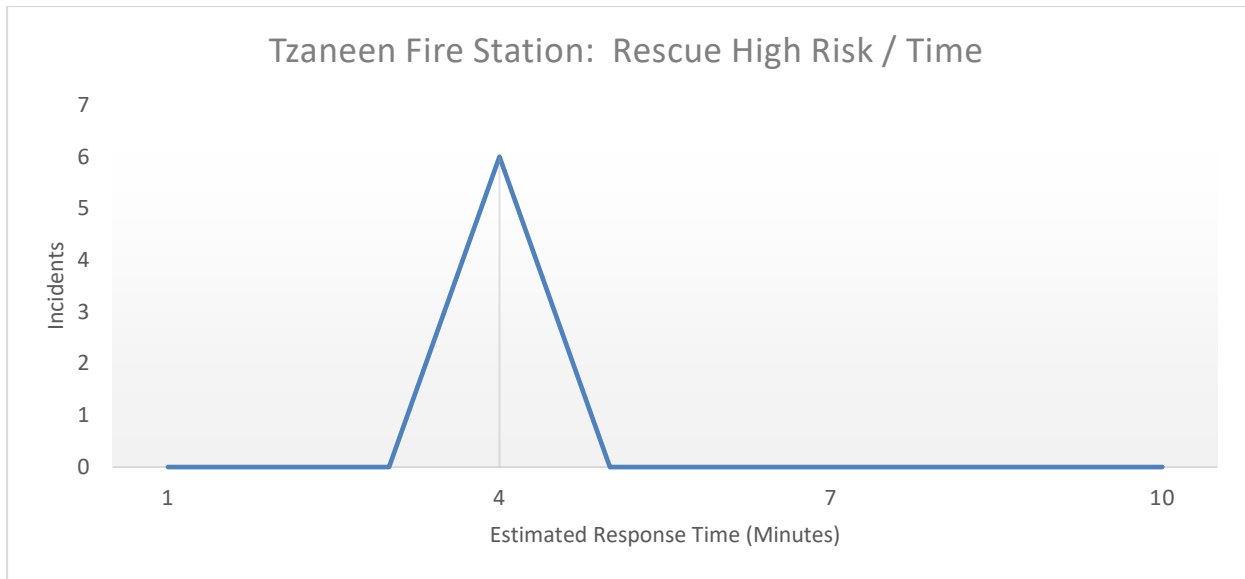


Figure 4-23: Sampled rescues plotted per time interval and high risk type attended to by the Tzaneen Fire Station

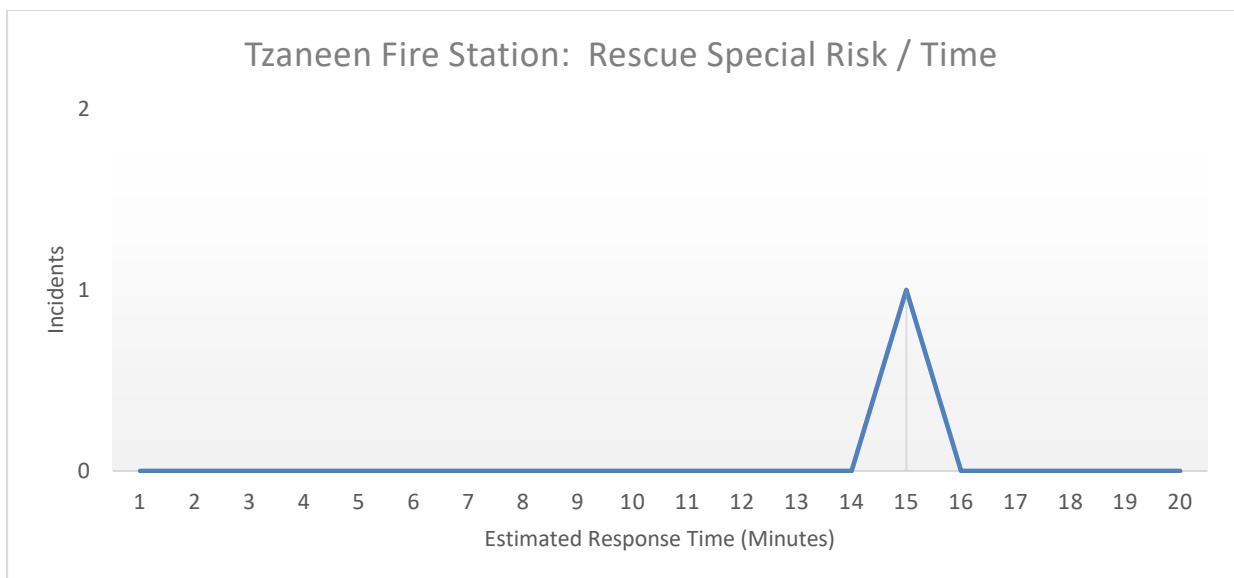


Figure 4-24: Samples rescues plotted per time interval and special risk type attended to by the Tzaneen Fire Station between 2016 and 2019

4.2.6 Giyani Fire Station overview

The Giyani Fire Station is located within the rapidly developing town of Giyani in the north of the Mopani District. The station is located with relatively quick access to major roads, including the R81 Giyani-Mooketsi road, the R578 Elim road and R81 Giyani-Malamulele road. Employment opportunities and population concentration are greatest within Giyani, but the municipal area includes 94 rural communities under 10 traditional authorities (GGM, 2019:18;23). The

government sector is the single greatest employer within the GGM, offering 39% of employment (MDM, 2019:37). Giyani, formerly part of the Gazankulu homeland, also serves as the administrative hub for most government departments, including the Mopani District Municipality (MDM, 2019:43). The deeply rural nature of communities and scattered spatial distribution is exacerbated by poor access roads which are mostly gravel (GGM, 2019:24). The town of Giyani can be considered to be a Category B (moderate) and Category C (low) fire risk according to the SANS, with the outlying rural communities considered a Category D (rural) fire risk (SANS 2018:4-5) – see Figure 4-25 below.

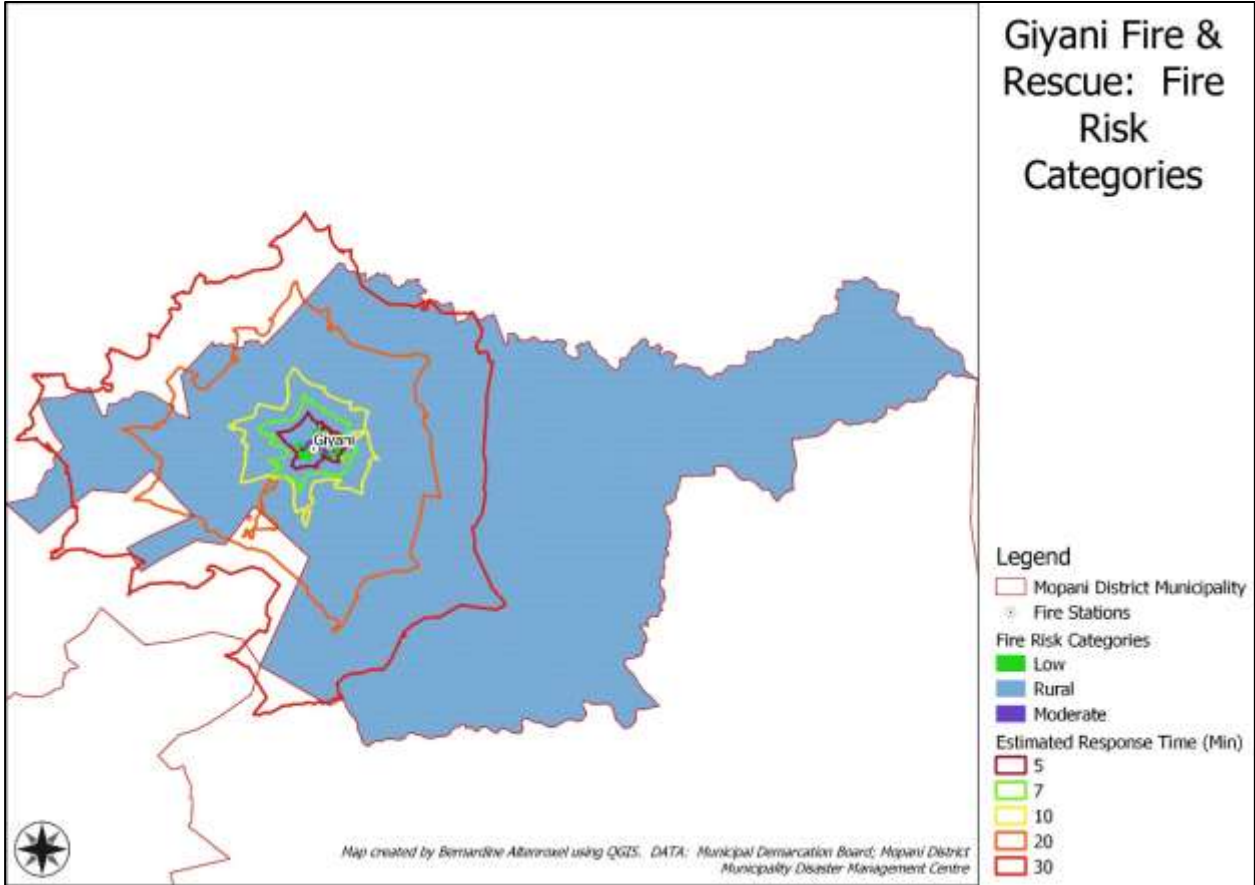


Figure 4-25: Risk categorisation of the Greater Giyani Municipality and estimated 5-, 7-, 10-, 20- and 30-minute reach from the Giyani Fire Station

The legacy of apartheid resulted in a large rural population where there is little economic activity and limited infrastructure (GGM, 2019:24). Furthermore, the scattered spatial distribution of these rural communities makes the development of infrastructure costly (GGM, 2019:24). Economic activity is thus largely concentrated around Giyani, where large shopping centres have been developed in recent years (GGM, 2019:24;67-68). From a fire management perspective, these large shopping centres require special consideration, particularly in terms of the provision of adequate resources for fire and rescue services. The largest of the newly developed shopping

centres is located directly opposite the Giyani Fire Station. Noted in the GGM IDP is that the network of gravel roads around the municipality is not easily accessible during the rainfall season, hampering the effectiveness of emergency service provision (GGM, 2019:24). This is also acknowledged in the MDM IDP in that poor access roads will increase the time it takes to respond to an emergency situation or disaster (MDM, 2019:115). The road network mostly consists of gravel roads (608km), with a limited number of tarred roads (79km) (GGM, 2019:49). This extensive gravel road network serves as an impediment to response times due to reduced safe travelling speeds on these roads. Additionally, many roads are in need of rehabilitation and maintenance, including bridges which need to be repaired (GGM, 2019:49). Most crucially for emergency services, few internal streets in Giyani have names, hampering response from emergency services and the police (GGM, 2019:54). Future development plans include new residential developments and development of commercial and industrial stands, pending the availability of land (GGM, 2019:28). Depending on the nature of this planned development, overall fire risk classification may change for Giyani. Informal settlements are located in and around Giyani, with these being identified as Hluphekani, Matshamahinkanu and an area located in Giyani Section A (GGM, 2019:31).

The Greater Giyani Municipality is characterised by a climate which produces low annual rainfall and very hot summers (GGM, 2019:29). This combination limits agricultural development and water provision for domestic use, forcing the municipality to rely more heavily on ground water (GGM, 2019:29). There are very few commercial farmers located in the GGM, with most farmers being classified as subsistence farmers (GGM, 2019:30). Water supply infrastructure is also inadequate to provide water to the whole municipal area (GGM, 2019:40). This has been attributed to the vast distances between the different rural communities, making it a difficult and expensive process in establishing a water reticulation network (MDM, 2019:104). This lack of water resources and water infrastructure has bearing on the provision of a fire and rescue service as well, meaning that water needs to be transported to site for fire-fighting. According to Mopani Fire and Rescue Services senior management, water tankers, with a capacity of 6000 litres must be taken to the site of the fire, or as close as possible, to ensure sufficient water supply for fire-fighting purposes. However, if this water supply runs out, the tankers must travel back to their base station to refill, hampering fire-fighting efforts. Greater attention is being paid to the water infrastructure, with the Department of Water and Sanitation having initiated water projects to augment water supply and replace old infrastructure (GGM, 2019:40). Water scarcity, combined with frequent high temperature, however, means that the risk of grass fires is great. Indeed, veld and forest fires are recognised as a severe problem that mostly affects grazing land and the Man'ombe Nature Reserve (GGM, 2019:30-31). Serious damage has been caused to the

Man'ombe Nature Reserves as a result of fire in previous financial years (MDM, 2019:80). It is also noted that the Giyani Fire Station requires better capacity in terms of resource availability (GGM, 2019:32).

Rural areas are not well served in terms of waste removal, with most using their own dump site (GGM, 2019:47). With little or no formal waste removal system in place, people burn household waste. This has the potential to result in runaway fires if the fires are not properly monitored or started on days when adverse fire weather is present. In terms of housing, 44.4% are formal houses, while informal and traditional dwellings account for 55.4% of houses (GGM, 2019:48). Of particular importance in this regard is that the majority of houses have thatched roofs and the walls are made of mud (GGM, 2019:48). The thatch can catch fire easily from burning embers from any fire nearby, particularly during the dry season. Rapid intervention is required to save these homes but, with response times hampered by poor access roads, help may arrive too late.

As in the case of the Tzaneen Fire Station, the fire station in Giyani is able to reach the entire commercial, residential and government complex within the administrative node of Giyani within less than 10 minutes (Figure 4-26). The station is also able to cover all of the Greater Giyani Municipality and most of the Greater Letaba Municipality within 60 minutes (Figure 4-27). Parts of Greater Tzaneen and Ba-Phalaborwa Municipality can also be reached within 60 minutes of Giyani. This provides the opportunity for the Giyani Fire Station to provide back-up support for these two sister stations should the need arise. The development of new commercial developments in recent times requires the Giyani Fire Station to be suitably equipped to deal with large structural fires. This includes the provision of major pumper and water tanker. The scattered spatial distribution of rural communities however makes reaching all house fires more challenging. The overall demand in outlying areas, particularly in terms of fires, and the degree to which house fires are scattered among the different outlying rural communities is however not sufficient to warrant the development of any additional fire station within Greater Giyani Municipality at this time.

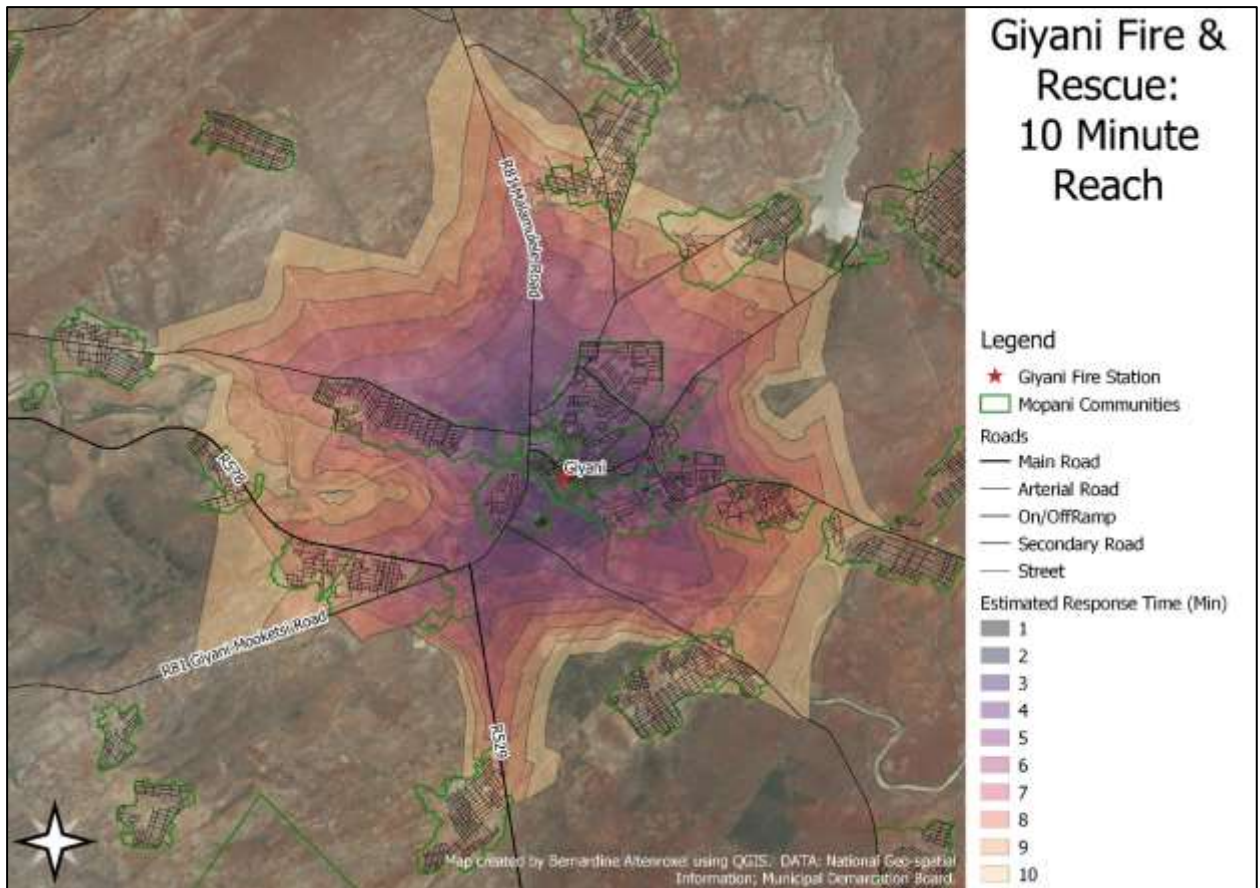


Figure 4-26: Areas within the estimated 10-minute reach of the Giyani Fire Station

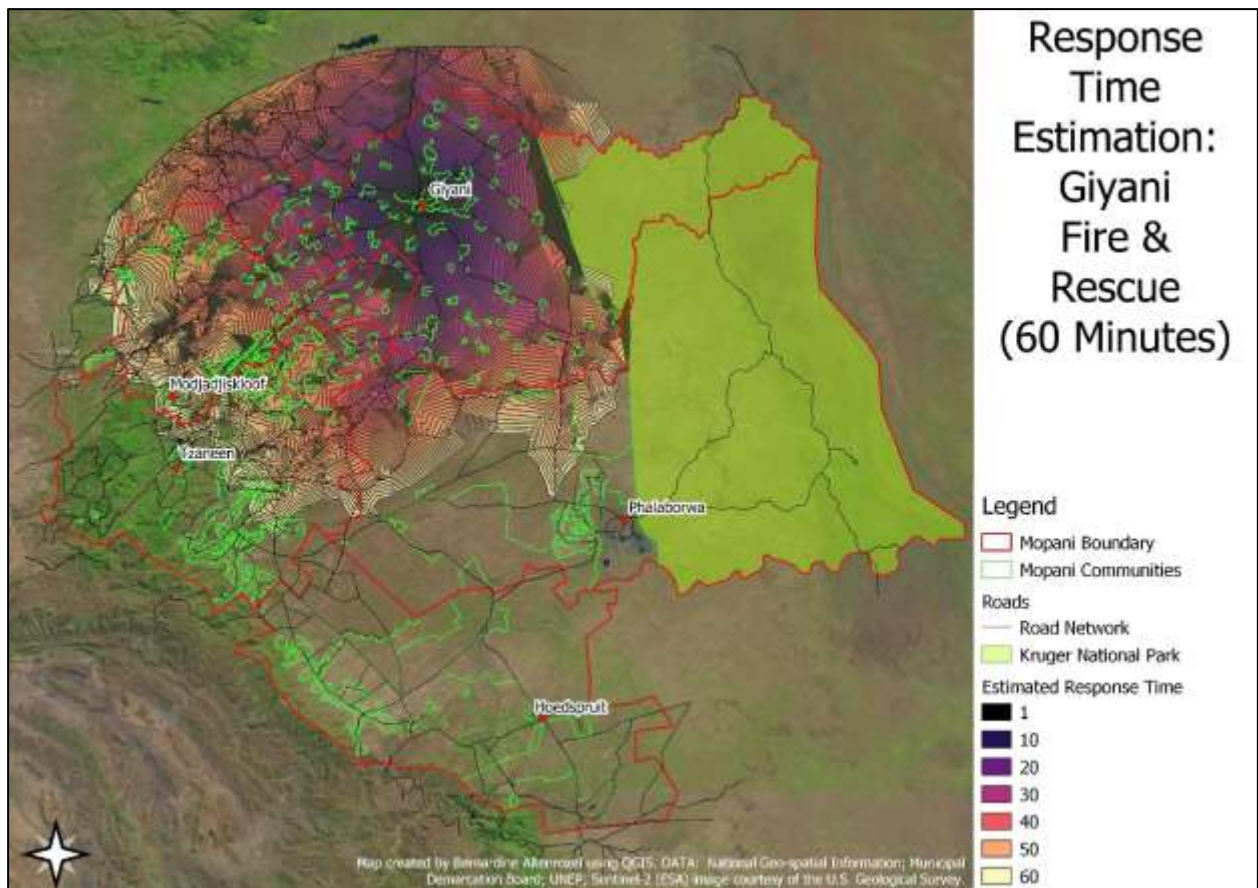


Figure 4-27: Areas within the estimated 60-minute reach of the Giyani Fire Station

4.2.6.1 Fires attended to by the Giyani Fire Station

Many of the fires attended to by the Giyani Fire Station occurred close to or within the town, with the remainder scattered among the numerous outlying rural communities (Figure 4-26). In Table 4-6 below, the proportion of fires by fire type can be noted. The majority of fires within the sample related to house fires (46.97%), followed by grass fires (22.73%) and structural fires (12.88%). Other fire types included electrical fires (3.79%), fires related to informal housing (7.58%) and a small number of rubbish or other fires. The Giyani Fire Station fares well in terms of reaching fires within recommended response times (Table 4-7). All fires within the low and moderate risk classification could be estimated to have been reached within the recommended response times. In terms of the rural risk classification, an estimated 73.13% could be reached within the estimated recommended response times. Those fire incidents which could not be reached on time were scattered among the numerous rural communities and mostly related to house fires, as can be seen in Figure 4-28. Distance alone may however not be the only limiting factor in terms of reaching these fires on time, with poor access roads likely being a significant limiting factor, as identified within the GGM IDP.

Table 4-6: The proportion of fire types within the sampled data for the Giyani Fire Station

FIRE TYPE	NUMBER	% OF TOTAL
Electrical Fires	5	3.79%
Structural Fires	17	12.88%
Grass Fires	30	22.73%
House Fires	62	46.97%
Informal Settlement Fires	10	7.58%
Other Fires	7	5.30%
Rubbish Fires	1	0.76%
TOTAL	132	

Table 4-7: The estimated number of fires reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	100%	0%
Moderate	7 Min	100%	0%
Rural	20 Min	73.13%	26.37%

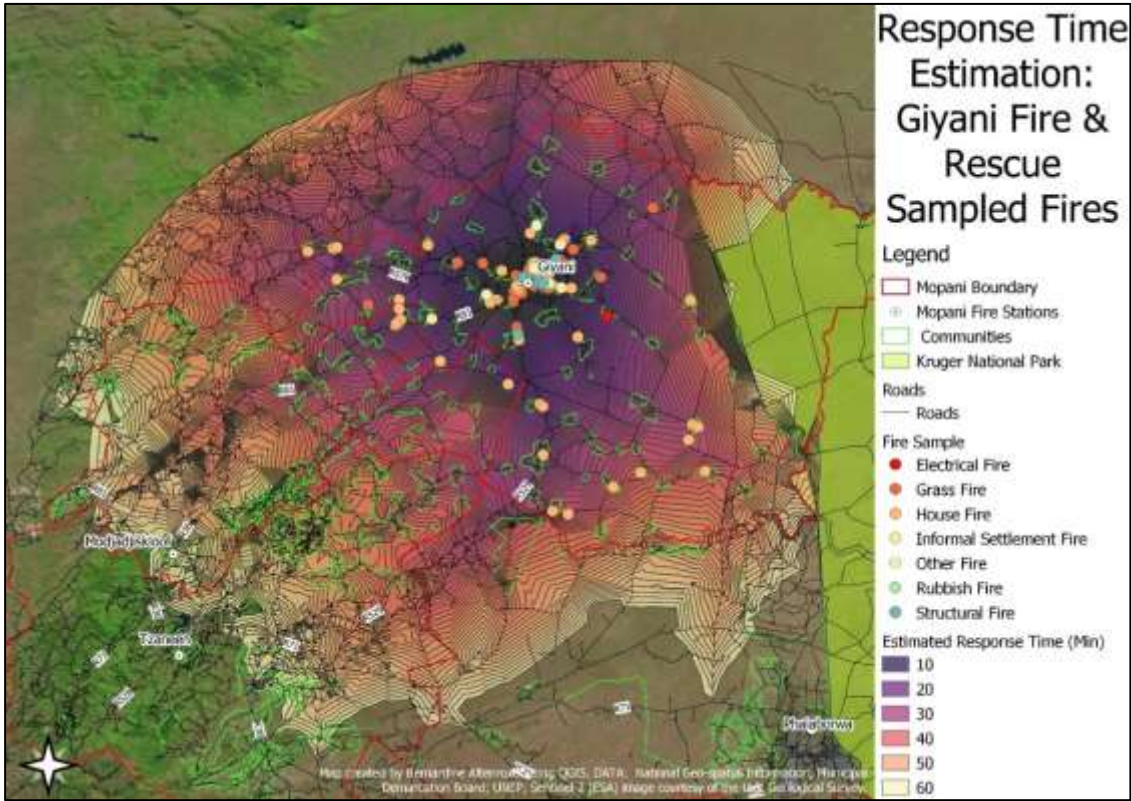


Figure 4-28: Areas within the estimated 60-minute reach of the Giyani Fire Station and all fires dealt with between 2016 and 2019

The spread in fire incidents over the different risk classifications can be seen in Figure 4-29 below. This clearly indicates that the areas designated as low and moderate risk classifications can be reached within the recommended response times. There is however a greater spread in the rural risk classification (Figure 4-30). All fires which occurred in the low and moderate risk classifications (Figure 4-31 and Figure 4-32 respectively) could be estimated to have been reached within the recommended response times. Reaching fire incidents on time is thus less of a problem for the Giyani Fire Station, but the station needs to be appropriately resourced to deal with the typical fire incident types encountered, particularly given the recent expansion of commercial properties and anticipated future industrial expansion indicated in the GGM IDP. The limitations of poor water and road infrastructure in response should also be considered.

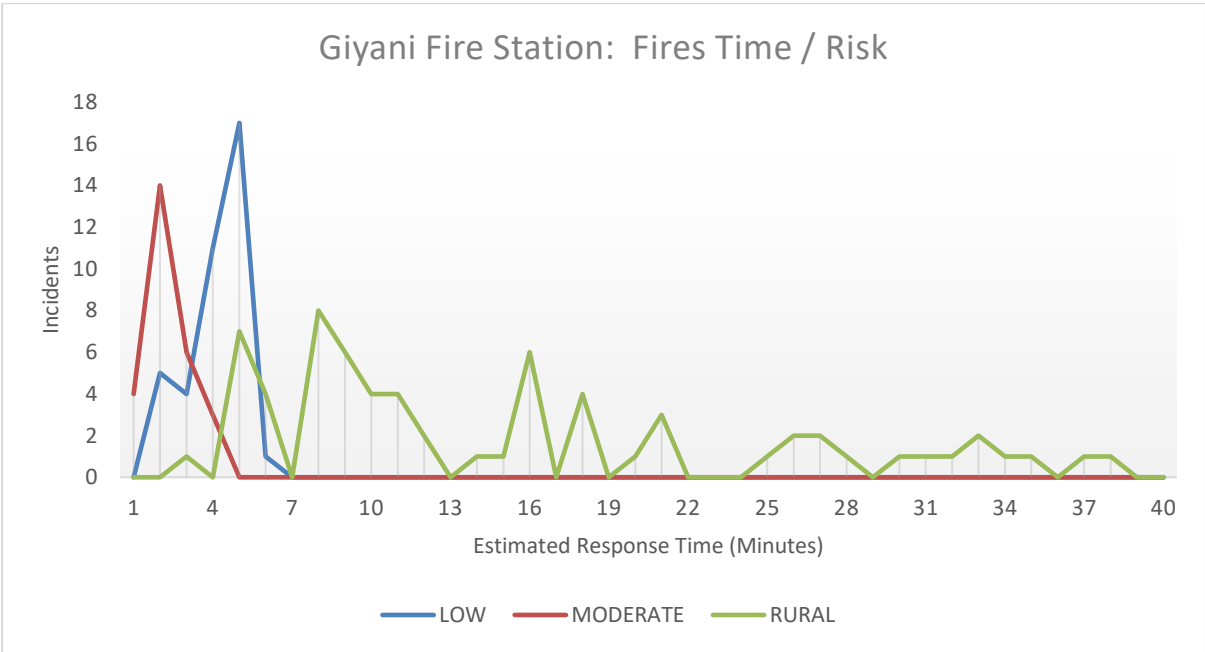


Figure 4-29: Sampled fires plotted per time interval and risk type for sampled fires attended to by the Giyani Fire Station between 2016 and 2019

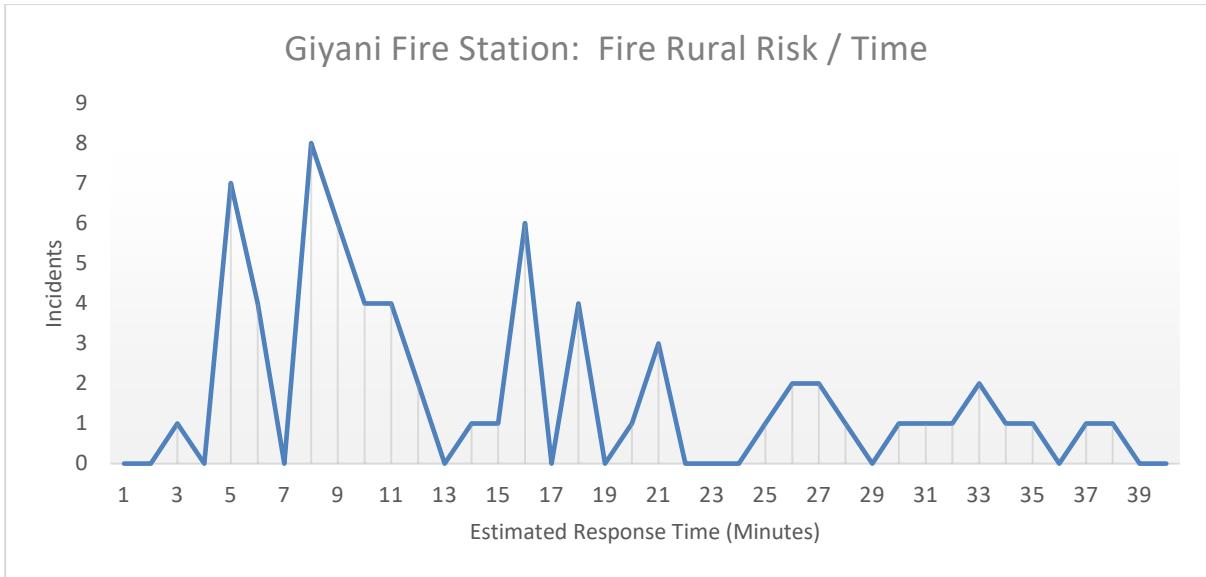


Figure 4-30: Sampled fires plotted per time interval and rural risk type for fires attended to by the Giyani Fire Station between 2016 and 2019

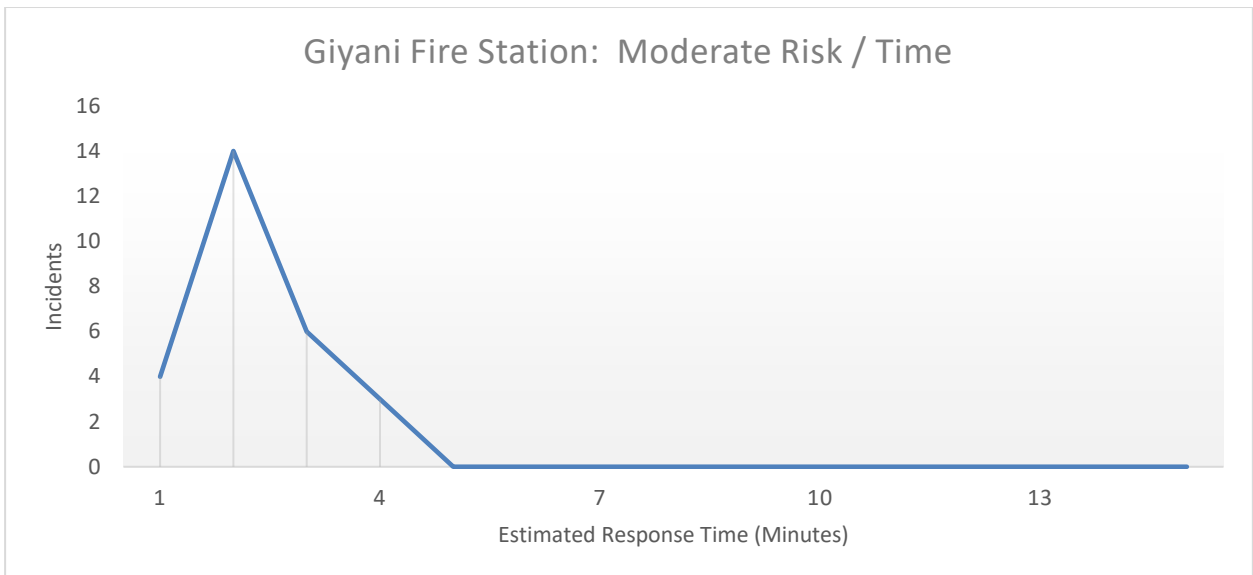


Figure 4-31: Sampled fires plotted per time interval and moderate risk type for sampled fires attended to by the Giyani Fire Station

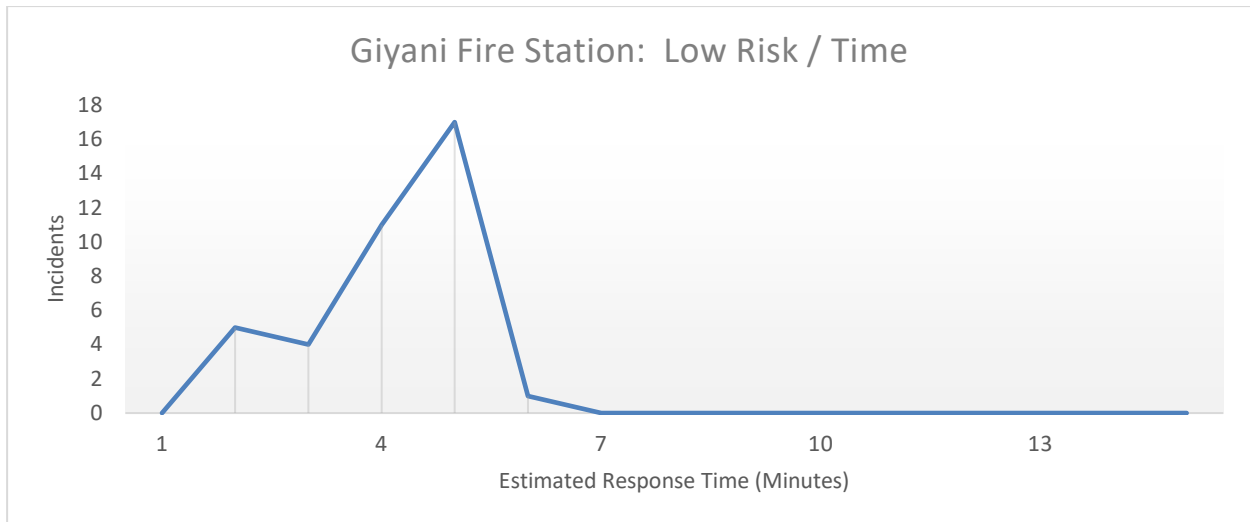


Figure 4-32: Sampled fires plotted per time interval and low risk type for fires attended to by the Giyani Fire Station

4.2.6.2 Rescue incidents attended to by the Giyani Fire Station

In Table 4-8 below, it is evident that the vast number of rescue-related incidents sampled involved light motor vehicle accidents (92.51%). The remainder of incident types related to taxi accidents (3.74%), truck accidents (2.14%), pedestrian accidents (1.07%) and one bus accident (0.54%). As in the case of fire incident response, all rescue incidents in the low and moderate risk classification, and 86.43% of rescue incidents in the rural risk classification could be estimated to have been reached within the recommended response time (Table 4-9). Figure 4-33 provides an overview of the spatial distribution of rescue incidents against response time. This also indicates that many of the rescue incidents were located on tar roads, which would have made access easier compared to fires located along gravel roads or deeply rural communities. The Greater Giyani Municipality shares a border with the Vhembe District Municipality. There was minimal overlap in response to rescue incidents across this boundary, with at least six of the incidents responded to, having been located within Vhembe.

Table 4-8: The proportion of rescue types within the sampled data for the Giyani Fire Station

RESCUE TYPE	NUMBER	%
Bus Accidents	1	0.54%
MVA	173	92.51%
Pedestrian Accident	2	1.07%
Taxi Accidents	7	3.74%
Truck Accidents	4	2.14%
TOTAL	187	

Table 4-9: The estimated number of rescues reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	7 Min	100.00%	0.00%
Moderate	10 Min	100.00%	0.00%
Rural	20 Min	86.43%	13.57%
Outside district		6	

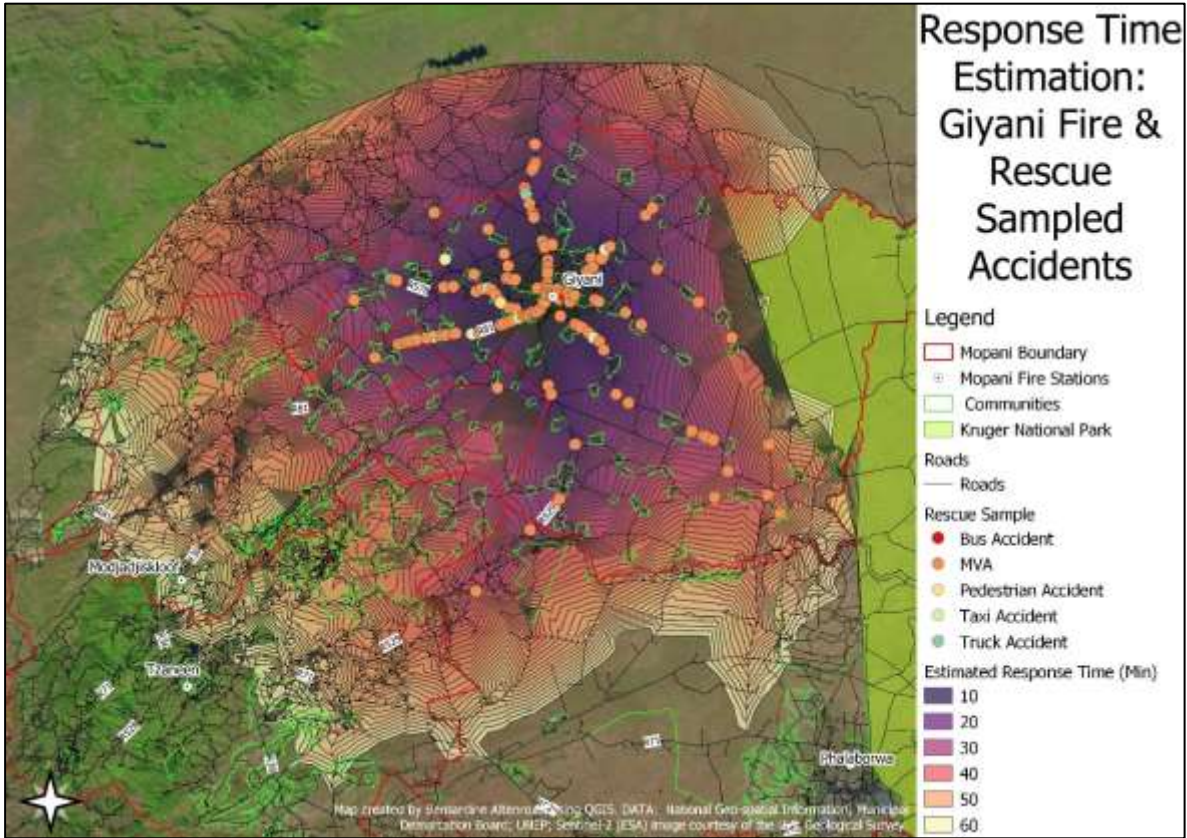


Figure 4-33: Areas within the estimated 60-minute reach of the Giyani Fire Station and accidents dealt with between 2016 and 2019

Figure 4-34 provides an overview of the spread in rescue incidents over the different risk categories and estimated response times. The majority of rescues within the rural risk classification (86.43%) could be estimated to have been reached within the recommended 20-minute response time (Figure 4-35). Considering the vastly rural nature of the Greater Giyani Municipality, this is a very good achievement. As discussed above, rescue-related incidents located in the low and moderate risk classification could all be estimated to have been reached within the recommended response times (Figure 4-36 and Figure 4-37 respectively).

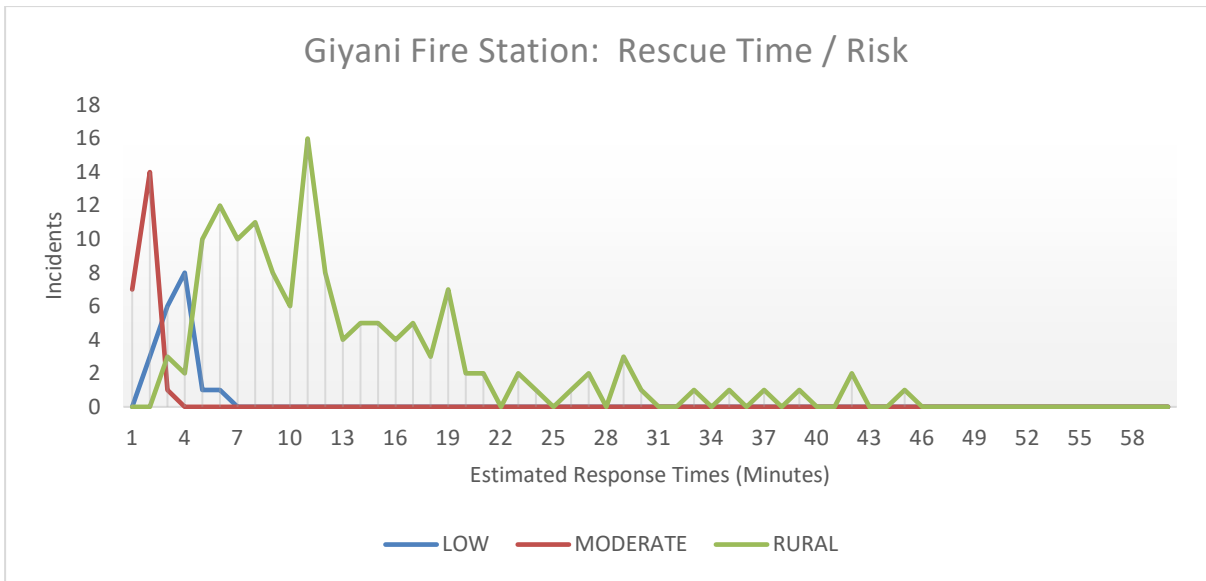


Figure 4-34: Sampled rescues plotted per time interval and risk type for incidents attended to by the Giyani Fire Station between 2016 and 2019

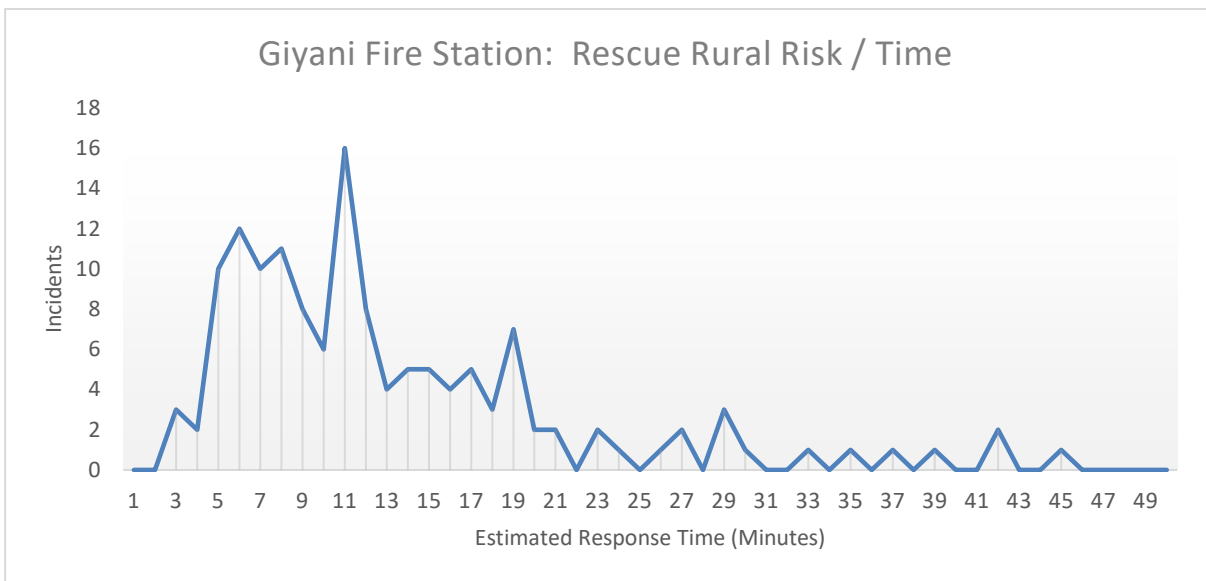


Figure 4-35: Sampled rescues plotted per time interval and rural risk type for incidents attended to by the Giyani Fire Station between 2016 and 2019

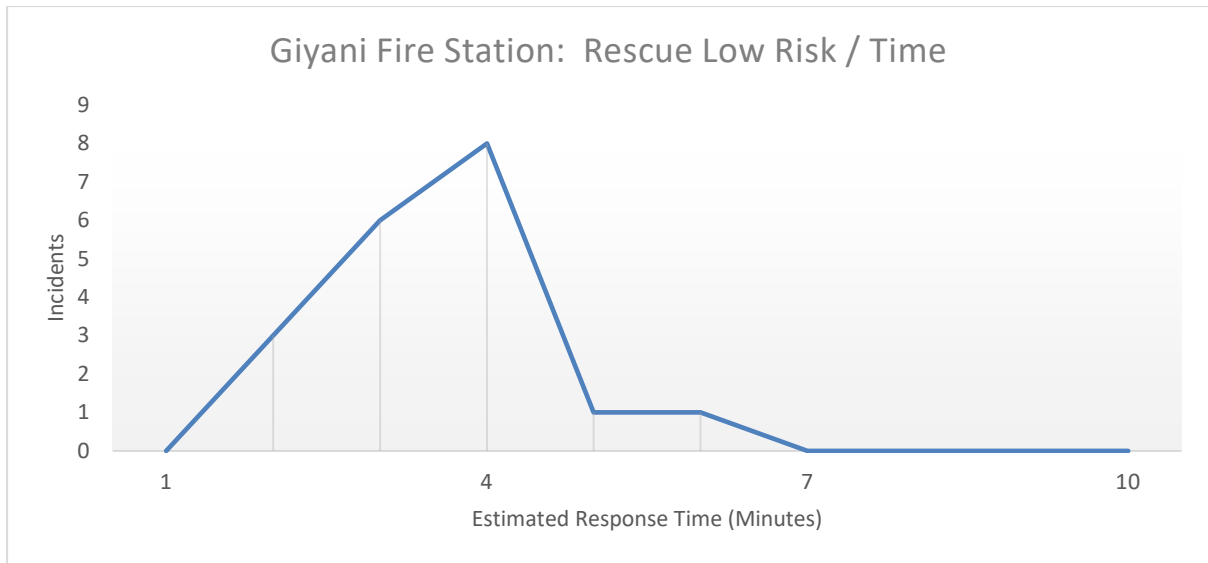


Figure 4-36: Sampled rescues plotted per time interval and low risk type for incidents attended to by the Giyani Fire Station between 2016 and 2019

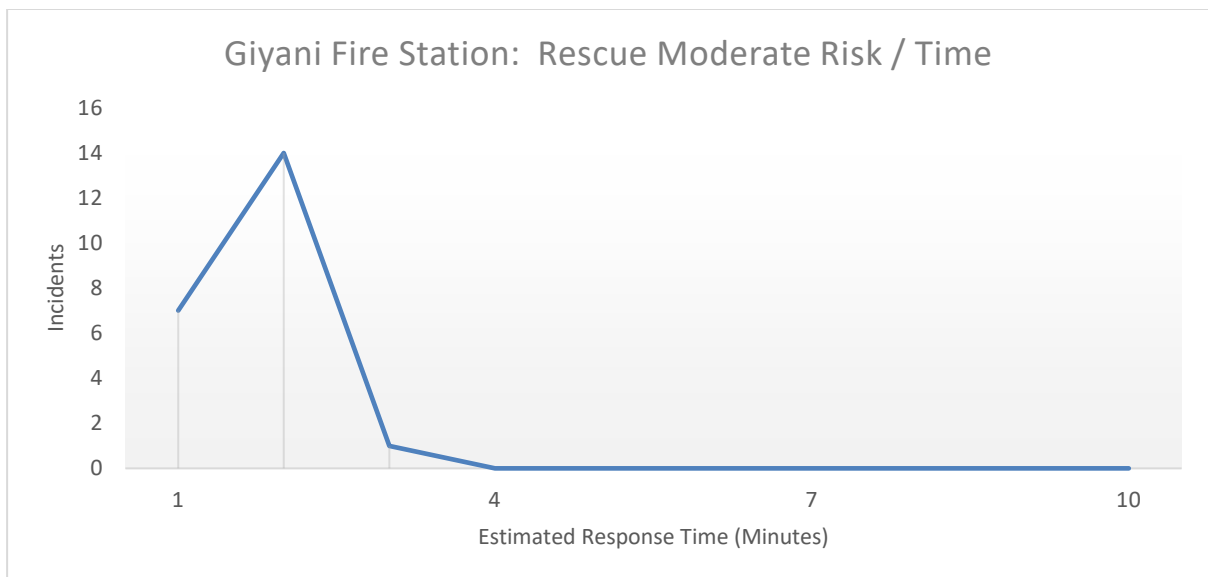


Figure 4-37: Sampled rescues plotted per time interval and moderate risk type for incidents attended to by the Giyani Fire Station between 2016 and 2019

4.2.7 Maruleng Fire Station overview

The Maruleng Fire Station is located in the town of Hoedspruit in the Maruleng Municipality and is the most recently established of the five fire stations in the Mopani District. Hoedspruit is the only urban area and serves as the administrative and economic centre for the municipality (MLM, 2019:165). Recent years have seen a substantial increase in the development of residential estates and commercial developments in the town (MLM, 2019:27). These developments require special consideration from a fire management perspective, since expanding residential and

commercial developments bring with them new fire risks. There is also a thriving retail sector in Hoedspruit, which is undergoing rapid development, but it is however also noted that limited availability of land is limiting business development (MLM, 2019:39;40). In addition to Hoedspruit, there are 36 rural communities (MLM, 2019:21) that are located through the Sekororo area. These rural areas are noted to have limited economic activity and infrastructure, although municipal planning within the spatial development framework supports greater development within the rural communities in the future (MLM, 2019:26;40).

There is clear fragmentation in the Maruleng Municipality between rural and urban areas, which resulted from the application of the segregation laws prior to democratic elections in 1994 (MDM, 2019:44). Some 90% of the population of the municipality reside in these rural communities, located in the western quadrant of Maruleng (MLM, 2019:17). Applications for new shopping malls within the Sekororo area indicate the possibility of further commercial development at The Oaks, Lorraine and Trichardtsdal (MLM, 2019:40). This shift to bigger commercial development within the rural areas will result in changes to the current fire risk classification. Given the location of the current fire station in Maruleng, and the considerable distance between Hoedspruit and Sekororo, future expansion of fire and rescue services will likely be required. The Sekororo rural area is mostly dominated by human settlements and subsistence agriculture, with most of the land in tribal trust (MLM, 2019:27). Although 8 209 households receive water from a regional or local water scheme, this only represents about 34.7% of the total number of households. The provision of water is thus a challenge, with many relying on boreholes, rivers or streams or other sources of water (MLM, 2019:36). These challenges are being addressed through the development of a water purification plant at The Oaks, which is expected to provide water to many of the rural households and major developments (MLM, 2019:38). The development of this water infrastructure would be key to the development of any new or satellite station to the Maruleng Fire Station.

There are numerous lodges and important tourism destinations that are located within the MLM or in surrounding areas, including the Kruger National Park, Blyde River Canyon, Thornybush, Kapama and Timbavati. Agriculture is also identified as a key economic driver, with commercial agriculture being the dominant economic activity and generator of employment (MLM, 2019:12). These economic drivers in the Maruleng Municipality also place pressure on the delivery of a fire and rescue service, and require well-informed consideration to adequately cover different fire risk categories. Eastgate airport is located just outside the town of Hoedspruit, linking the Lowveld to major tourism transit hubs (MLM, 2019:11;27;46). The Hoedspruit Air Force Base is located alongside Hoedspruit and shares part of its airstrip with Eastgate Airport (MLM, 2019:21;34). With the airport located on the premises of the Hoedspruit Air Force Base, the fire and rescue service

located on the Air Force Base acts as the primary first response for the airport as well as for the extended Air Force Base property. Although most of the Lekgalameetse Nature Reserve falls within the adjoining Lepelle-Nkumpi Municipality (located within the Capricorn District), the main entrance to the Reserve is reached via the Maruleng Municipality. There is thus an interesting mix of land use types and activities within Maruleng, including high-value property, all of which requires careful consideration for fire management. Based on the various types of land use types described in the IDP, the Maruleng Municipality can be divided into low, moderate and rural risk categories (Figure 4-38). Some overlap in sampled incidents occurs with two neighbouring district municipalities, namely Sekukhune and Ehlanzeni District (Mpumalanga). There is however more overlap with the Sekukhune District than with Ehlanzeni District. Maruleng Municipality is also located within close proximity to the Kruger National Park. The development of MOUs with Capricorn, Sekukhune and Ehlanzeni District Municipalities for the rendering of a fire service could be mutually beneficial.

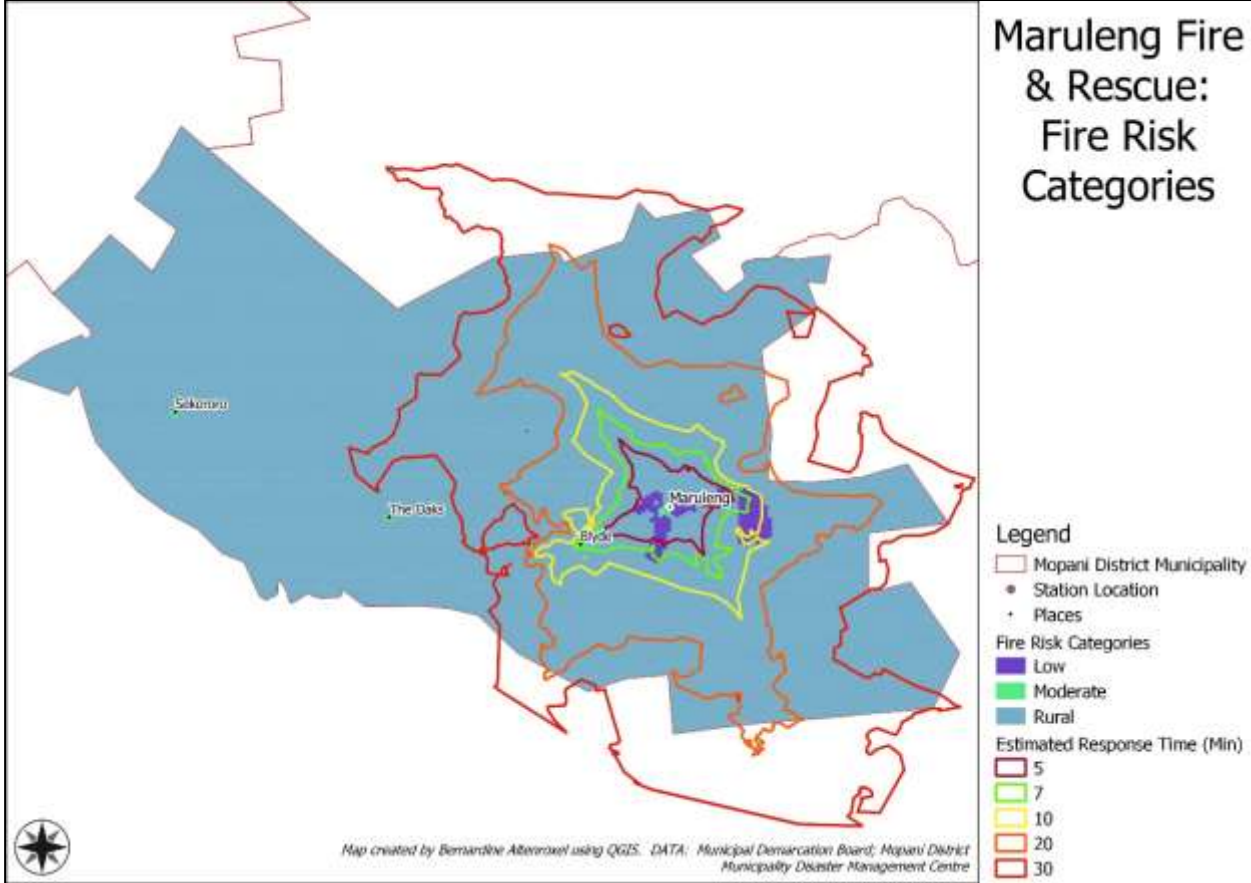


Figure 4-38: Risk categorisation of the Maruleng Municipality and estimated 5-, 7-, 10-, 20- and 30-minute reach from the Maruleng Fire Station

Of further interest for fire and rescue services are the previous flooding and veld fire events (MLM, 2019:65). A flooding event occurred in January 2012 and caused extensive flooding along parts

of the eastern escarpment of South Africa (Barrat, 2018:21; Chikoore, *et al.*, 2015:2082), which included the Hoedspruit and Greater Kruger area. The extensive flooding triggered a large-scale rescue involving a number of stakeholders, including Mopani Fire and Rescue Services. This flooding event highlighted vulnerabilities through Maruleng Municipality and could serve as a motivation to ensure local rescue groups have appropriate resources at their disposal.

Road infrastructure is noted as being fairly good, with all major roads being tarred, although maintenance of roads remains a challenge (MLM, 2019:13;31). It is also recognised that this road infrastructure facilitates economic activity in the MLM (MLM, 2019:31). Major roads include the R527, the R40 and the R36 (MLM, 2019:31). The Sekororo road (D21) provides a key link for local communities to economic hubs (MLM, 2019:31), including those in Tzaneen and Hoedspruit. The road is, however, not in good condition (MLM, 2019:31). This poor road condition may well contribute towards a greater risk of accidents. A railway line also runs through Maruleng Municipality, cutting through Hoedspruit before heading north towards Mica (MLM, 2019:34). As highlighted for the Tzaneen Fire Station, the railway line and major routes along which dangerous goods may be transported must be considered for the allocation of appropriate resources to deal with potential dangerous goods incidents. Refuse removal is not dealt with in much detail in the MLM IDP, other than to indicate the number of households with access to refuse removal (38.9%) and that there is a licensed landfill site (MLM, 2019:34). However, it is also noted in the MDM IDP that there is no refuse removal for households in some communities and waste is burnt by these residents as a result (MDM, 2019:115). The risk in these cases includes the uncontrolled spread of fire originating from the burning of household waste (MDM, 2019:115). The same holds true for other rural communities located in the remaining four local municipalities in the MDM with regard to waste disposal.

Hoedspruit, as the main administrative centre, is a small town, and can easily be reached within 10 minutes from the Maruleng Fire Station (Figure 4-39). All areas of Maruleng as well as part of the Greater Tzaneen and Ba-Phalaborwa Municipalities, can be reached within 60 minutes (Figure 4-40).

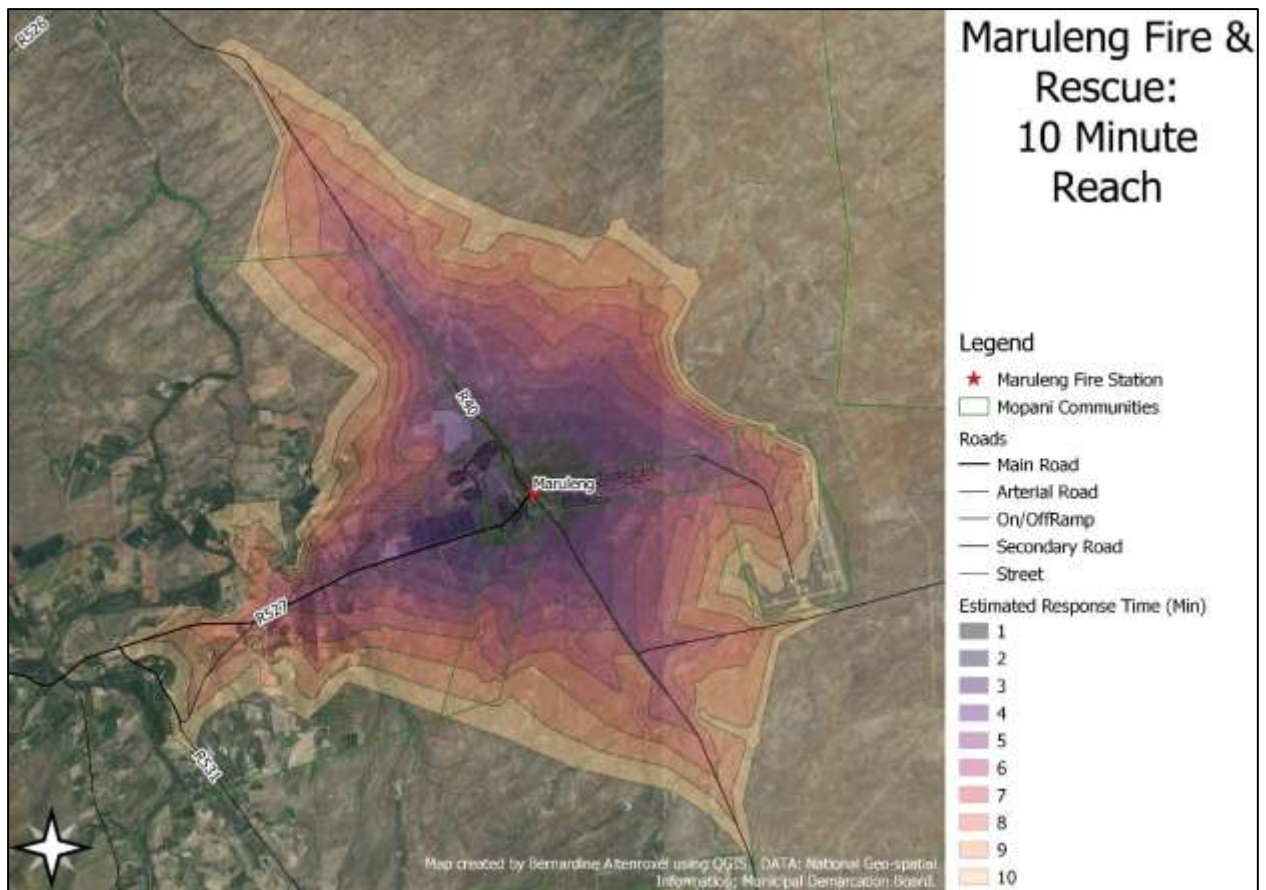


Figure 4-39: Areas within the estimated 10-minute reach of the Maruleng Fire Station

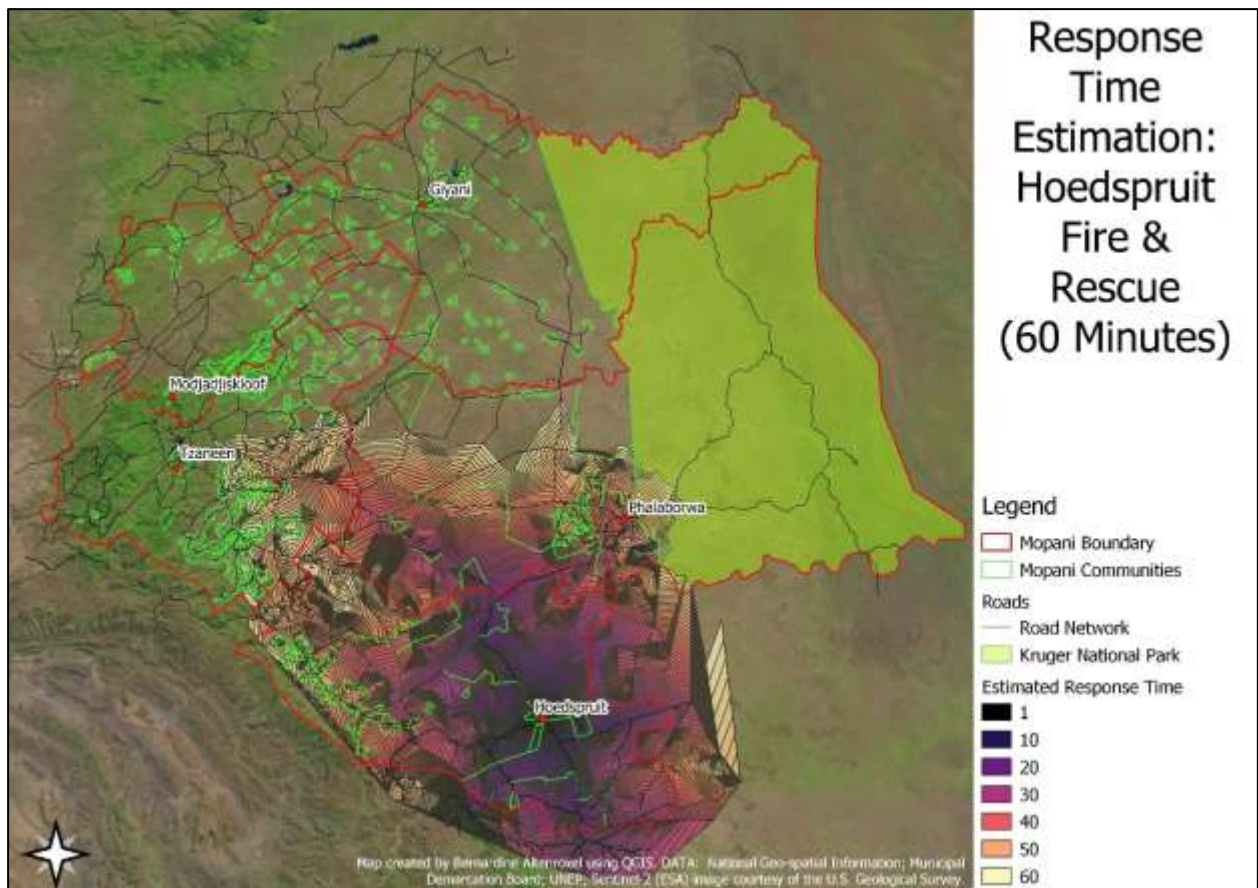


Figure 4-40: Areas within the estimated 60-minute reach of the Maruleng Fire Station

4.2.7.1 Fires attended to by the Maruleng Fire Station

In Table 4-10 below, sampled fires indicate a range of different fire types attended to. The majority of the sampled fires related to house fires (31.13%) and grass fires (30.77%). The remaining fire types included vehicle fires (16.04%), rubbish fires (9.43%), structural fires (3.77%) and fires involving informal housing (1.89%). Table 4-11 provides information on the estimated number of the sampled fires which could be reached within and outside the recommended response times. All fires in the low risk category and 94.12% of fires within the moderate risk classification are estimated to have been reached within the recommended response time. However, only an estimated 36.36% of fires within the rural classification could be reached within the recommended response time.

Table 4-10: The proportion of fire types within the sampled data for the Maruleng Fire Station

FIRE TYPE	NUMBER	%
House Fires	33	31.13%
Structural Fires	4	3.77%
Grass Fires	32	30.77%
Vehicle Fires	17	16.04%
Informal Settlement Fires	2	1.89%
Other Fires	8	7.55%
Rubbish Fires	10	9.43%
Total	106	

Table 4-11: The estimated number of fires reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	100.00%	0.00%
Moderate	7 Min	94.12%	5.88%
Rural	20 Min	36.36%	63.64%
Outside district	7		

Figure 4-41 below provides an overview of the distribution of the sampled fire incidents for the Maruleng Fire Station. This provides an indication of the number and range of fire types which occur within the Maruleng Municipality. The map also provides an indication of the wide distribution of fire-related incidents within the rural areas, and why it is difficult for the Maruleng Fire Station to meet the 20-minute target in these areas.

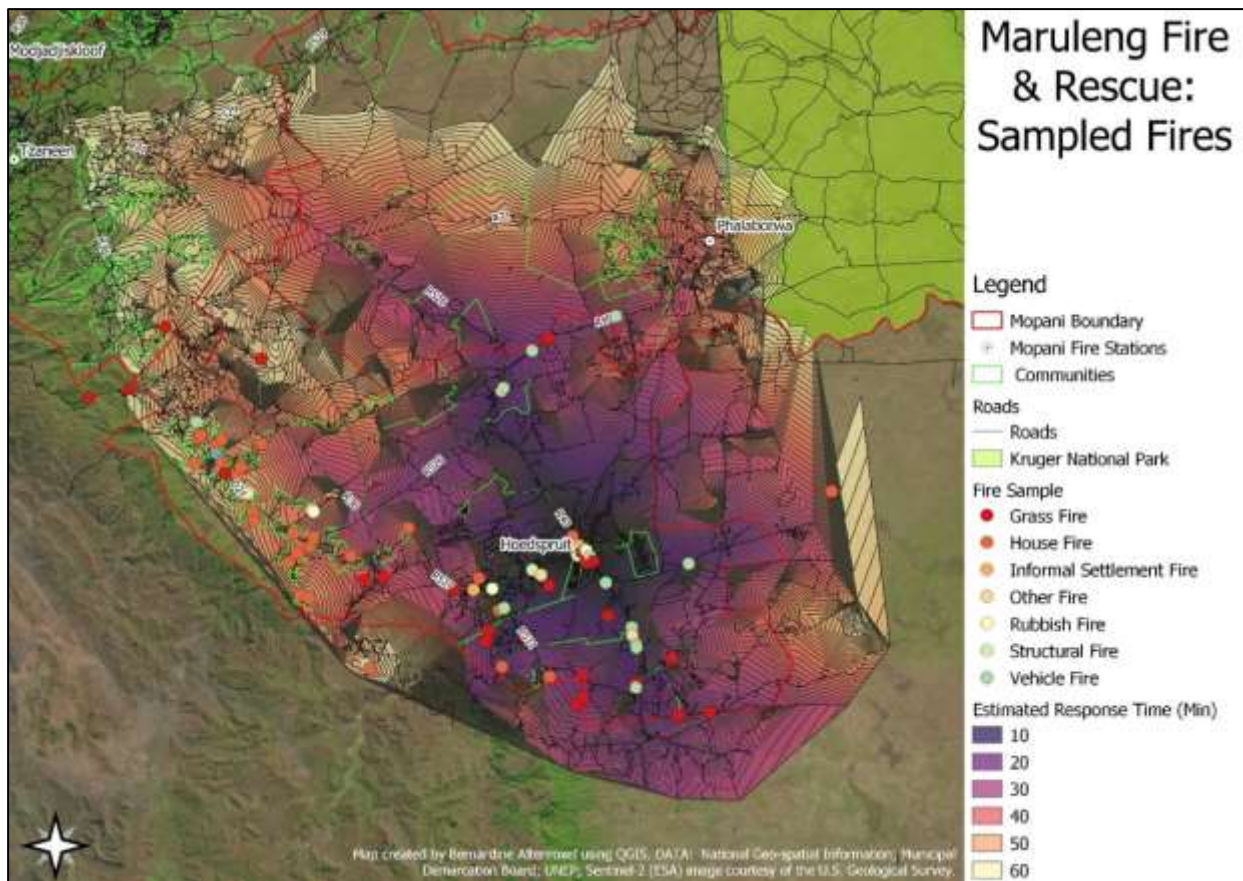


Figure 4-41: Areas within the estimated 60-minute reach of the Maruleng Fire Station and sampled fires dealt with between 2016 and 2019

Figure 4-42 below provides an overview of estimated response times against the different fire risk categories. All the sampled fires within the low fire risk classification could be reached within the recommended response time (Figure 4-43), as well as an estimated 94.12% of sampled fires in the moderate risk classification (Figure 4-44). A single outlier can however be noted, which relates to a fire in the vicinity of the new shopping complex developed at Sekororo. The area can be classified as falling under the ‘moderate’ risk category considering the size of the development. The rural risk classification shows a far greater spread in the number of fire incidents across estimated response times (Figure 4-45). This is created by a need within the Sekororo rural communities as well as surrounding game farms.

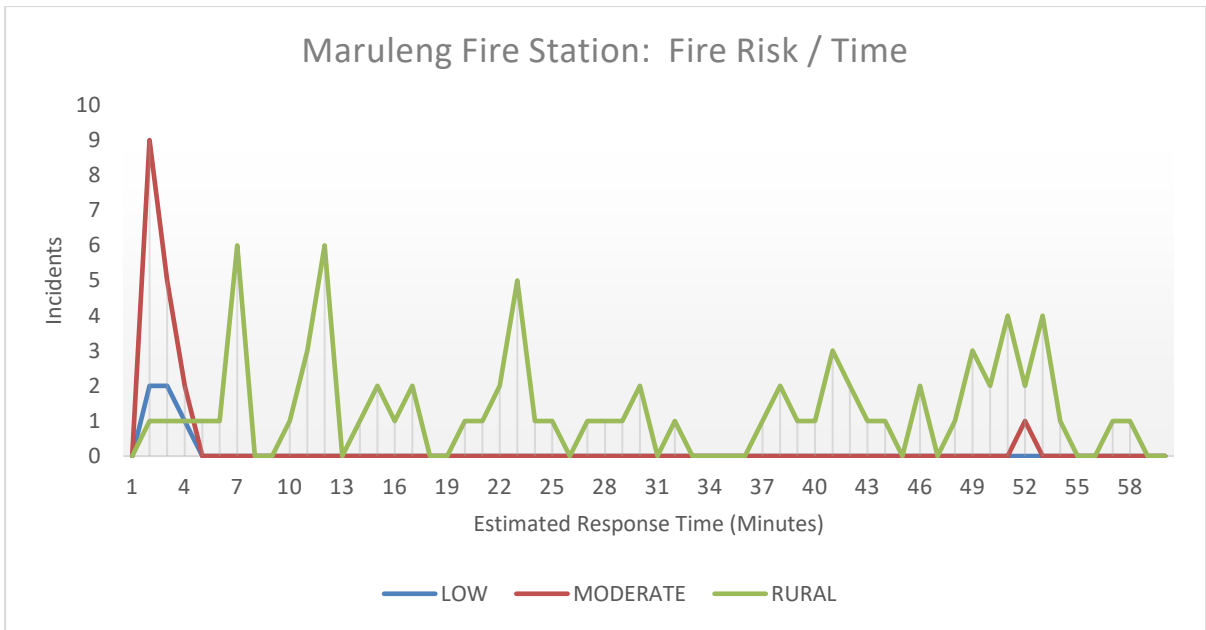


Figure 4-42: Sampled fires plotted per time interval and risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

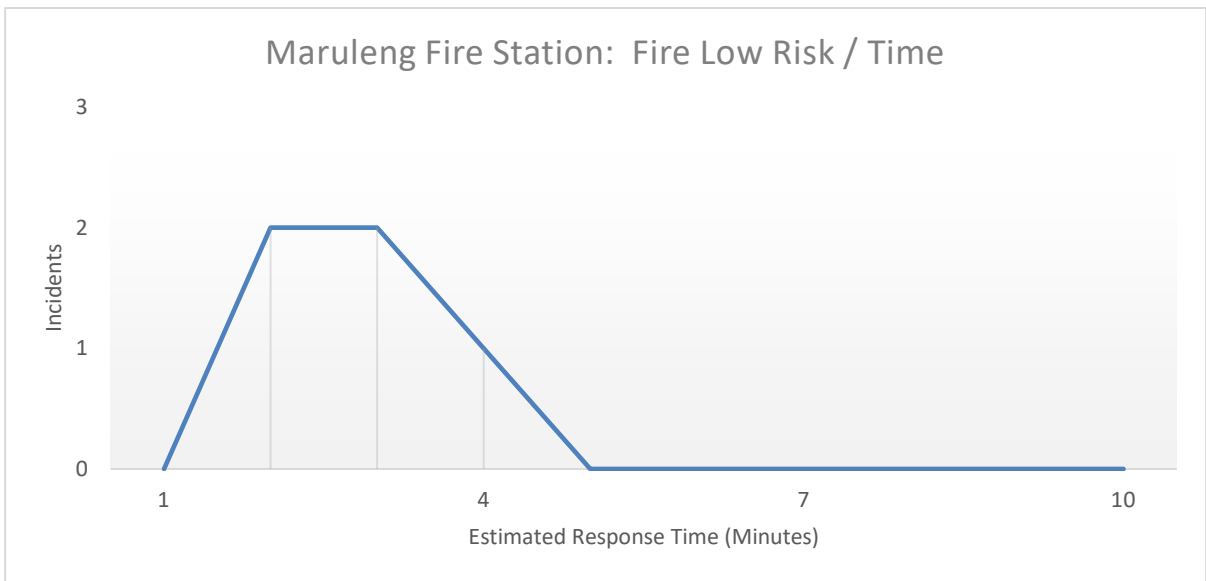


Figure 4-43: Sampled fires plotted per time interval and low risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

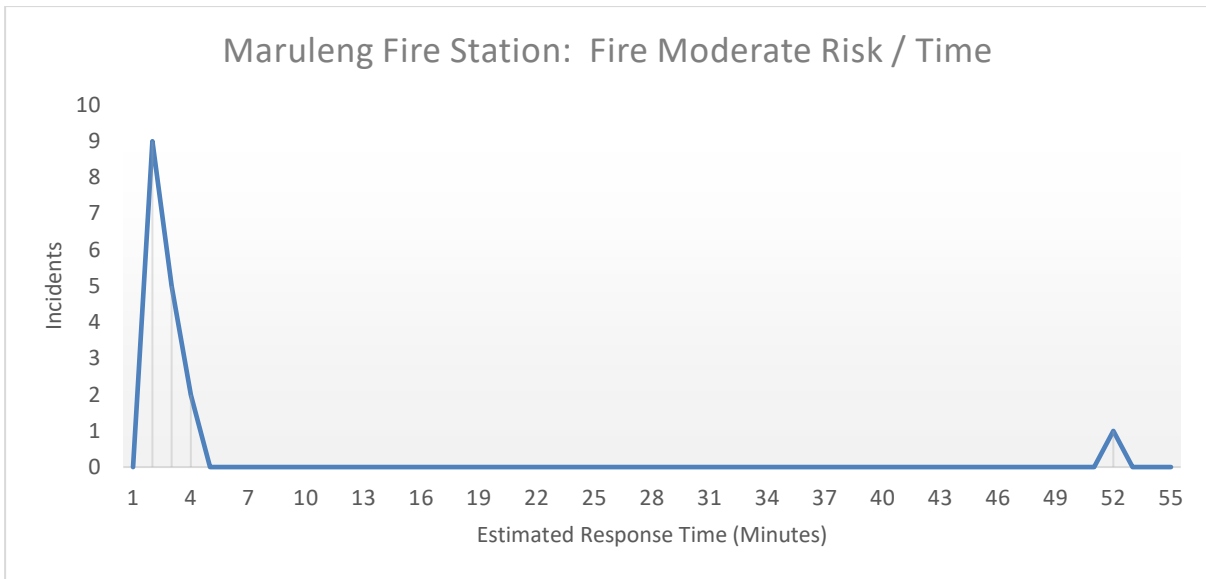


Figure 4-44: Sampled fires plotted per time interval and moderate risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

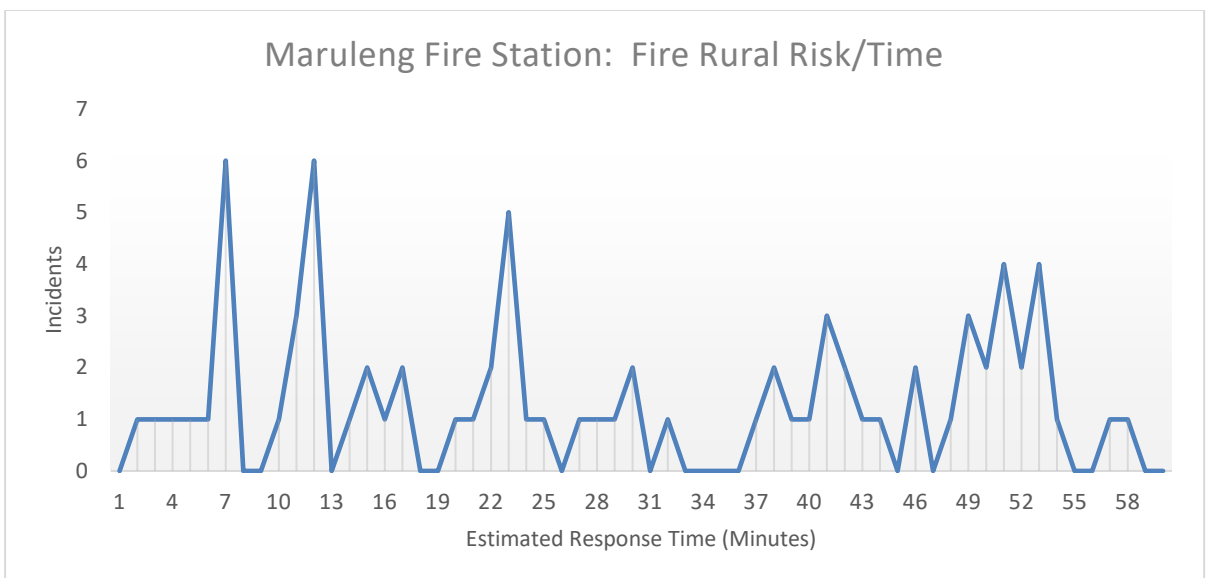


Figure 4-45: Sampled fires plotted per time interval and rural risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

4.2.7.2 Rescue incidents attended to by the Maruleng Fire Station

In Table 4-12 below, it can be noted that the majority of rescues in the sample data were light motor vehicle accidents (91.88%). This is followed by truck accidents (5.41%), taxi accidents (1.62%), a bus accident (0.54%) and a pedestrian accident (0.54%). Where the risk category is considered against estimated response time (Table 4-13), it can be noted that all rescue incidents within the low risk category could be estimated to have been reached within expected response

times. In total, there were not many rescue incidents in the moderate risk category (n=5), but only an estimated 60% of these could be reached within the recommended response time, while only an estimated 54.36% of rescue incidents in the rural rescue category could be reached within an estimated 20 minutes or less. Maruleng Municipality shares boundaries with Capricorn, Sekhukhune and Ehlanzeni Districts. There is substantial overlap detected in the sample with regard to rescue incidents responded to over the four-year period considered. A total of 22 rescue incidents (11.89%) are estimated to have occurred across these boundaries, particularly into Sekhukhune and Ehlanzeni Districts.

Table 4-12: The proportion of rescue types within the sampled data for the Maruleng Fire Station

RESCUE TYPE	NUMBER	%
MVA	170	91.89%
Truck Accidents	10	5.41%
Pedestrian Accidents	1	0.54%
Taxi Accidents	3	1.62%
Bus Accidents	1	0.54%
Total	185	

Table 4-13: The estimated number of rescues reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	100%	0%
Moderate	7 Min	60.00%	40.00%
Rural	20 Min	54.36%	45.64%
Outside district		22	11.89%

Figure 4-46 indicates that most rescue incidents occurred on formal tar roads, including the R40, R527, R36 and D21. Figure 4-47 provides an overview of the different risk categories against estimated response time. Given the vastly rural nature of the Maruleng Municipality, the majority of rescue incidents in the sampled data occurred within the rural risk category (Figure 4-48). By comparison, relatively few rescue incidents occurred in the low and moderate risk classifications. The latter two risk categories are however also considered in Figure 4-49 and Figure 4-50 to indicate their distribution against estimated response times.

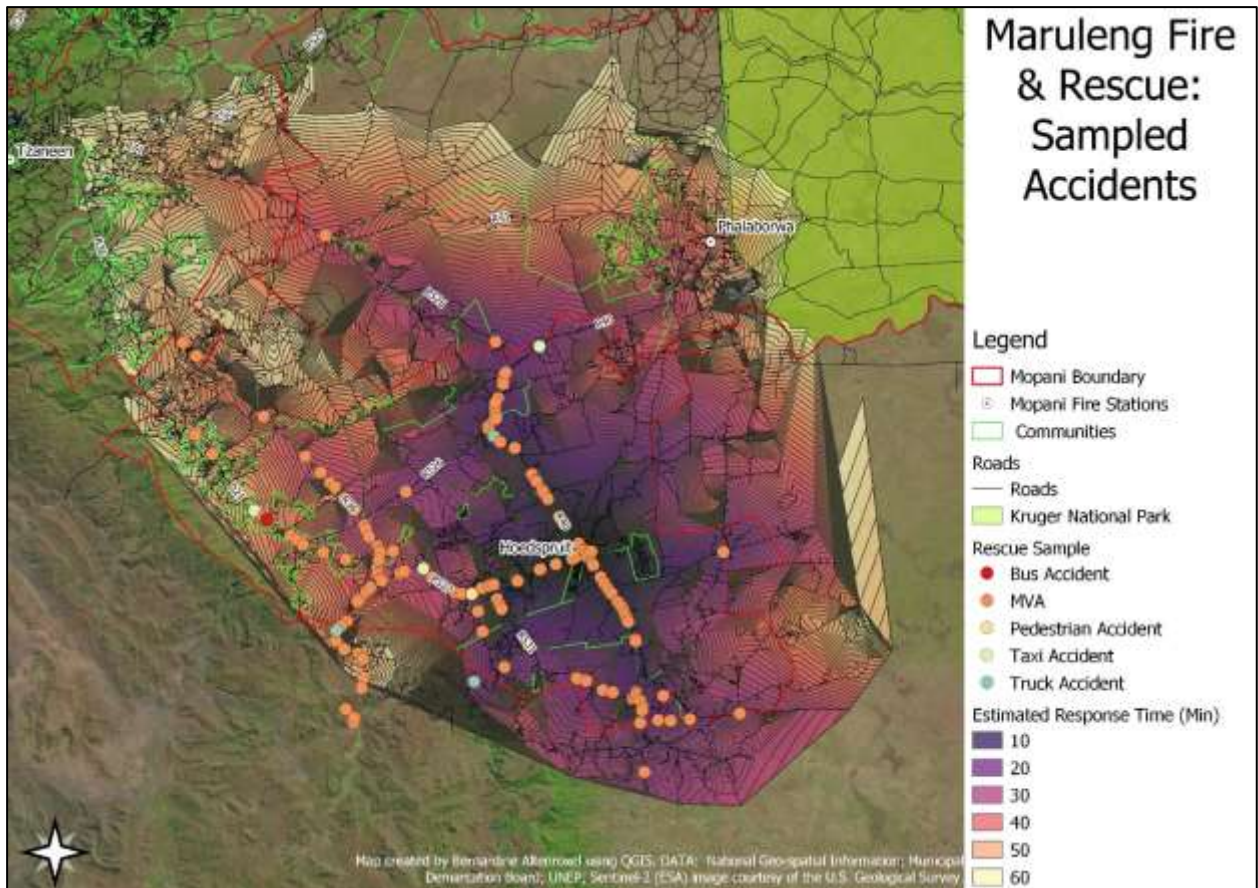


Figure 4-46: Areas within the estimated 60-minute reach of the Maruleng Fire Station and accidents dealt with between 2016 and 2019

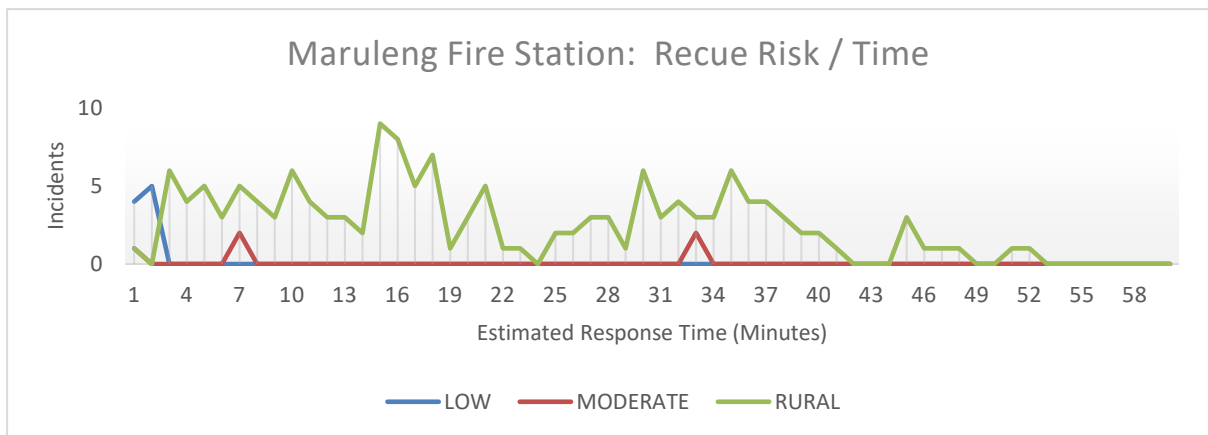


Figure 4-47: Sampled rescues plotted per time interval and risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

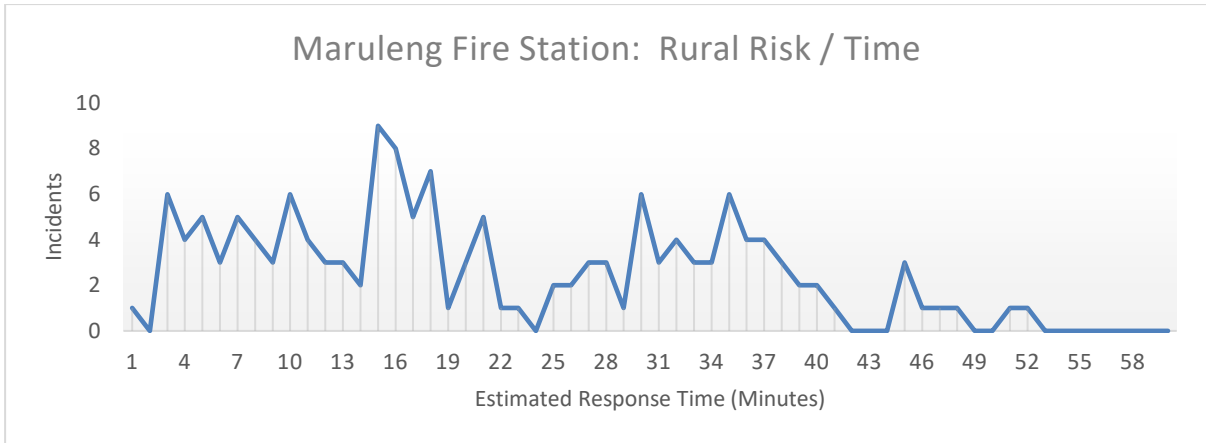


Figure 4-48: Sampled rescues plotted per time interval and rural risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

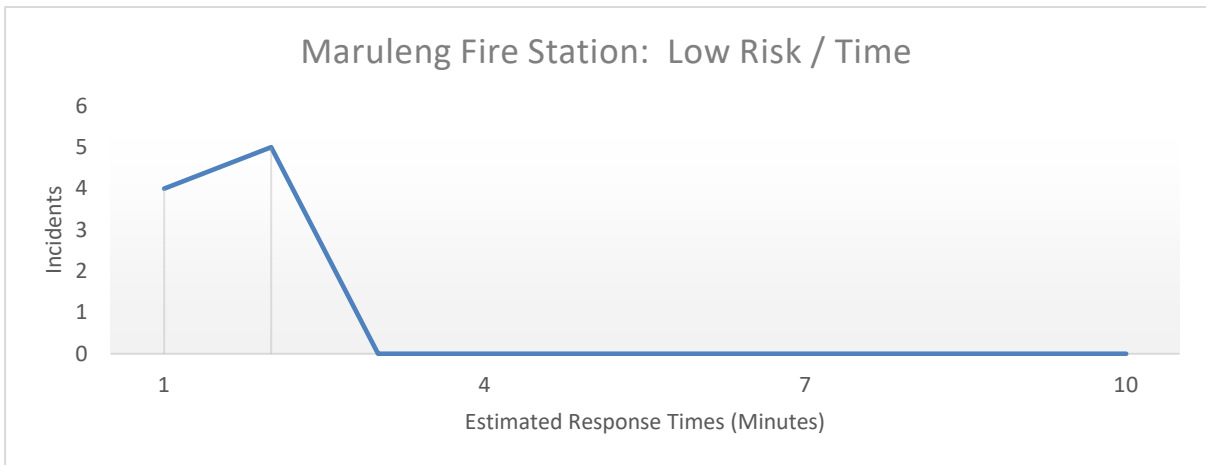


Figure 4-49: Sampled rescues plotted per time interval and low risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

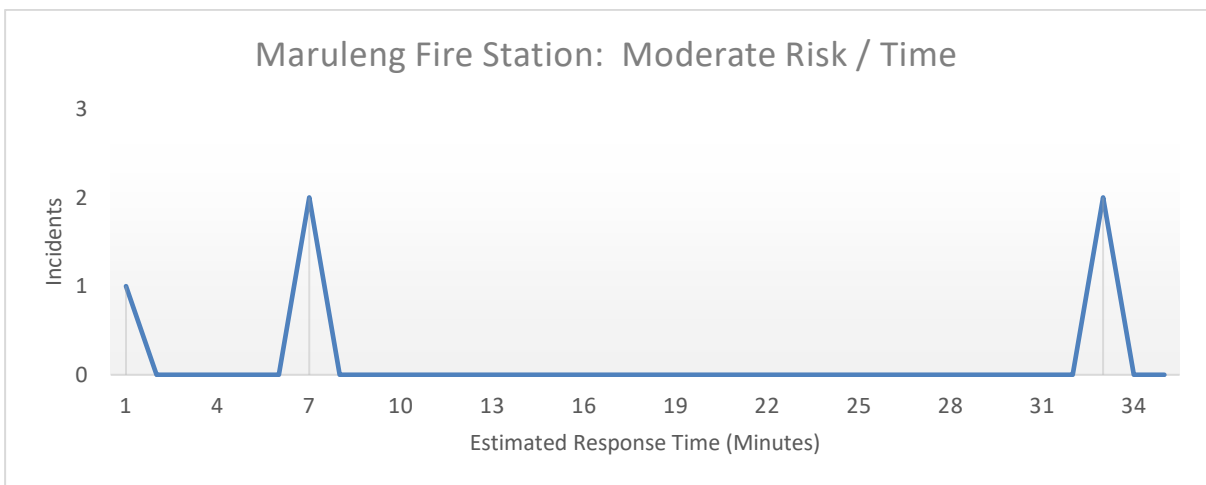


Figure 4-50: Sampled rescues plotted per time interval and moderate risk type for incidents attended to by the Maruleng Fire Station between 2016 and 2019

4.2.8 Modjadjiskloof Fire Station overview

The Modjadjiskloof Fire Station is located in the administrative centre of the Greater Letaba Municipality (GLM) in the small town of Modjadjiskloof. According to the GLM IDP, Ga-Kgapane, Senwamokgope and Modjadjiskloof are proclaimed towns within the municipality (GLM, 2020:50). The GLM serves 132 rural communities which are evenly scattered across the municipal area (GLM, 2020:41). Illegal informal settlements are noted to have been established at Meshasheng (Ga-Kgapane), Mokgoba outside Modjadjiskloof and on Portion 4 of the farm Mooiplaats (GLM, 2020:53). Since much of the land in Modjadjiskloof is privately owned, further expansion of the town remains limited (GLM, 2020:53). There are however future plans for the establishment of residential areas and shopping centres in many of the rural and urbanised areas, including Kgapane, areas outside Modjadjiskloof and Senwamokgope (GLM, 2020:57). Should these developments go ahead, fire risk classification for the GLM will have to be updated for future planning within fire and rescue services. Modjadjiskloof and Ga-Kgapane, which are more extensively developed, can be considered a mix of Category B (moderate) and Category C (low) fire risks, while the remainder of the municipal area can be considered rural and thus a Category D fire risk (Figure 4-51).

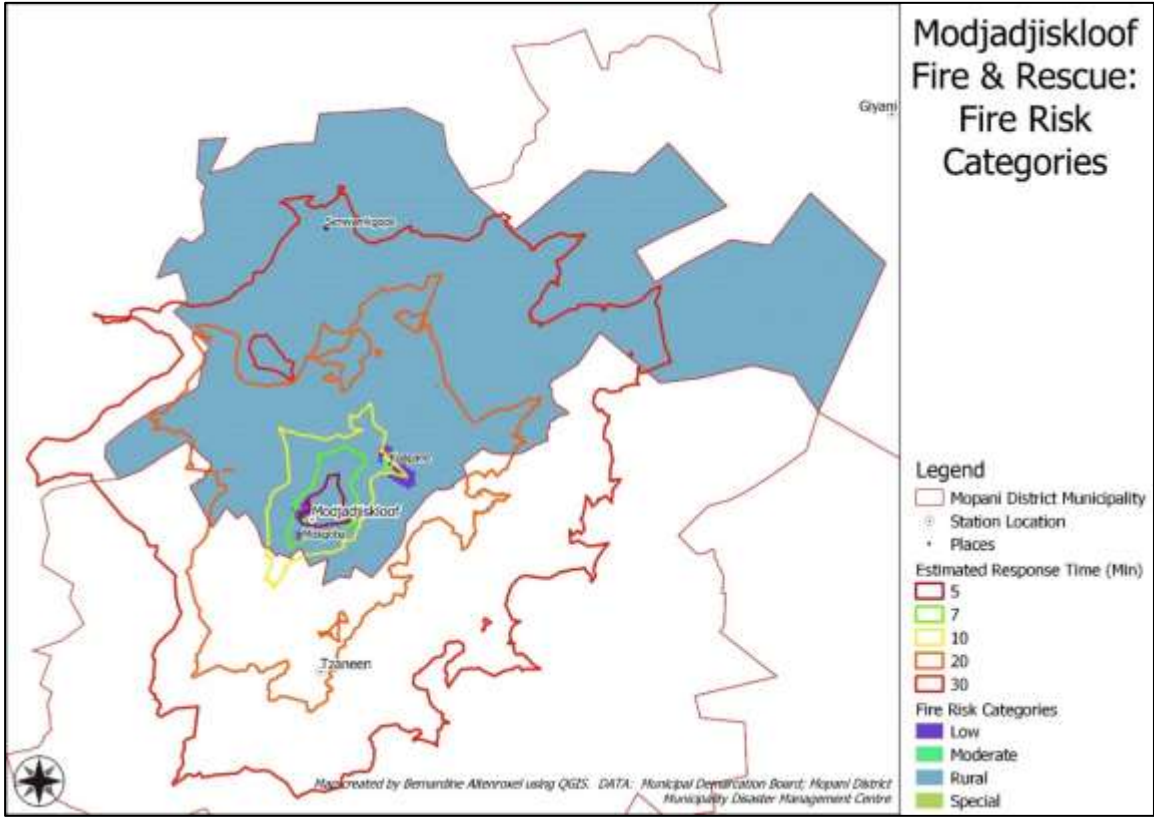


Figure 4-51: Risk categorisation of the Greater Letaba Municipality and estimated 5-, 7-, 10-, 20- and 30-minute reach from the Modjadjiskloof Fire Station

Veld and forest fires (grass fires) are identified in the IDP as a problem which poses a risk to livestock farmers in the GLM, affecting Meidingen, Thakgalang and Goudplaas (GLM, 2020:59). In the analysis which follows in the section below, the extent of the fire problem will be explored in more detail. The analysis clearly indicates that grass fires are indeed a leading problem in the GLM. Alien invasive plant species, such as lantana and castor oil plant, are also recognised in the IDP as a problem in many areas of the GLM including Sekgosese, Thakgalang, Mokokwaila and Rapitsi. These alien invasive plant species provide highly flammable biomass, which contributes towards the veld and forest fire problem (GLM, 2020:59-60). In this regard, a proper analysis of affected areas and the implementation of a properly structured program aimed at invasive plant removal could potentially reduce this risk.

There is currently insufficient bulk water supply to meet demand within the GLM, leaving affected communities to resort to other sources of water (GLM, 2020:70). A total of 9.3% of households do not have access to piped water (GLM, 2020:71). Added to this burden is an ageing water and sanitation infrastructure in Modjadjiskloof and Ga-Kgapane, reliance on boreholes and poor maintenance, amongst others (GLM, 2020:73). With poor or no water infrastructure, fire-fighting efforts will be hampered and water will have to be transported to site using a water tanker.

The GLM indicates an improvement in the condition of roads, with a reduction in the backlog of roads which needed to be paved (GLM, 2020:76). Gravel roads are mostly restricted to internal streets in rural communities, according to the GLM IDP, yet inaccessible road networks are cited as a problem for ambulance access (GLM, 2020:76;86). Among those hazards identified in the GLM are fire, flooding, dam failure and road accidents (GLM, 2020:96). These hazards are all factors which must be considered by fire and rescue services to ensure that appropriate resources and vehicles are allocated to the Modjadjiskloof Fire Station. Some overlap in incidents responded to occurs with neighbouring Capricorn District in terms of fires and accidents, particularly along the R81 Ga-Sekgopo-Munnik road and around Goudplaas (between Mooketsi and Morebeng). An MOU with the Capricorn District Municipality may improve the rendering of a fire service through these two areas. To assist in dealing with truck accidents along the steep mountain pass through Buffelsberg at Ga-Sekgopo, heavy duty rescue equipment is also required by the Modjadjiskloof Fire Station. Agriculture is identified as a key sector in the GLM, and is one of the major employers (GLM, 2020:100). Only about 5% of the land area within the GLM is utilised for residential development, while 30% is used for agriculture (MDM, 2019:43). The timber industry also plays an important economic role, as do tourism and the retail sector (GLM, 2020:101-102). As with the GTM, these high-value plantations require special consideration with regard to resource allocation for fire and rescue services.

Modjadjiskloof is a relatively small town and can easily be reached within 7-10 minutes or less from the Modjadjiskloof Fire Station (Figure 4-52). However, it is unlikely that Ga-Kgapane, which has undergone rapid expansion in recent years, can be reached within this space of time. The entire Greater Letaba Municipality and Greater Tzaneen Municipality can be reached by the Modjadjiskloof Fire Station within 60 minutes (Figure 4-53), meaning that they are able to lend support to the Tzaneen Fire Station when necessary. There are very few informal settlements located within the Mopani District, and those which do exist are relatively small. In known informal settlements, it was indicated during interviews with Mopani Fire and Rescue Services senior management that road layout has been improved to allow for easier access, such as in the case of Mokgoba outside Modjadjiskloof. Water availability was however identified as often being a problem since water must be transported to site. Shacks that are developed by farm workers on some farms have been found to be problematic as there is typically poor access to these sites. It was however also indicated during the interviews that commercial farmers have provided better structured accommodation for workers.

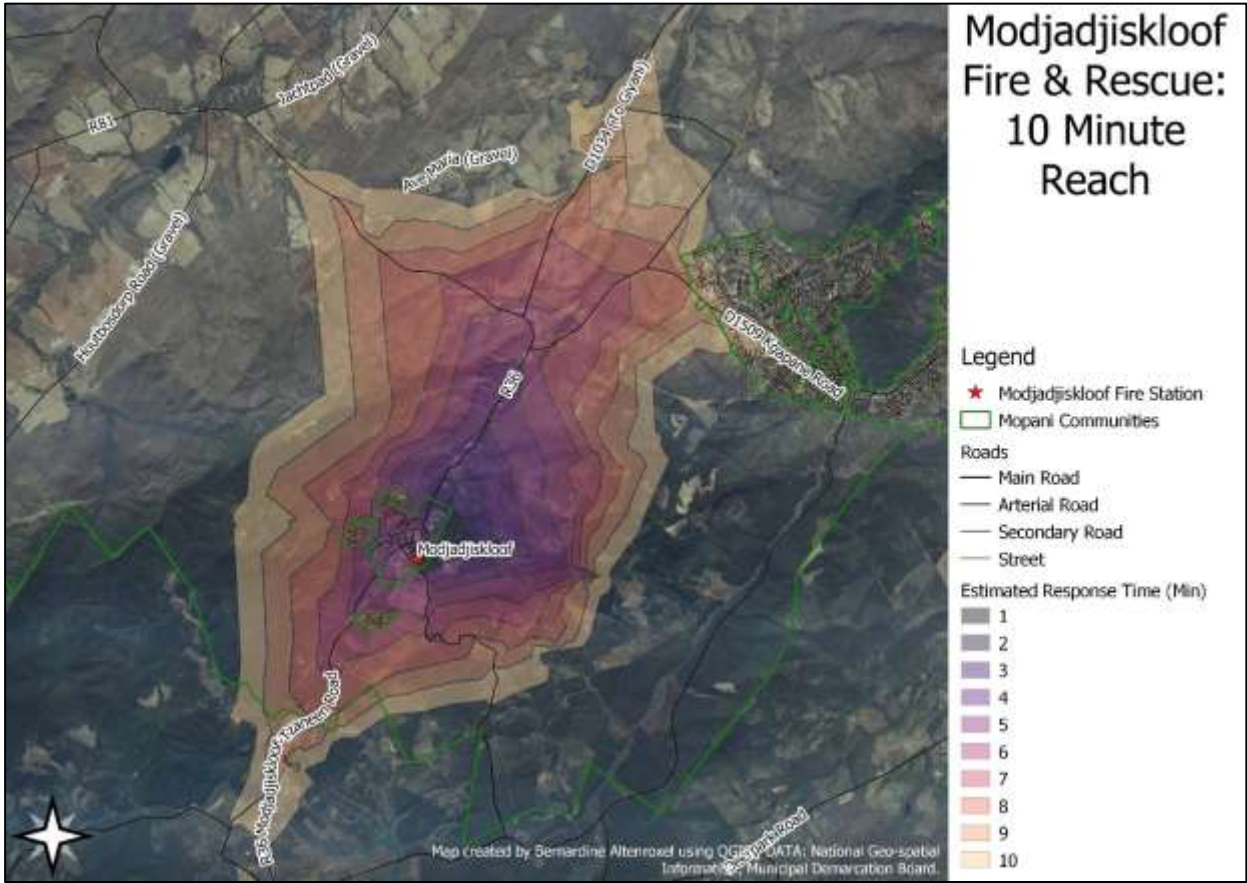


Figure 4-52: Areas within the estimated 10-minute reach of the Modjadjiskloof Fire Station

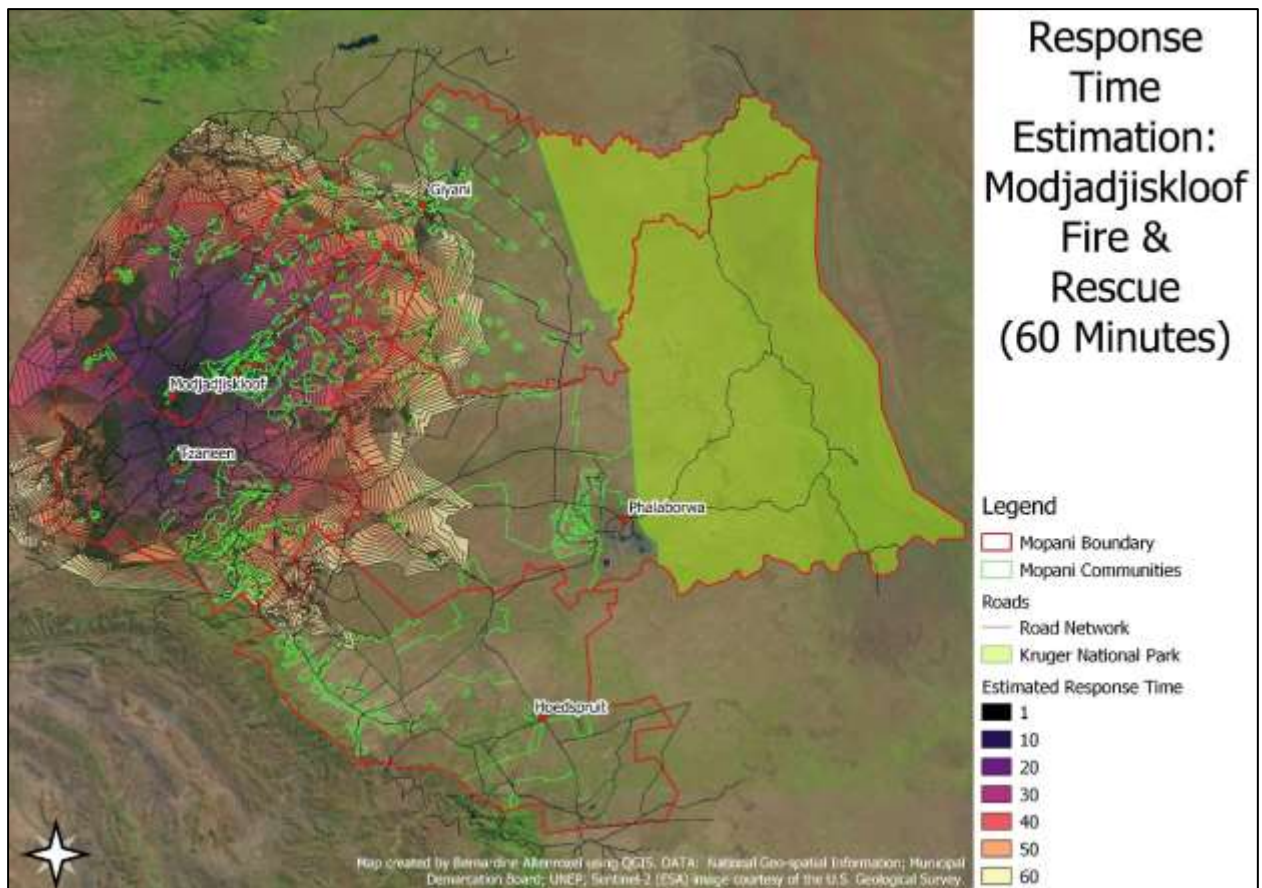


Figure 4-53: Areas within the estimated 60-minute reach of the Modjadjiskloof Fire Station

4.2.8.1 Fire incidents dealt with by the Modjadjiskloof Fire Station

Figure 4-54 below provides an overview of the distribution of the sampled fires within the Greater Letaba Municipality. Here, vehicle fires stand out and can be noted as having occurred more to the western side of the area under the jurisdiction of the GLM, along the R81. The R81 includes a steep section where the road sweeps down the Great Escarpment into the Lowveld via the Buffelsberg Pass and Ga-Sekgopo. Many of the vehicle fires occurred on this section of the road and may be attributed to brakes having caught fire and failed after the steep descent. Also, many of the house fires were attended to in the rural communities scattered throughout the GLM. Grass fires were mostly located within or around Modjadjiskloof and the Kgapanne / Bolobedu area, with some also reported from Sekgosese / Senwamkgope.

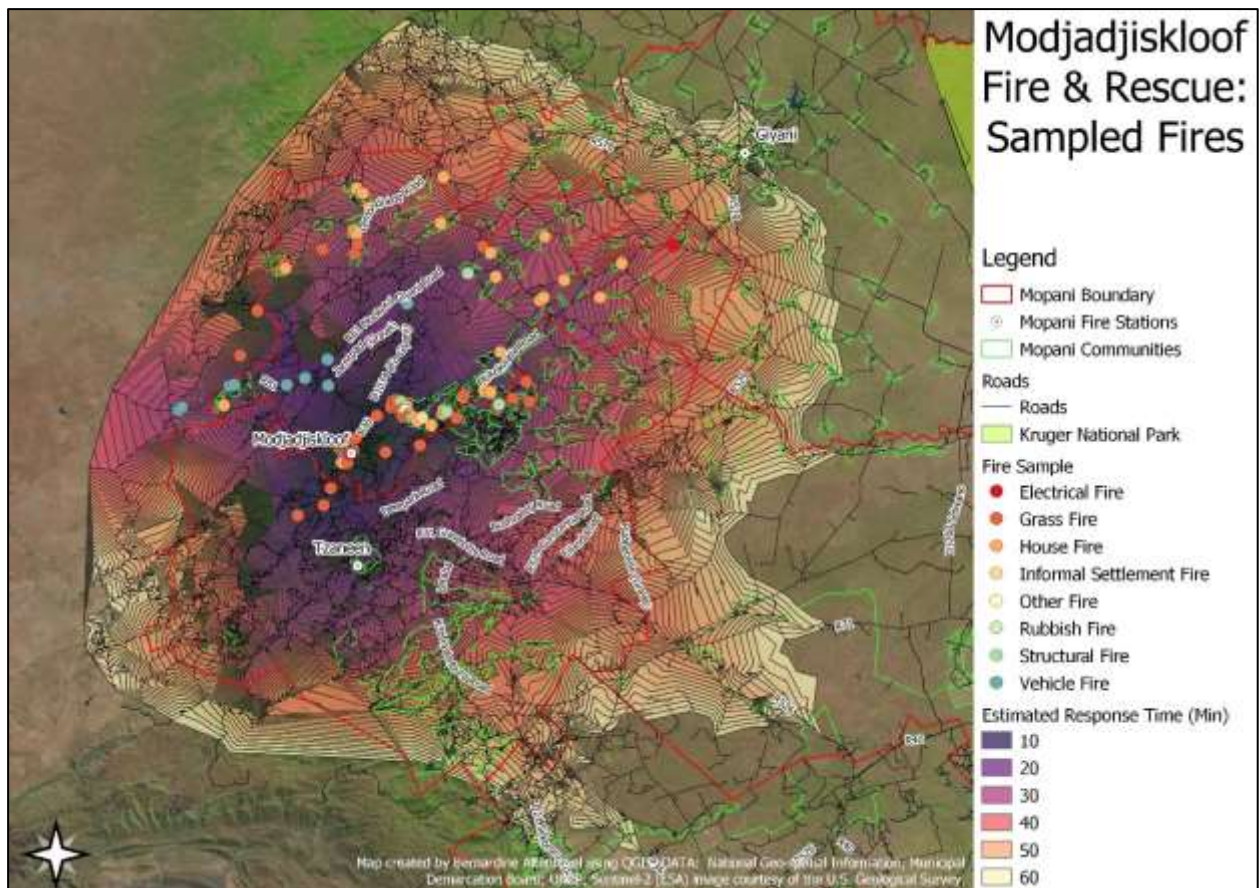


Figure 4-54: Areas within the estimated 60-minute reach of the Modjadjiskloof Fire Station and all fires dealt with between 2016 and 2019

In table 4-14 below the proportion of different fire types is tabulated. This indicates that most fires (45.93%) of the sampled fire incident data were grass fires, followed by house fires (23.26%) and vehicle fires (9.30%). Remaining fire types include informal housing fires (5.23%), rubbish fires (4.65%) and structural fires (4.65%). Table 4-15 provides the proportion of fire incidents reached within and outside the recommended response times per fire classification. This indicates that 90% of fires in the low risk classification, 70% of fires in the moderate classification and 62.84% of fires in the rural classification could be estimated to have been reached within the recommended response times.

Table 4-14: The proportion of fire types within the sampled data for the Modjadjiskloof Fire Station

FIRE TYPE	NUMBER	%
Electrical Fires	3	1.74%
Structural Fires	8	4.65%
Grass Fires	79	45.93%
House Fires	40	23.26%

Informal Settlement Fires	9	5.23%
Other Fires	9	5.23%
Vehicle Fires	16	9.30%
Rubbish Fires	8	4.65%
Total	172	

Table 4-15: The estimated number of fires reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	90.00%	10.00%
Moderate	7 Min	70.00%	30.00%
Rural	20 Min	62.84%	37.16%

Figure 4-55 below provides an overview of the different fire risk classifications plotted against estimated response times for sampled fires. This indicates that a higher proportion of fire incidents could be attended to within recommended response times compared to rescue incidents. A high proportion of fires in the low risk classification could be reached within the recommended response times (Figure 4-56). The bulk of the incidents in the moderate risk classification could also be reached within the recommended response time. The rural risk classification indicates a greater spread in the estimated response time to reach fire incidents (Figure 4-57). This is an indication of fire-related incidents which occurred within the scattered rural communities. Figure 4-54 above indicates that many of the house fires were reported within these communities. These are spatially distant from the Modjadjiskloof Fire Station base and many are located on gravel roads which impede response time. The poor water infrastructure indicated in the GLM IDP also needs to be considered in this respect since, without piped water, fire and rescue services are forced to transport water to the site of the fire with a water tanker.

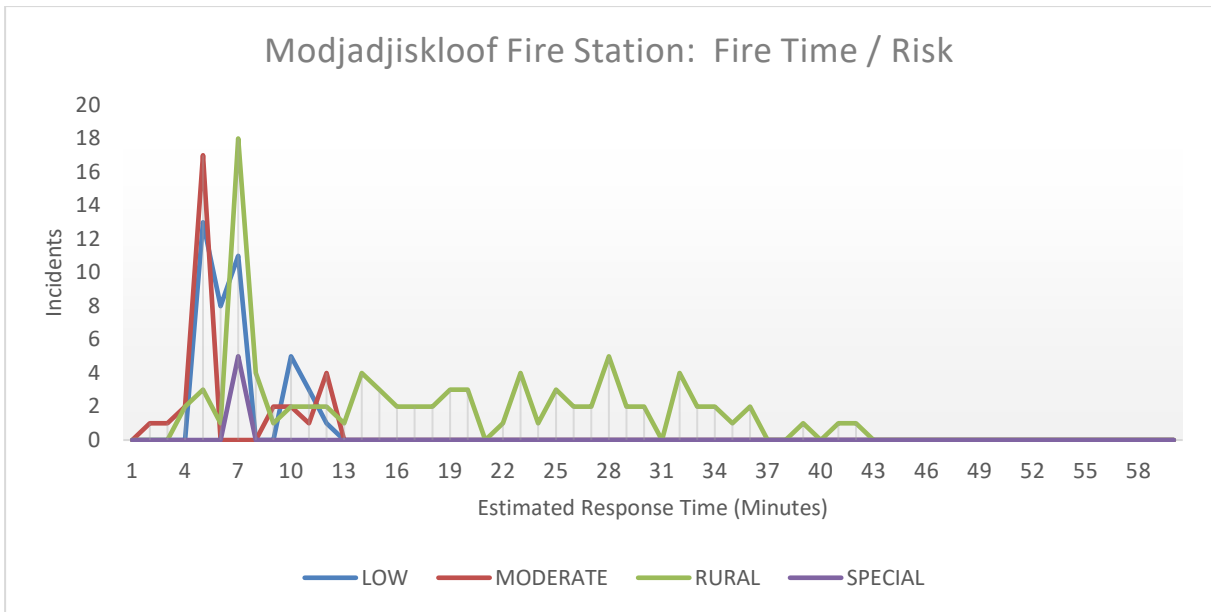


Figure 4-55: Sampled fires plotted per time interval and risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

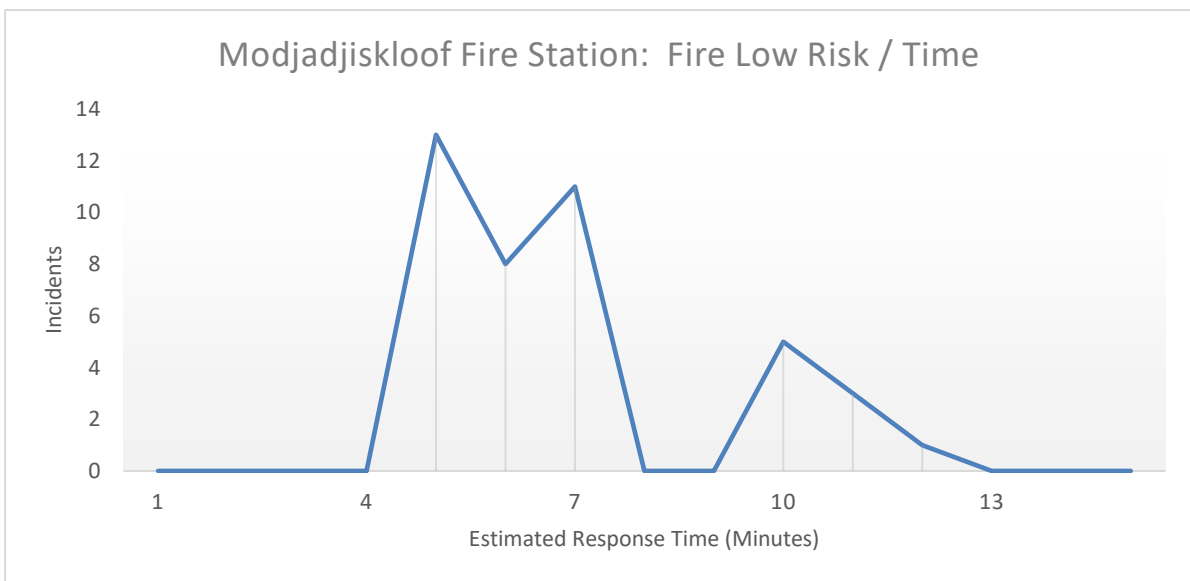


Figure 4-56: Sampled fires plotted per time interval and low risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

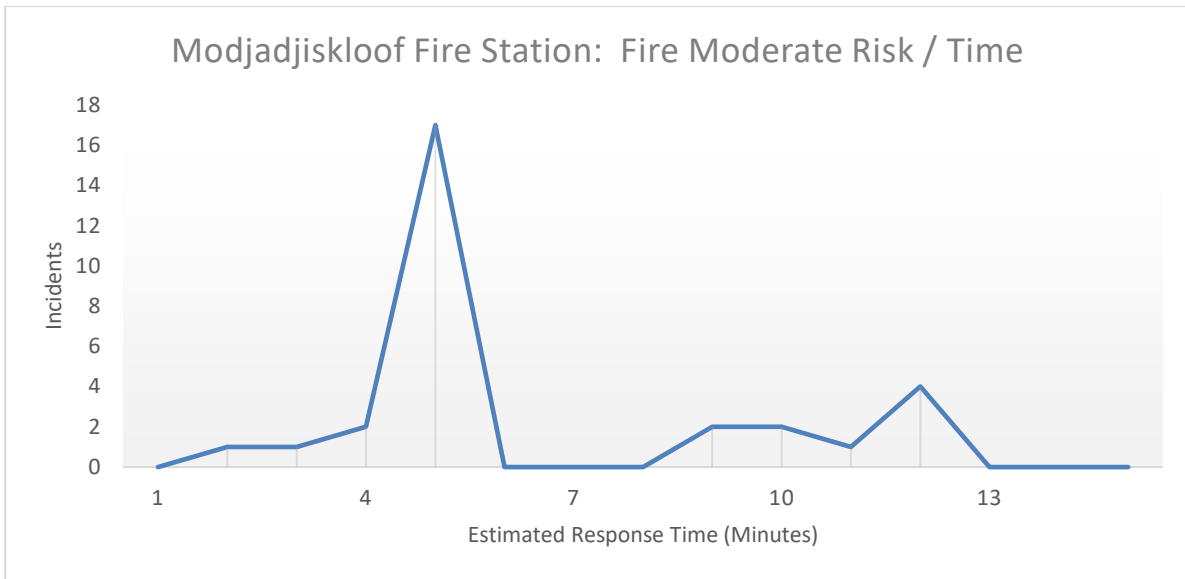


Figure 4-57: Sampled fires plotted per time interval and moderate type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

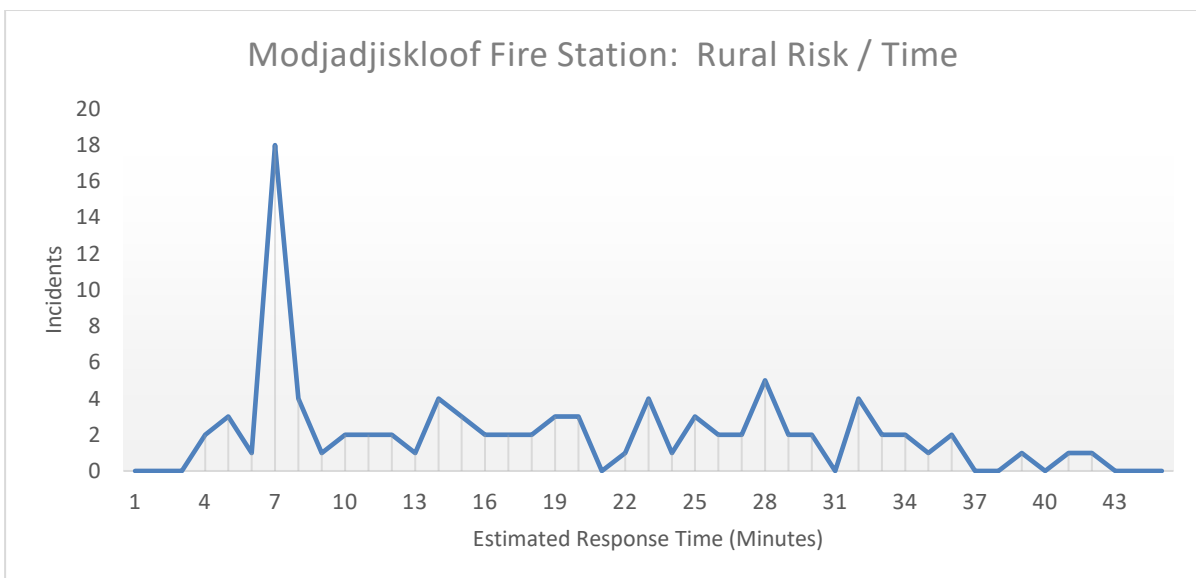


Figure 4-58: Sampled fires plotted per time interval and rural risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

4.2.8.2 Rescue incidents dealt with by the Modjadjiskloof Fire Station

Table 4-16 below provides a tabulated summary of rescue incidents that were sampled for the Modjadjiskloof Fire Station. The majority of incidents (79.10%) involved light motor vehicles, followed by truck accidents (14.12%) and taxi accidents (3.39%). A small number of pedestrian, bus and train accidents were also reported. Figure 4-59 provides an overview of the spatial distribution of the sampled rescue incidents, and indicates that many of the truck accidents

occurred along the R81 road through Ga-Sekgopo. As it has already indicated, the R81 sweeps down the side of the Great Escarpment through the Buffelsberg Pass into the Lowveld. At the time of writing, this section of road was being rehabilitated by SANRAL at a cost in excess of R160-million to make it safer for road users (SANRAL, 2019; National Treasury, 2019). Some rescue-related incidents are also indicated to have occurred outside the Mopani District into the Capricorn District through the R81.

The vastly rural nature and extensive road network through the GLM makes reaching rescues within recommended response times extremely difficult. In the low risk classification, an estimated 55.56% of rescues could be reached within recommended response times. Only 60% of rescues in the moderate risk classification and 62.84% in the rural risk classification could be reached within the recommended response times (Table 4-17). However, it is worth noting that there were very few incidents within the low and moderate risk categories.

Table 4-16: The proportion of rescue types within the sampled data for the Modjadjiskloof Fire Station

RESCUE TYPE	NUMBER	%
MVA	140	79.10%
Truck Accidents	25	14.12%
Pedestrian Accidents	2	1.13%
Taxi Accidents	6	3.39%
Train Accident	1	0.57%
Bus Accidents	3	1.70%
Total	177	

Table 4-17: The estimated number of rescues reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	55.56%	44.45%
Moderate	7 Min	60.00%	40.00%
Rural	20 Min	62.84%	37.16%

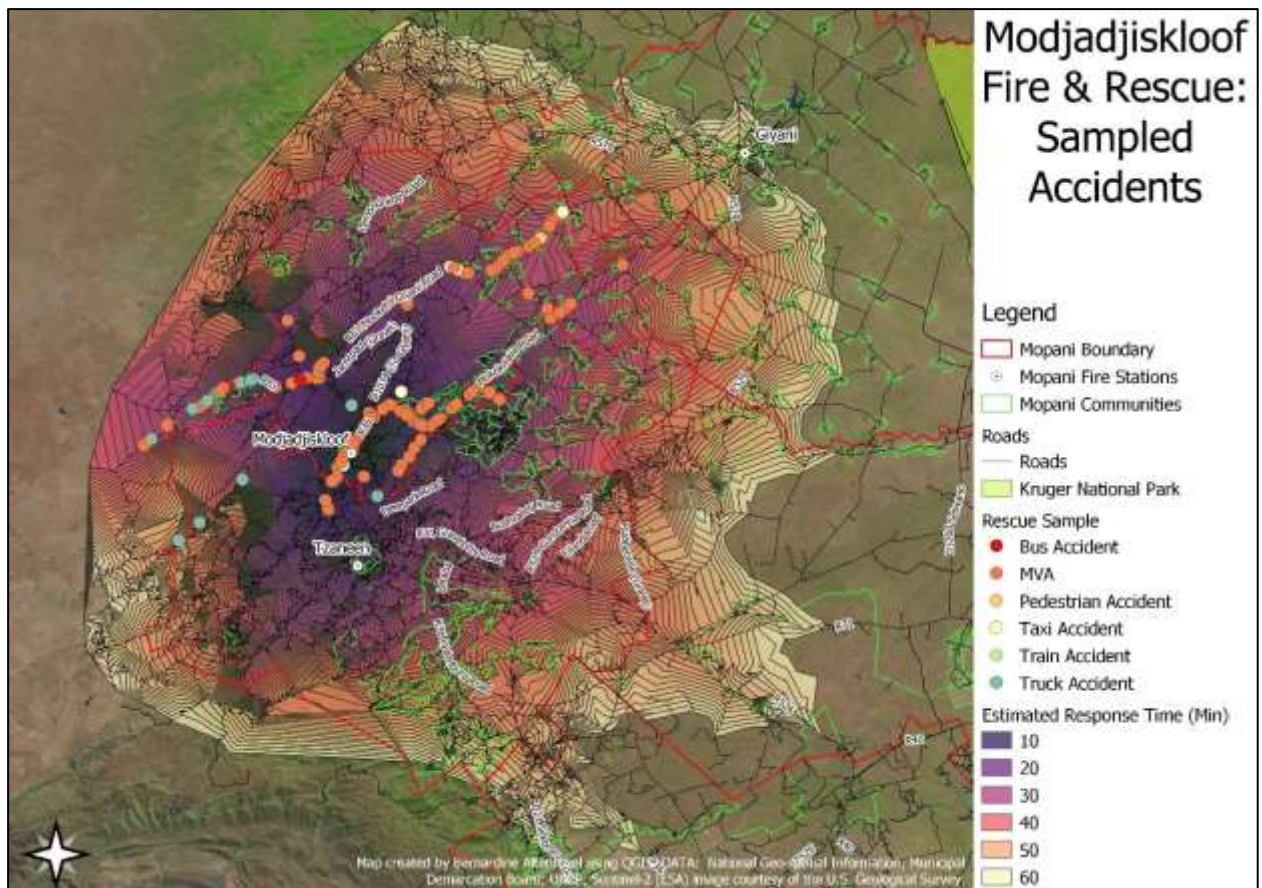


Figure 4-59: Areas within the estimated 60-minute reach of the Modjadjiskloof Fire Station and accidents dealt with between 2016 and 2019

In Figure 4-60 below, rescue-related incidents in the sampled data are plotted against time and risk category. This provides a clearer indication of the relatively low number of incidents in the low and moderate risk categories, which can also be seen in Figure 4-61 and Figure 4-62 respectively. Given the vastly rural nature of the GLM, it is understandable that in the rural risk classification, there is a far greater number of incidents and more challenging distribution (Figure 4-63).

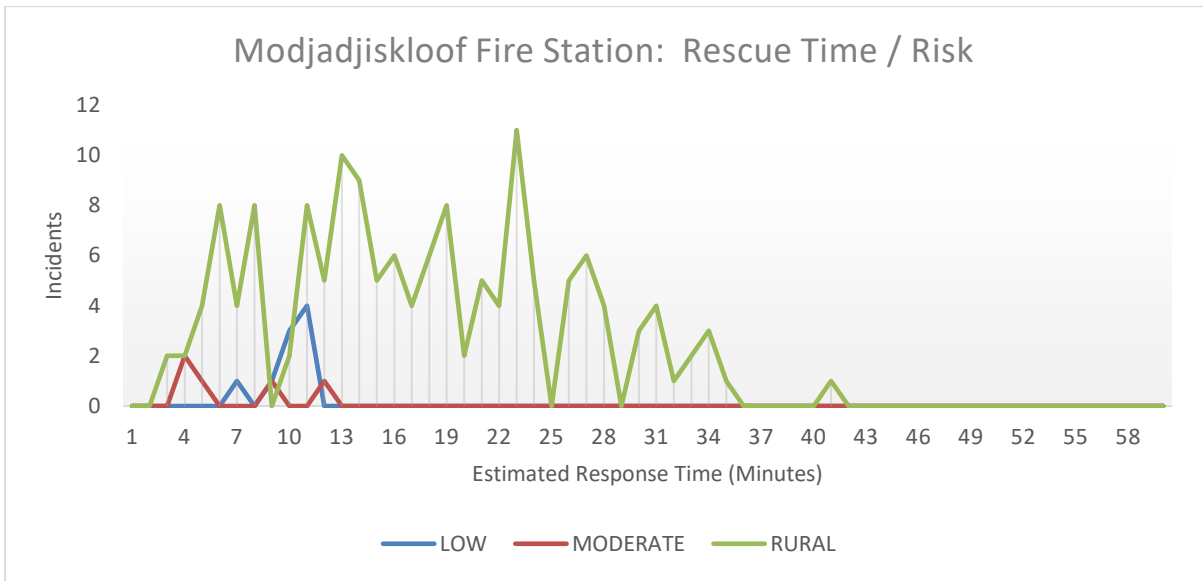


Figure 4-60: Sampled rescues plotted per time interval and risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

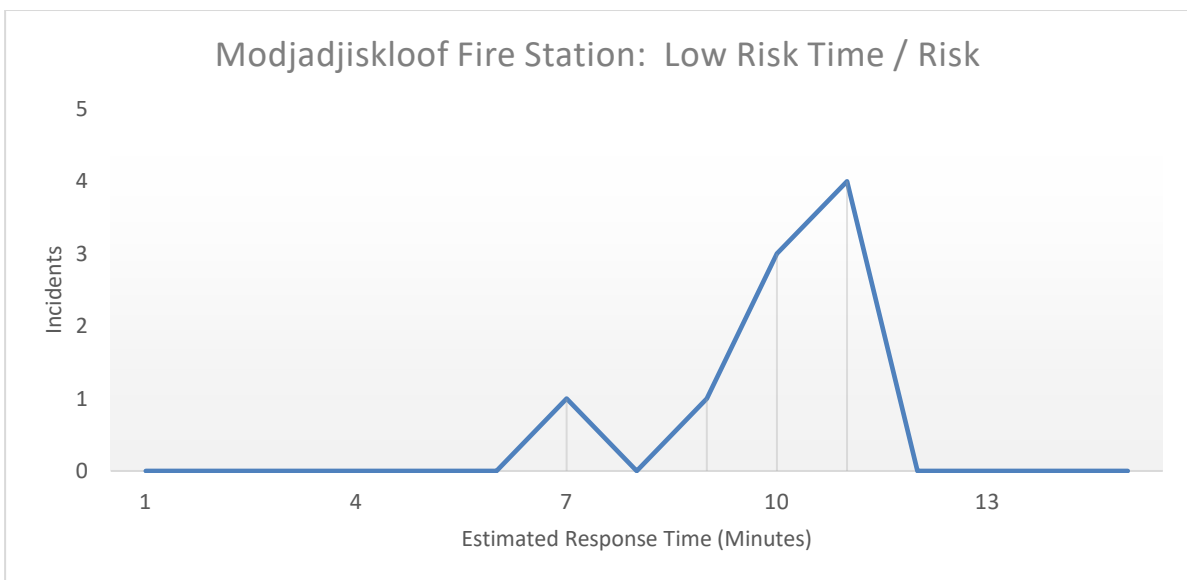


Figure 4-61: Sampled rescues plotted per time interval and low risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

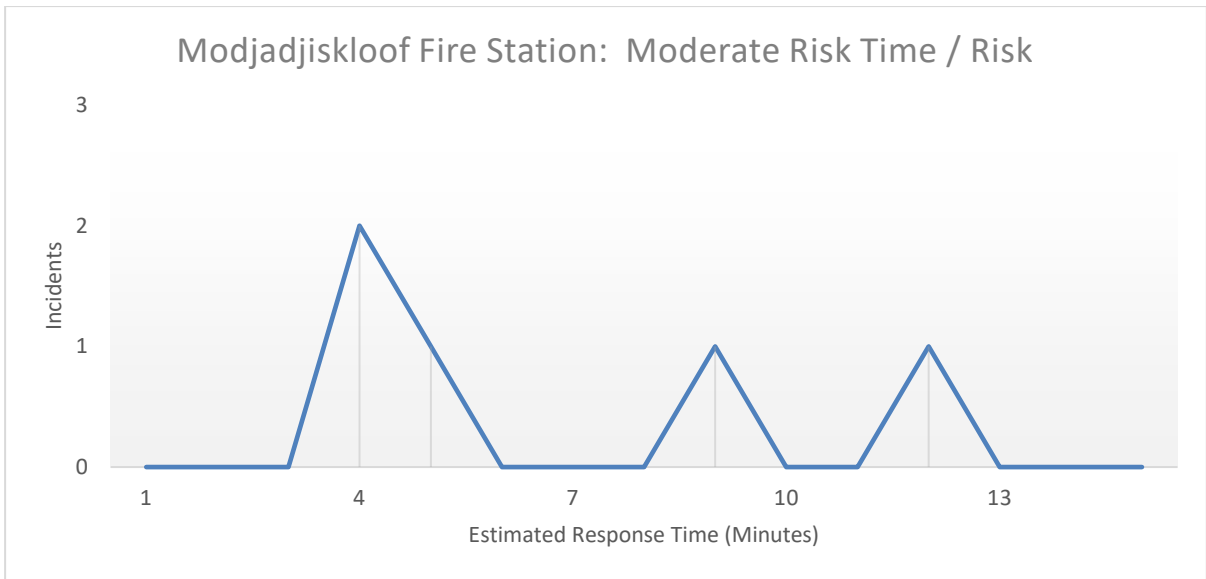


Figure 4-62: Sampled rescues plotted per time interval and moderate risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

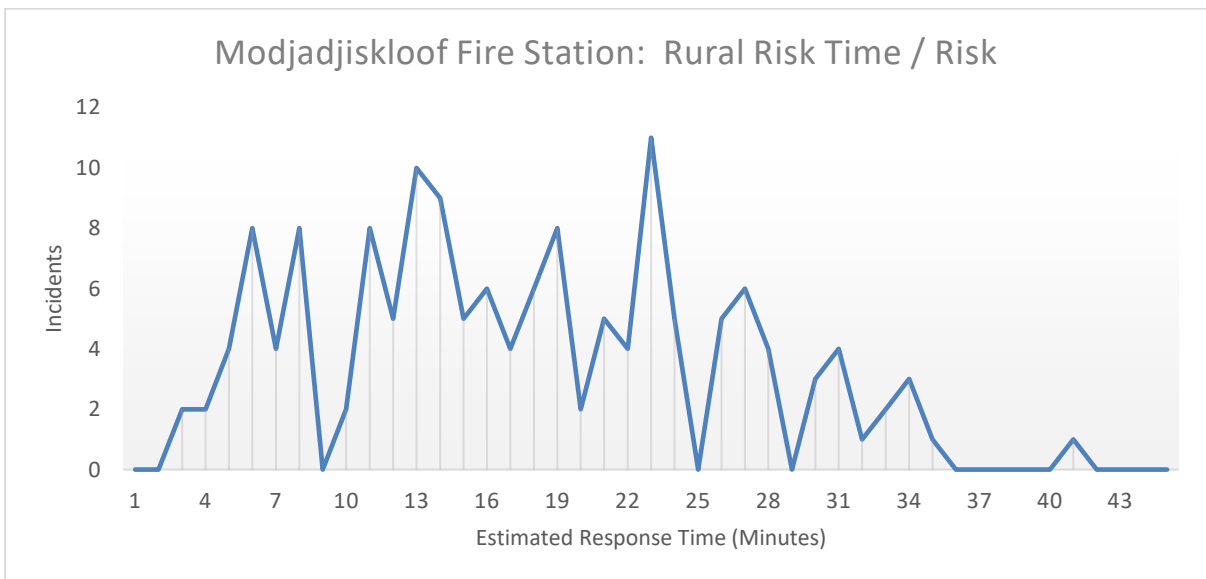


Figure 4-63: Sampled rescues plotted per time interval and rural risk type for incidents attended to by the Modjadjiskloof Fire Station between 2016 and 2019

4.2.9 Phalaborwa Fire Station overview

The Phalaborwa Fire Station is located within the heart of the town of Phalaborwa, with easy access to the retail and manufacturing sector, as well as the two major feeder roads leading into Ba-Phalaborwa Municipality, the R71 and the R40. Home to the famous opencast copper mine, Phalaborwa also serves as a gateway to the Kruger National Park through Phalaborwa Gate.

Phalaborwa is a central gateway to the Greater Limpopo Trans-frontier Park via the Giryondo Border (BPM, 2020:15). As such, Phalaborwa has been identified as a provincial growth point (MDM, 2019:44). The proximity to the Kruger National Park, with the Phalaborwa Gate entrance located on the outskirts of Phalaborwa, means that the Phalaborwa Fire Station has the quickest access to the Letaba, Mopani and Olifants Rest Camps. The three camps are located within the district management area. Based on the sampled fire and rescue data, however, there have been relatively few incidents of fire or accidents which required a response into the Kruger National Park over the last four years. Careful planning and training with the Kruger National Park, particularly in terms of fire, should nonetheless be considered in order to enhance capacity in respect of incident management. The presence of the mines and the types of chemicals typically transported to these mines, the Phalaborwa Fire Station needs to be suitably resourced and trained to deal with dangerous goods incidents.

The majority of the population (94%) live within 15km of Phalaborwa, which includes some of the semi-rural communities located within the municipal area (BPM, 2020:15). The spatial arrangement of some communities, particularly Namakgale, Lulekani and Ben Farm are considered to be hallmarks of the apartheid era spatial segregation policies (BPM, 2020:55). According to the Ba-Phalaborwa Municipality IDP, there are four towns, namely Phalaborwa, Gravelotte, Namakgale and Lulekani, and 35 rural communities (BPM, 2020:18). Land suitable for further residential and commercial development has been identified and is located between Phalaborwa, Lulekani and Namakgale (BPM, 2020:22). Key economic sectors in BPM are agriculture, mining, manufacturing, tourism and property development, with mining identified as the single greatest employer (BPM, 2020:45). The continued productivity of the mines may however be constrained in the future (MDM, 2019:44). Tourism, on the other hand, has the greatest potential for future development (BPM, 2020:49). In terms of fire risk categories, the formal residential areas of Phalaborwa, Namakgale, Gravelotte and Lulekani can be considered Category C or low risk, with the CBDs of Phalaborwa, Namakgale and Lulekani considered Category B or moderate risk. The mines located to the south of Phalaborwa can be considered a special risk (Category E). The remainder of the municipality can be considered a Category D or rural risk. The different risk categories are displayed in Figure 4-64 below along with estimated response times at 5-, 7-, 10-, 20- and 30-minute increments.

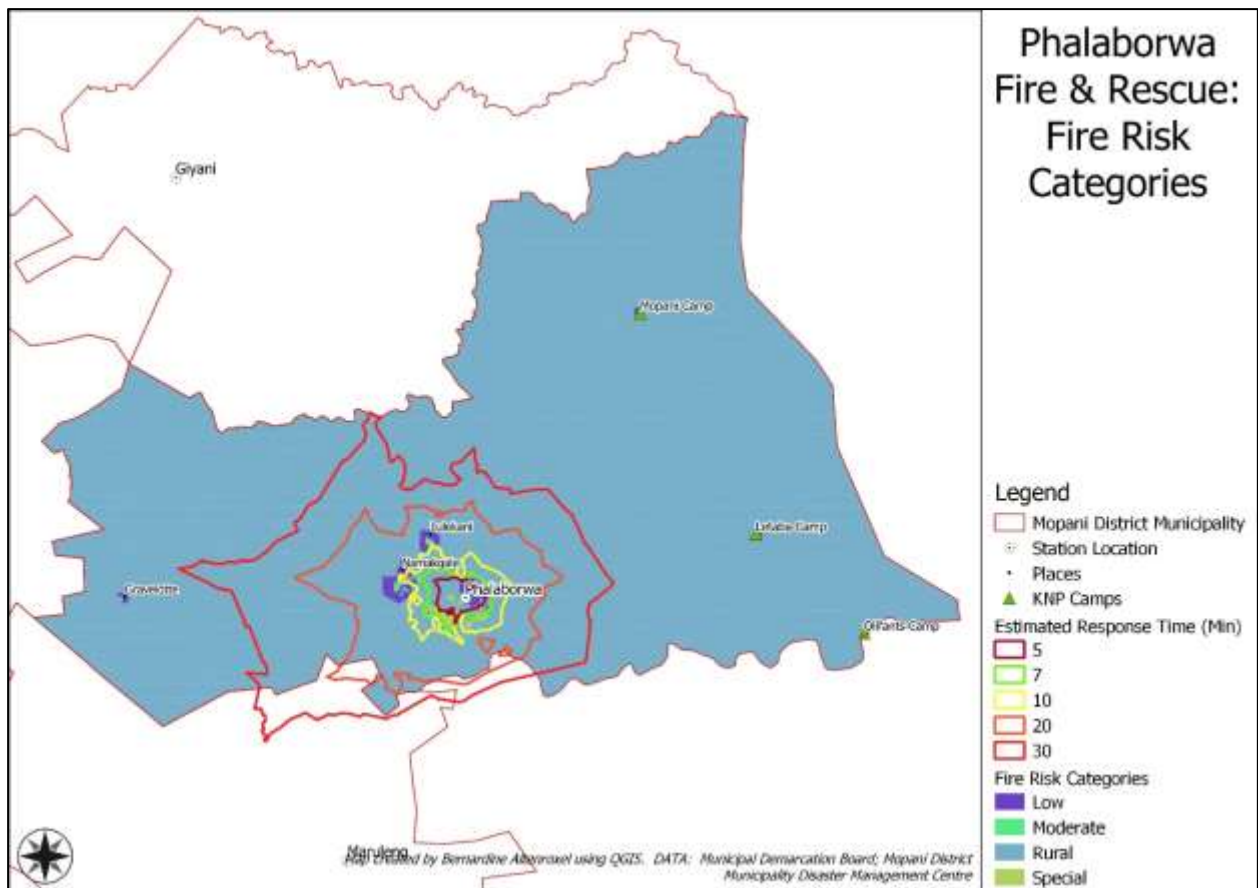


Figure 4-64: Risk categorisation of the Ba-Phalaborwa Municipality and estimated 5-, 7-, 10-, 20- and 30-minute reach from the Phalaborwa Fire Station

Although 91.3% of households in Ba-Phalaborwa Municipality have access to water, there is still a struggle to meet water demand and to maintain an ageing system (BPM, 2020:57;59). Challenges with water supply are mostly experienced at Ben Farm, Matikoxikaya, Mashishimale, Maseke, Lulekani and Selwane (BPM, 2020:57). Compared to other local municipalities reviewed thus far in the Mopani District, Ba-Phalaborwa has the most households with ready access to water. The availability of water has a direct impact on the provision of a fire and rescue service, particularly in terms of resource needs related to the types of vehicles required. For example, water tankers will be required in those areas where there are challenges in terms of water supply, as indicated above.

The extensive road network through the Ba-Phalaborwa Municipality includes paved and unpaved roads, some managed by Sanral, while others are managed by RAL and Ba-Phalaborwa Municipality (BPM, 2020:64). Although a road master plan has been developed by the municipality, this is not being implemented due to budget and resource limitations, preventing much-needed rehabilitation and maintenance of roads under its jurisdiction (BPM, 2020:64). The transport network within Ba-Phalaborwa Municipality includes a railway network and airport (BPM,

2020:66). However, the railway network needs to be upgraded for the transportation of magnetite from Phalaborwa's mine. At present, magnetite is being transported by road from Phalaborwa to Mozambique using trucks, and this places additional strain on the R40 (BPM, 2020:66). The presence of the mines in Ba-Phalaborwa means that dangerous goods may be transported by road and rail. This factor must thus be given special consideration for appropriate resource allocation for the Phalaborwa Fire Station to be adequately equipped for dealing with dangerous goods incidents. Dealing with the most accidents in the Mopani District, reaching rescue-related incidents in time and having sufficient resources to deal with these accidents are important considerations for the Phalaborwa Fire Station. Sufficient rescue vehicles and rescue equipment are thus required. Light motor vehicle accidents make up the vast majority of rescue-related incidents for the Phalaborwa Fire Station.

A challenge raised in the Ba-Phalaborwa Municipality IDP is the placement of the Phalaborwa Fire Station which is deemed too far from communities to reach fires in time (BPM, 2020:39). This claim will be explored in the section which follows.

Phalaborwa and the surrounding mines can be easily reached within an estimated 10 minutes or less from the Phalaborwa Fire Station (Figure 4-65). However, only small portions of Namakgale, Lulekani and Ben Farm can be reached within an estimated 10 minutes. Most of Ba-Phalaborwa Municipality can be reached within 60 minutes from Phalaborwa, with overlap into Maruleng, Greater Tzaneen and Greater Giyani Municipalities (Figure 4-66). This places the Phalaborwa Fire Station in a good position to offer support to both Maruleng and Tzaneen Fire Stations, should the need arise.

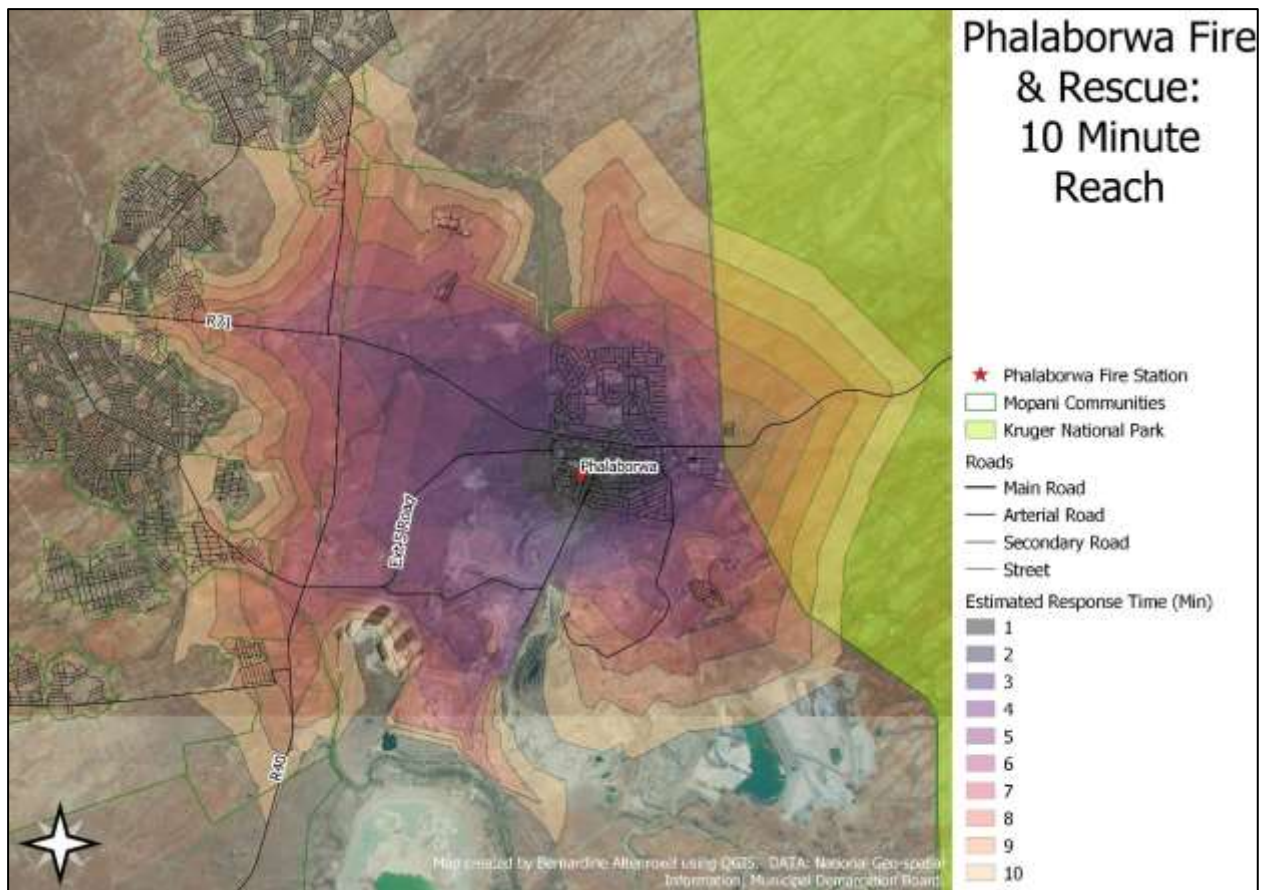


Figure 4-65: Areas within the estimated 10-minute reach of the Phalaborwa Fire Station

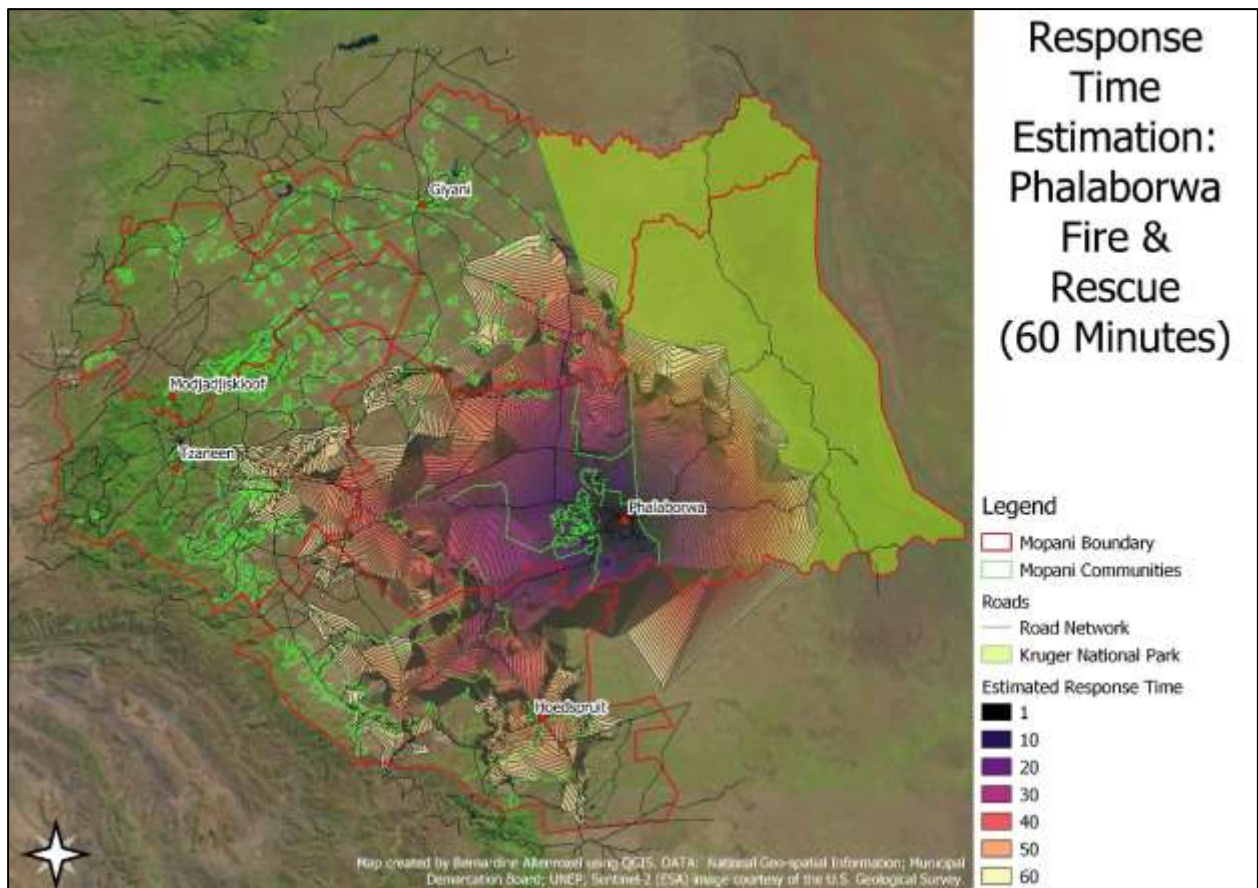


Figure 4-66: Areas within the estimated 60-minute reach of the Phalaborwa Fire Station

4.2.9.1 Fire incidents dealt with by the Phalaborwa Fire Station

Table 4-18 below provides an overview of the proportion of different fire types contained in the sampled fire data. This indicates that most fire incidents related to grass fires (32.73%), followed by house fires (30.18%) and vehicle fires (10.18%). Other fire types attended to included structural fires (9.46%), rubbish fires (7.64%) and electrical fires (5.09%). Although there was only one train fire (0.36%), this is a notable incident which requires future consideration in the allocation of resources for the Ba-Phalaborwa Fire Station, especially considering the intention mentioned in the BPM IDP to expand on the use of railways for the transportation of magnetite from Phalaborwa. Table 4-19 considers the proportion of fires estimated to have been reached within recommended response times per risk classification. The result indicates that an estimated 71.02% of fires in the low risk classification and 60.61% of fires in the moderate risk classification could be reached within the recommended response times. For the rural risk classification, an estimated 84.85% of fire incidents could be reached within recommended response times. Although there were only five incidents located within the special risk category, these must also be considered. It is estimated that two (40%) of fires in the special risk classification could be

reached within the recommended time of five minutes. With 94% of the Ba-Phalaborwa population located within just 15km of Phalaborwa (as per the BPM IDP), the spatial distribution of fires is strongly tied to population density and human activity associated with this (Figure 4-67).

Table 4-18: The proportion of fire types within the sampled data for the Phalaborwa Fire Station

FIRE TYPE	NUMBER	%
Electrical Fire	14	5.09%
Grass Fires	90	32.73%
House Fires	83	30.18%
Informal Housing	1	0.36%
Other Fire	11	4.00%
Rubbish Fire	21	7.64%
Structural Fire	26	9.46%
Train Fire	1	0.36%
Vehicle Fire	28	10.18%
Total	275	

Table 4-19: The estimated number of fires reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	71.02%	28.99%
Moderate	7 Min	60.61%	39.39%
Rural	20 Min	84.85%	15.15%
Special	5 Min	40.00%	60.00%

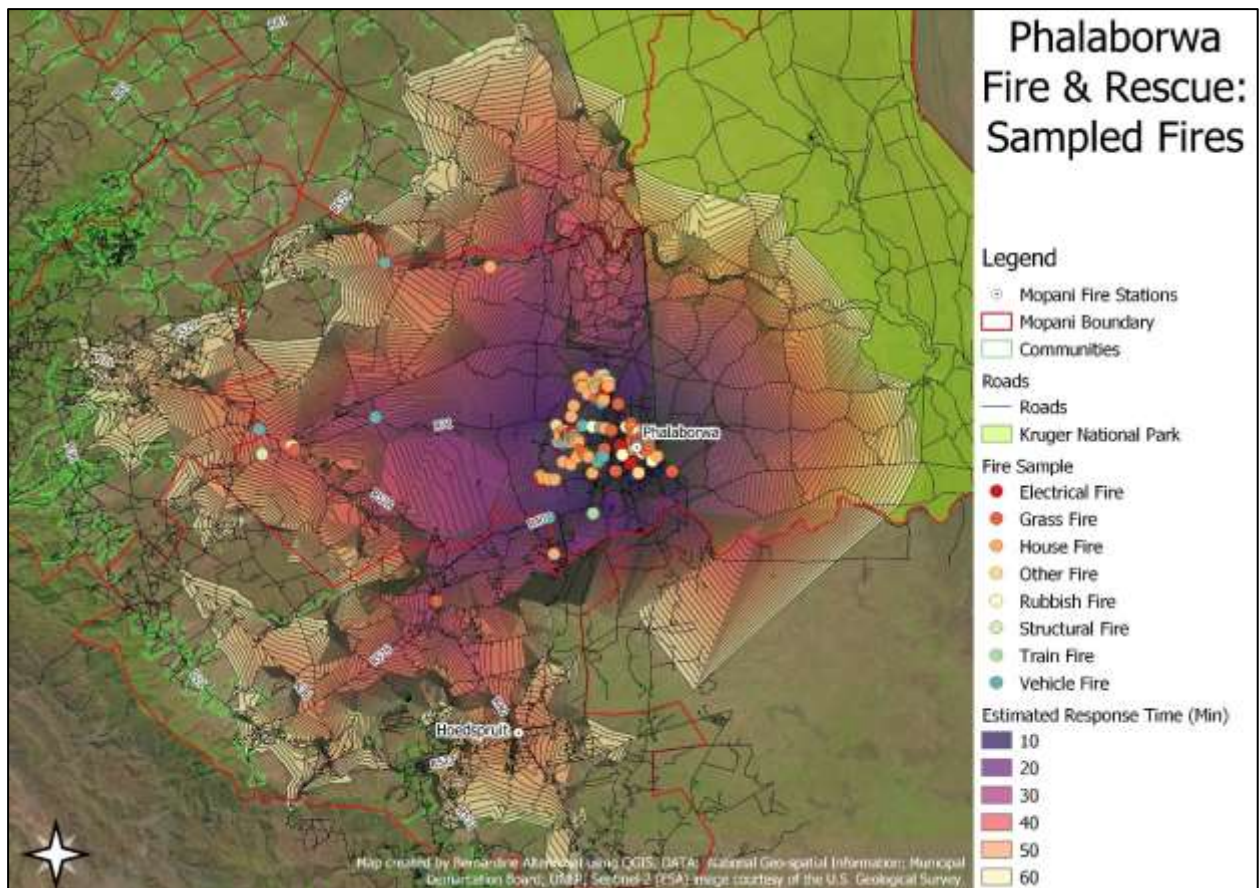


Figure 4-67: Areas within the estimated 60-minute reach of the Phalaborwa Fire Station and fires dealt with between 2016 and 2019

Figure 4-68 below provides an overview of fire risk plotted against estimated response time for the Phalaborwa Fire Station. Fire response to the different residential areas, most prominently represented by Phalaborwa, Namakgale and Lulekani, are indicated in Figure 4-69. Although most fires in the low risk category are estimated to have been reached within expected response times (71.02%) the disparity between the different residential areas is clearly indicated by the two separate peaks seen on the graph. A similar trend can be seen in Figure 4-70, which indicates moderate risk and estimated response times to fires within this risk category. There is a greater spread in the rural risk category, with an appreciable 84.85% of fires in this risk category estimated to have been reached within the recommended response time of 20 minutes (Figure 4-71). In terms of this risk category, most of the most populated areas can be reached within the recommended response time. The clustering of such a high proportion of the population around one node is unique to Ba-Phalaborwa Municipality and somewhat simplifies the delivery of service compared to the remaining four local municipalities within the Mopani District Municipality. Figure 4-72 indicates special risk. Although within relative close proximity to Phalaborwa, reaching all areas of the special risk area may not always be possible. This risk is however offset by the mine's

own emergency service which is located on site and will be the first-line response in the event of an emergency.

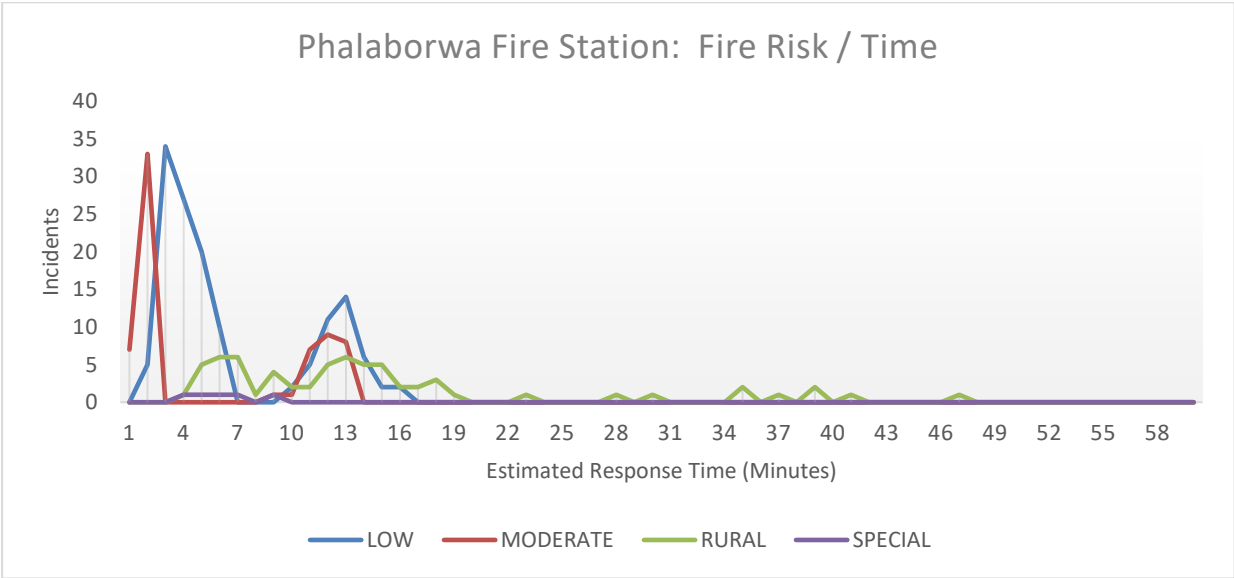


Figure 4-68: Sampled fires plotted per time interval and risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

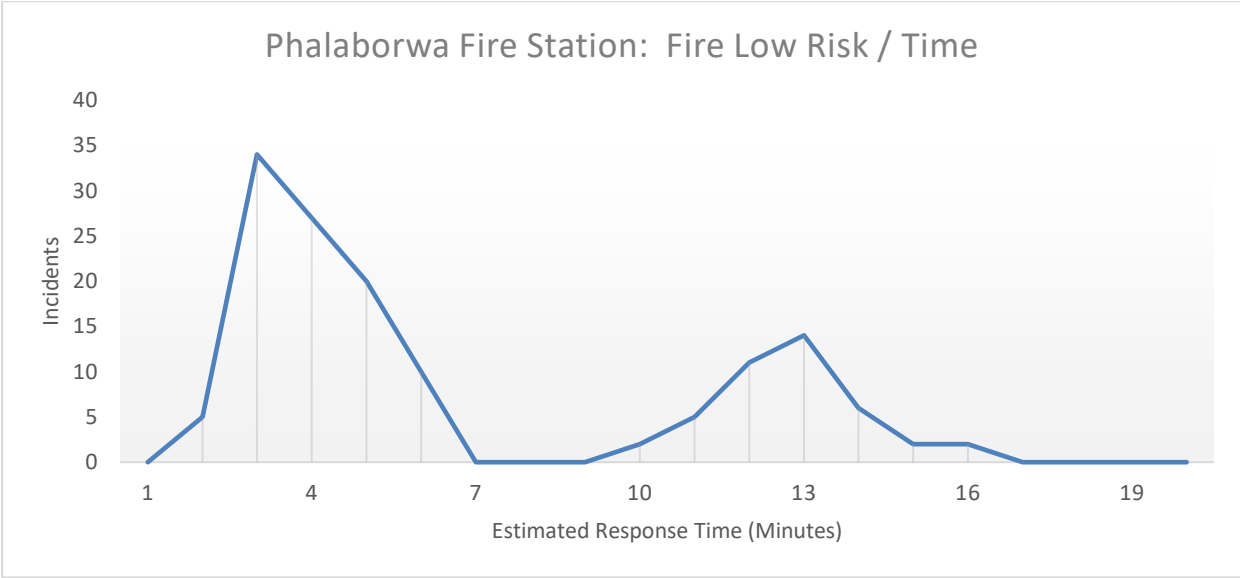


Figure 4-69: Sampled fires plotted per time interval and low risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

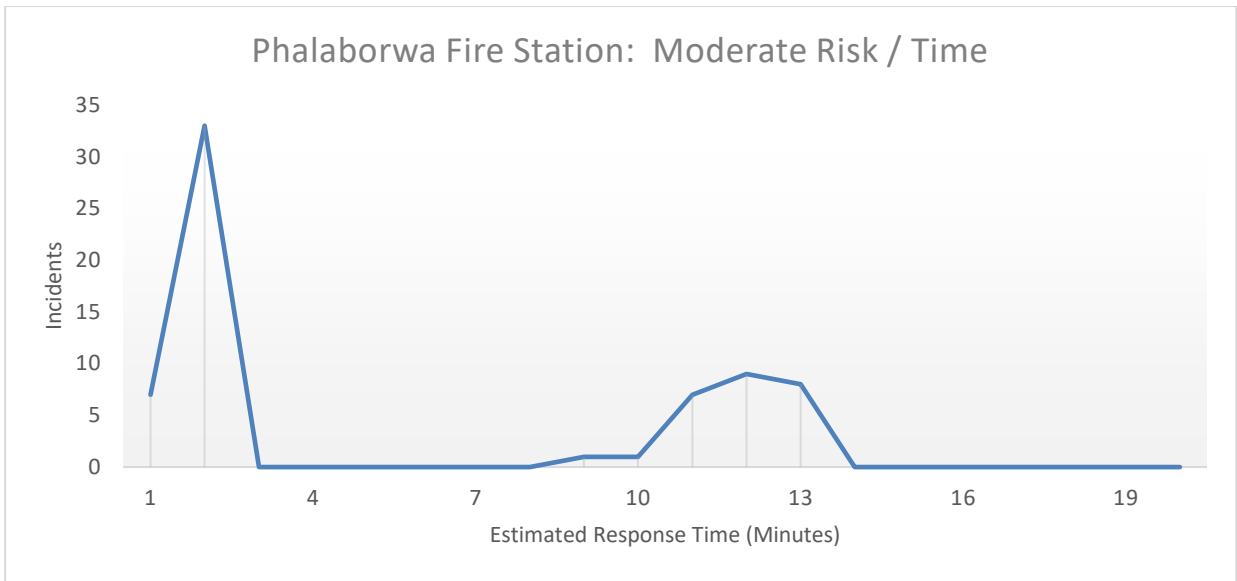


Figure 4-70: Sampled fires plotted per time interval and moderate risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

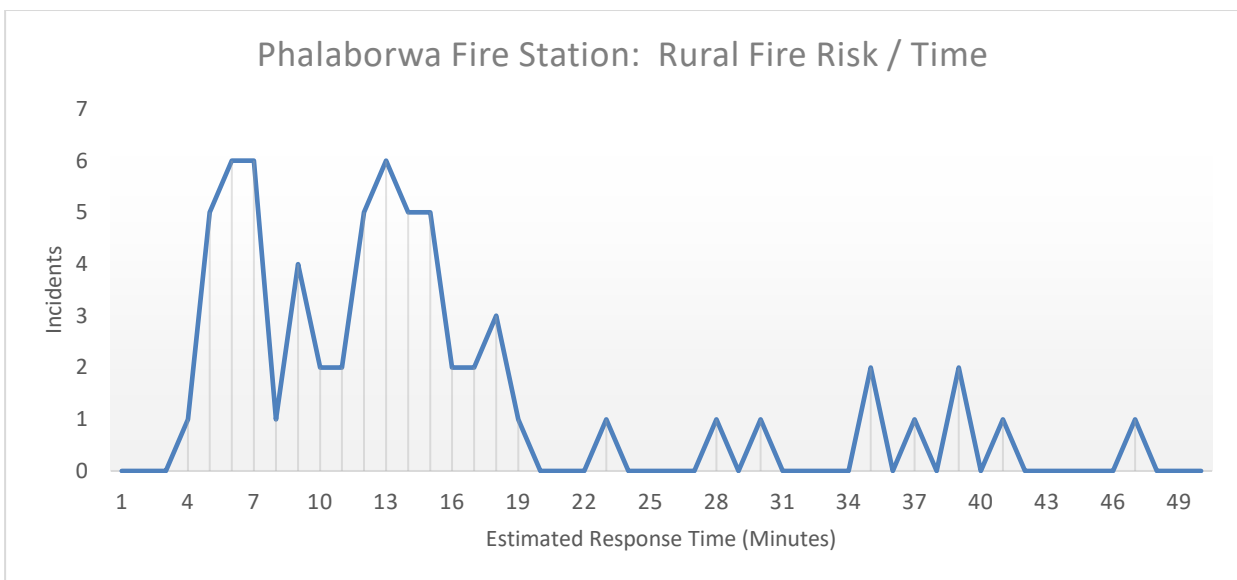


Figure 4-71: Sampled fires plotted per time interval and rural risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

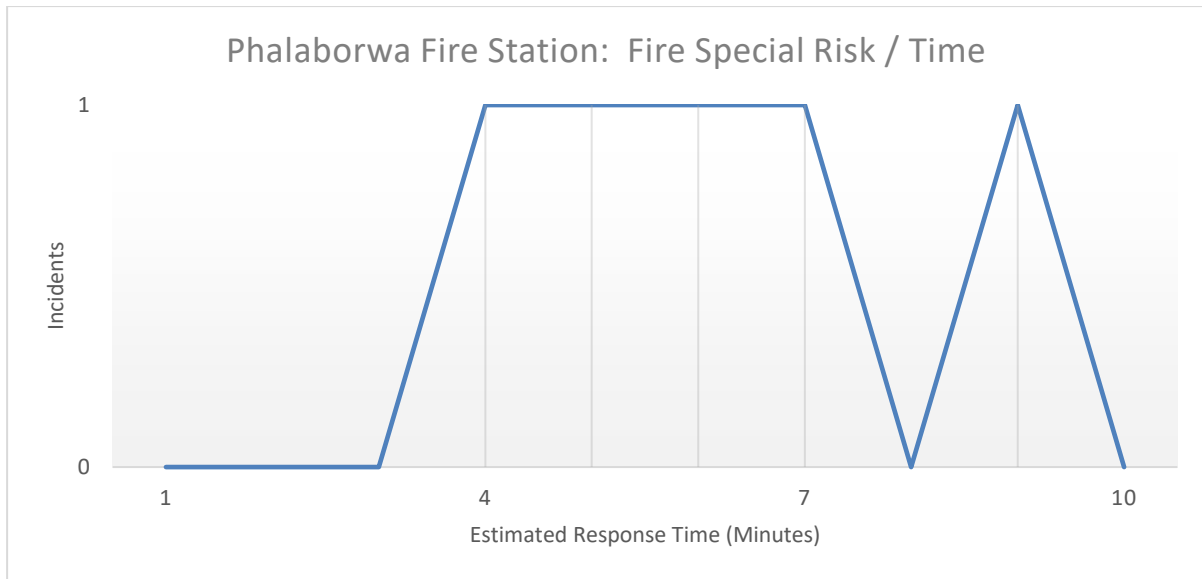


Figure 4-72: Sampled fires plotted per time interval and special risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

4.2.9.2 Rescue incidents dealt with by the Phalaborwa Fire Station

Table 4-20 provides a tabulated summary of the proportion of rescue types from the sampled rescue data for the Phalaborwa Fire Station. The overwhelming majority of rescue incidents related to light motor vehicle accidents (95.29%), followed by a smaller number of other rescue types, such as truck, pedestrian and taxi accidents. Figure 4-73 indicates that these rescue-related incidents mostly occurred on the main access routes to Phalaborwa / Lulekani / Namakgale, as well as within these settlements. The unique spatial distribution of the population of Ba-Phalaborwa is highly likely to contribute towards this spatial arrangement of rescue incidents since there must be a daily influx of people travelling to and from work, as well as delivery vehicles travelling to and from the mine. Mining is recognised as the main economic driver in BPM, according to the BPM IDP, but there are only two access routes to the mine from the west (via the R71 or R40), meaning that there is probably more traffic congestion on these two routes. There is no access to the mine from the east as the mine is located alongside the western boundary of the Kruger National Park. With access on a limited number of routes, and only from one side, a unique situation has developed with traffic flow, which is probably contributing significantly to the occurrence of accidents on these two routes. Additionally, these two routes accommodate traffic flow for tourism, particularly for the Phalaborwa Gate entrance to the Kruger National Park. The end result is a bottle-neck of traffic flow. Although finding a solution to this problem falls outside the scope of work of fire and rescue services, the data can be used to inform decisions by the responsible sector department i.e. the Department of Transport and SANRAL. The Phalaborwa Fire Station, which has been shown to deal with many light motor

vehicle accidents, requires sufficient rescue equipment – possibly multiple sets and vehicles – to ensure that sufficient rescue resources are available at all times.

In Table 4-21 it can be noted that an estimated 61.91% of rescue-related incidents in the low risk category, 55.56% of incidents in the moderate risk category and 64.80% of incidents in the rural risk category could be reached within recommended response times. In the special risk category, only an estimated 25% of incidents could be reached within recommended response times. As in the case of fire, there were a limited number of rescue-related incidents which occurred within this risk category (n=8).

Table 4-20: The proportion of rescue types within the sampled data for the Phalaborwa Fire Station

RESCUE TYPE	NUMBER	%
MVA	263	95.29%
Truck Accidents	5	1.81%
Pedestrian Accidents	3	1.09%
Taxi Accidents	5	1.81%
Total	276	

Table 4-21: The estimated number of rescues reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	61.91%	32.10%
Moderate	7 Min	55.56%	44.44%
Rural	20 Min	64.80%	35.20%
Special	5 Min	25.00%	75.00%

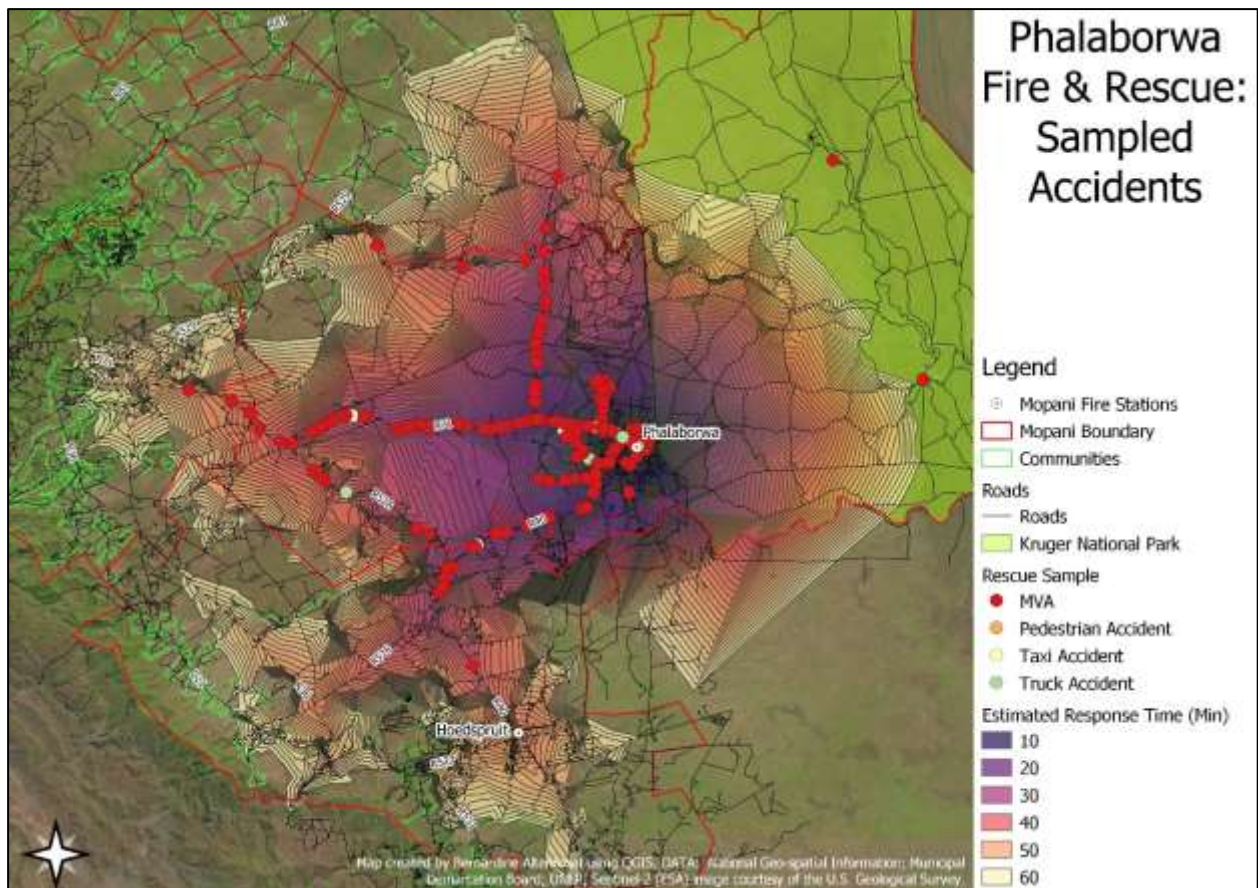


Figure 4-73: Areas within the estimated 60-minute reach of the Phalaborwa Fire Station and accidents dealt with between 2016 and 2019

The estimated response time plotted against the different risk categories is considered for the Phalaborwa Fire Station in Figure 4-74 below. As in the case of Phalaborwa’s fire-related incidents, the low and moderate risk categories (Figure 4-75 and Figure 4-76) indicate distinct peaks which reflect the different urbanised areas of Phalaborwa, Lulekani, Namakgale and Gravelotte. Given the road network leading to Phalaborwa, and the relative distances from surrounding local municipalities, there is a greater spread of rescue-related incidents in the rural risk category (Figure 4-77). The distinctive peak around Phalaborwa / Lulekani / Namakgale in the number of rescue incidents within an estimated 15 minutes from Phalaborwa Fire Station is, however, still evident. Although there were few rescue incidents within the special risk category (n=8), it is estimated that very few of these could be reached within recommended response times (Figure 4-78). The gravel roads located here are likely to have been an inhibiting factor in this regard.

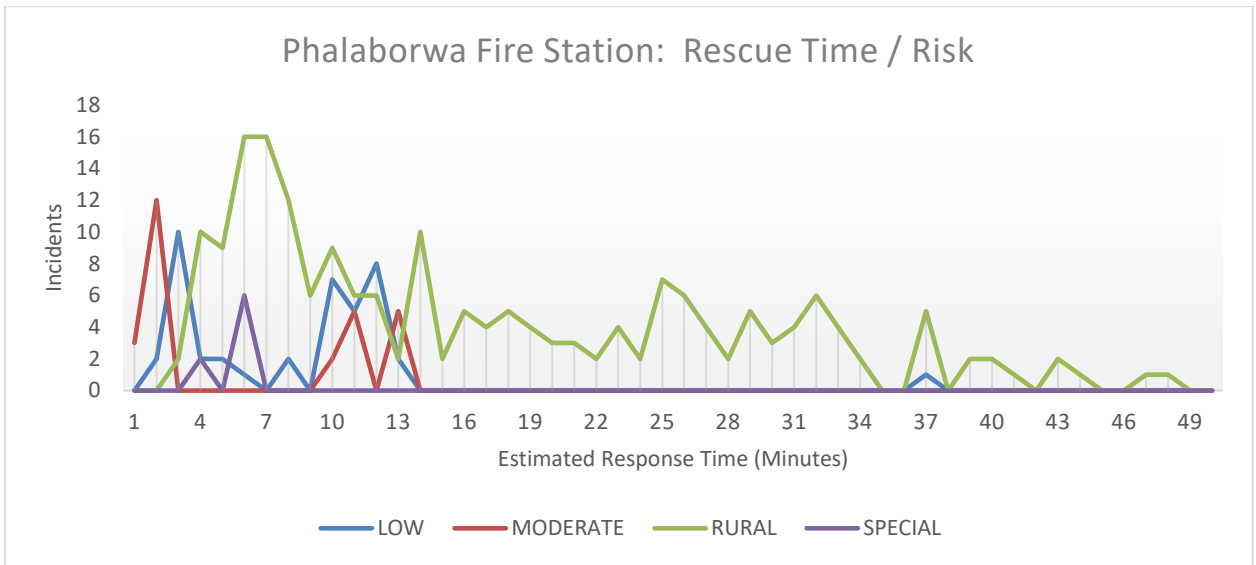


Figure 4-74: Sampled rescues plotted per time interval and risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

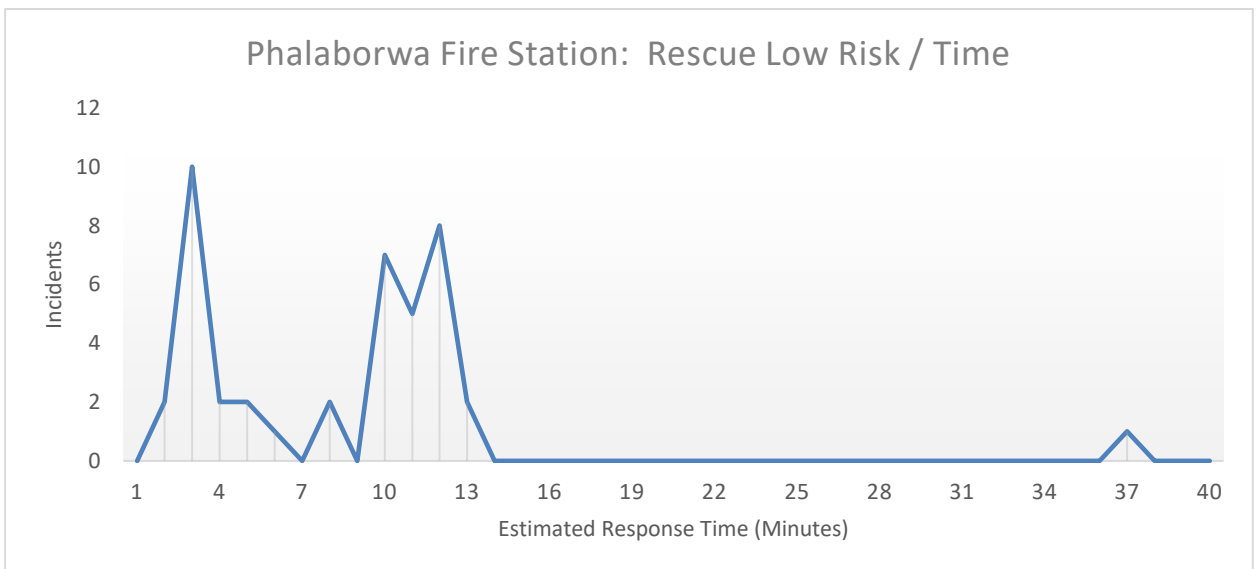


Figure 4-75: Sampled rescues plotted per time interval and low risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

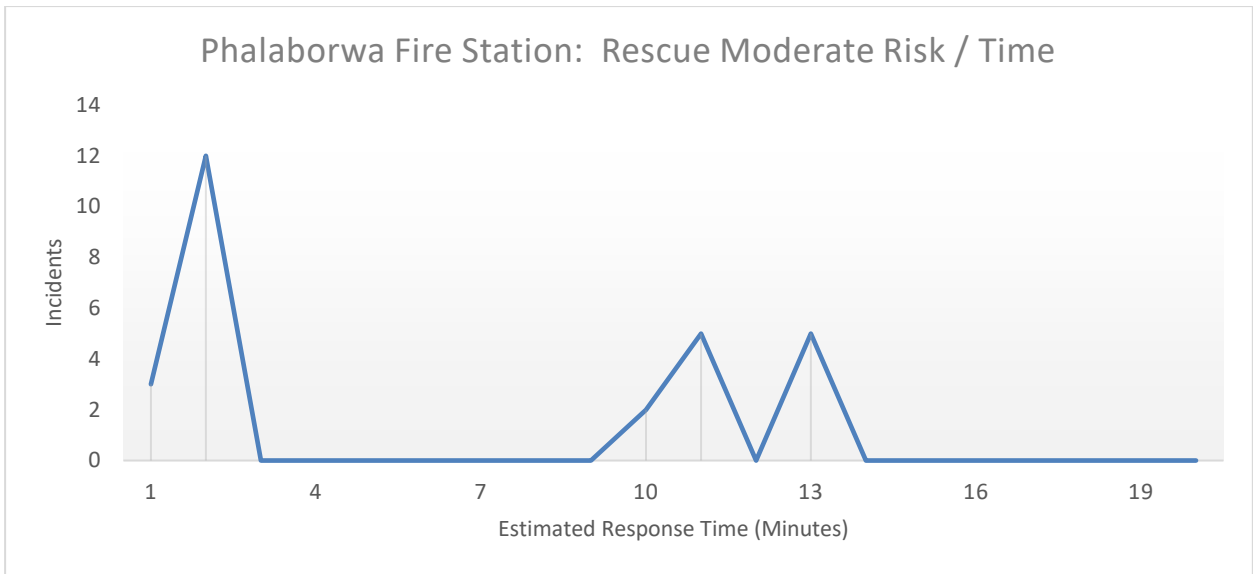


Figure 4-76: Sampled rescues plotted per time interval and moderate risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

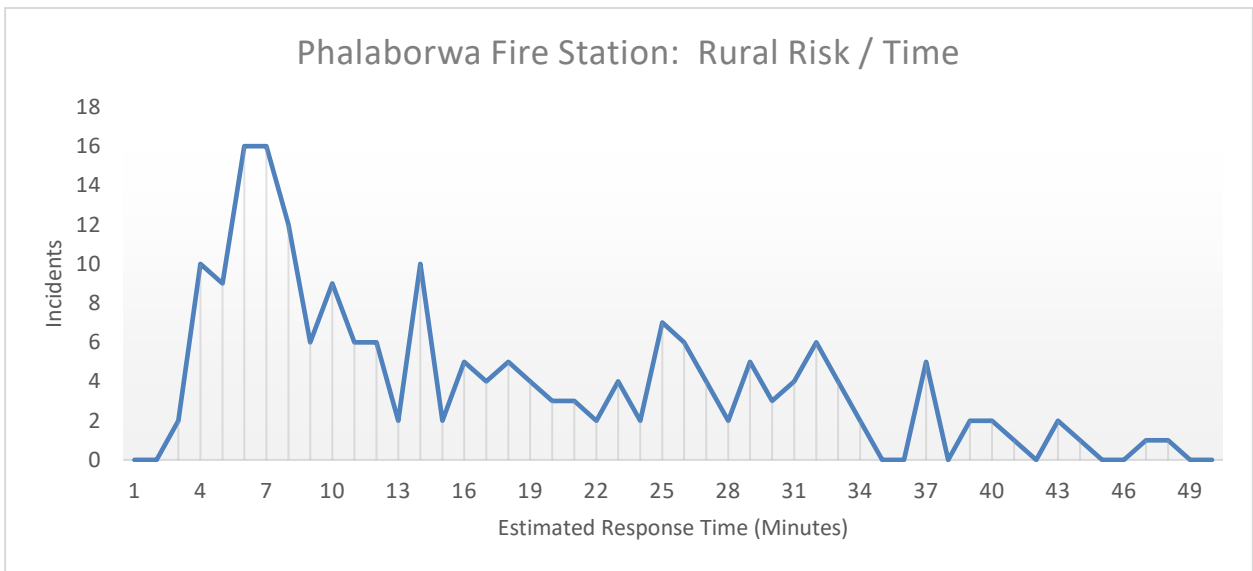


Figure 4-77: Sampled rescues plotted per time interval and rural risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

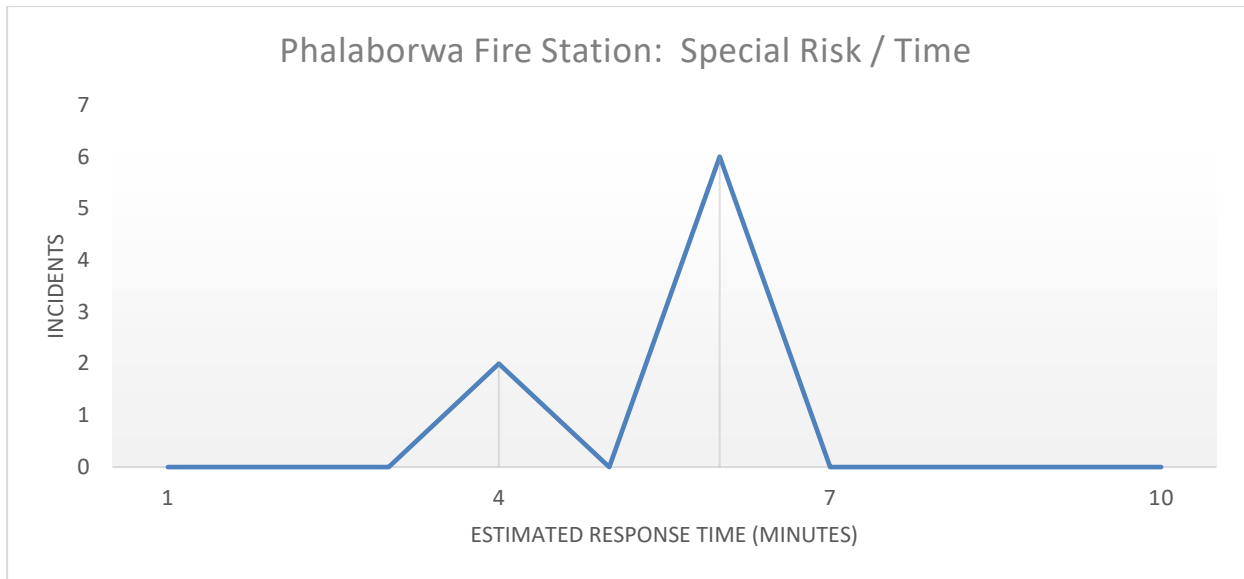


Figure 4-78: Sampled rescues plotted per time interval and special risk type for incidents attended to by the Phalaborwa Fire Station between 2016 and 2019

4.3 Management perspectives on fire and rescue services

In keeping with the explanatory sequential research design, following the quantitative data collection and analysis, the qualitative phase seeks to be further explored and explained. As such, Key Informant Interviews were held with senior managers from fire and rescue services. Among key aspects discussed were the application of SANS (Section 4.3.1), expansion of service (Section 4.3.2), the PIER system (Section 4.3.3) and the use of collaborative networks (Section 4.3.4).

4.3.1 Application of SANS

Besides responding to demand, applicable national standards in the provision of fire and rescue services should be considered. The SANS 10090:2018 provides guidance on the effective provision of a fire service and offers mechanisms through which performance can be measured (SANS, 2018:ii). Feasibility of the establishment of new stations is thus a very important consideration to justify the cost involved, not only in the establishment of new stations, but also the long-term running costs, such as vehicle maintenance, staff salaries and operating costs. The feasibility of station establishment and financial implications associated herewith are also acknowledged in the study by Green, *et al.* (2014:54). However, Respondents from Mopani Fire and Rescue Services conceded that additional fire stations may be required in some areas. Using the data from this study in combination with SANS requirements, the potential reduction in response times through the development of an additional fire station will be tested. The use of the

data generated in this study will show how it can aid in better decision-making and thus risk reduction

As illustrated in the data analysis section covered in section 4.2 above, there is a wealth of data which can be extracted, analysed and used for strategic decision-making through the information management process and use of GIS. This includes the identification of peak times of the day and days of the week when specific types of incidents are likely to occur and, in the case of accidents, which roads are most likely to be affected. This information, according to fire and rescue service management, aids in decisions on aspects of personnel management, such as requirements for standby and overtime. Incorporating the SANS recommended response times into the analysis provides additional opportunity to improve service delivery. Estimated response times from each fire station according to different fire risk categories (according to the SANS) can be measured and visualised in such a way that which areas where service delivery can be improved or where needs are not being met can be easily identified. Through the same process, proposed new fire station locations can be identified and tested to determine their likely effect in improving service delivery. In the case of Mopani District Municipality, the interviews with Respondents from fire and rescue services indicated that the close working relationship between disaster management and fire and rescue services has yielded results which work towards improved service delivery and disaster risk reduction. This is in line with the proactive approach advocated by the NDMA (57 of 2002) and NDMF.

According to Respondents from fire and rescue services management, the visualisation and analysis of incident data has provided a better understanding of individual fire station needs for fire and rescue services management members, and has subsequently resulted in better resource allocation, particularly in terms of specialised vehicle allocation. The long-term analysis and visualisation of the data using GIS also gave rise to the realisation that additional stations or satellite stations would be required to meet demand. This was indicated by areas of high demand, which were spatially distant from individual fire stations. In section 2.2.1 of chapter 2, the role of capacity as a component in disaster risk reduction was explained at length. The UNDRR definitions recognise that capacity can include infrastructure and institutions (UNDRR, 2017b). Wentink and Van Niekerk (2017) were also cited for recognising that capacity development is required for the effective functioning of disaster risk management (Wentink and Van Niekerk, 2017:3). In applying the results of the analysis undertaken on Mopani Fire and Rescue Service, disaster risk reduction can be achieved through capacity building of individual stations and the development of new stations, where required.

According to senior fire and rescue service management, using the analysed and visualised spatial data as motivation, of the three proposals for new stations, the proposal for the Gavaza Fire Station has already received Council approval from the MDM and proposals for the establishment of stations at The Oaks and Ga-Kgapane have also been supported, but Council approval has not yet been received. This is an indication that information management and GIS can be used to support decision-making on aspects such as station location and resource needs for fire and rescue services. The studies by Green *et al.* (2014) and Isa *et al.* (2018) also clearly illustrated this relationship as well as the potential for improved capacity for disaster response (Green, *et al.* 2014:53; Isa, *et al.*, 2018:42).

4.3.2 Expansion of service

The expansion of fire and rescue services is a daunting task which requires a carefully-considered, strategic approach which must also take future development into account. According to respondent 1 and respondent 2, interviewed as part of this study, of the five current stations in the Mopani District, the Tzaneen Fire Station was the first to be established. They further explained that as jurisdictional boundaries and administrative structures changed over the years, other main towns were considered for the establishment of additional fire stations to cover risk. This would eventually give rise to the establishment of fire stations in Giyani and Phalaborwa, followed in later years by Hoedspruit and Modjadjiskloof during the 2000's. Respondent 1 also indicated that the development of a new fire station is a long-term process, which can span several years, with various motivations needed for such an addition.

Respondents explained that once a site has been identified for development, a process of long-term budgeting and planning for the new station follows, including a linkage to the municipal IDP. Once completed, suitable equipment and vehicles need to be procured and personnel deployment and appointment will complete the process. According to the respondents, the main drivers that will inform decisions regarding station location include increased demand, upscaling of residential properties (especially in the rural areas) and increased development, such as large shopping complexes. Changes in demand over time can be determined through information management and the application of GIS analysis. Approval has already been granted by the MDM Council for the development of a new fire station at Gavaza, with another two stations approved in principle. The analysis of the data and research this study generates can provide tremendous insight into how, where and with what resources these stations should be established. This is an indication of how GIS, coupled with information management, has been used as a tool to guide decision-making in fire station location for improved service delivery.

4.3.2.1 Gavaza Fire Station as a satellite station to Tzaneen Fire Station

Gavaza is located about 30km south-east of Tzaneen in the Maake area. The site, which has been earmarked with good potential for the development of a satellite fire station to Tzaneen, is located right alongside the R36 and a mere 4.3km from the Maake Plaza shopping complex. As noted in the GTM IDP, Lenyenye, Nkowankowa, Letsitele and Haenertsburg are proclaimed towns, in addition to Tzaneen. The placement of a satellite fire station at Gavaza is anticipated to substantially reduce travelling time to fire- and rescue-related incidents at Lenyenye, Nkowankowa and Letsitele, compared to a response from Tzaneen alone. The placement of this station would also bring fire services closer to the informal settlements noted in the GTM IDP in the Ritavi and Maake areas. Additionally, this would bring better service provision of fire and rescue services to the vast rural communities that are found around Ritavi and Maake, located to the south-east of the Greater Tzaneen Municipality.

The establishment of a fire station, or even a fire house, at Gavaza has the potential to provide a substantial increase in footprint which would not only improve response times in and around Nkowankowa, Lenyenye and Letsitele, but would also enable further reach into Maruleng, which can be of assistance to the Maruleng Fire Station (Figure 4-79). Given the different fire risk categories, estimated response times of 5-, 7-, 10-, 20- and 30-minutes have been considered against these categories to indicate areas where service can be enhanced (Figure 4-80). To evaluate the effectiveness of this site, historic response data from the Tzaneen Fire Station was used to measure potential differences in response time. This historic incident data may also be used to determine specific resource needs in terms of vehicles and equipment that would be required by the Gavaza Fire Station.

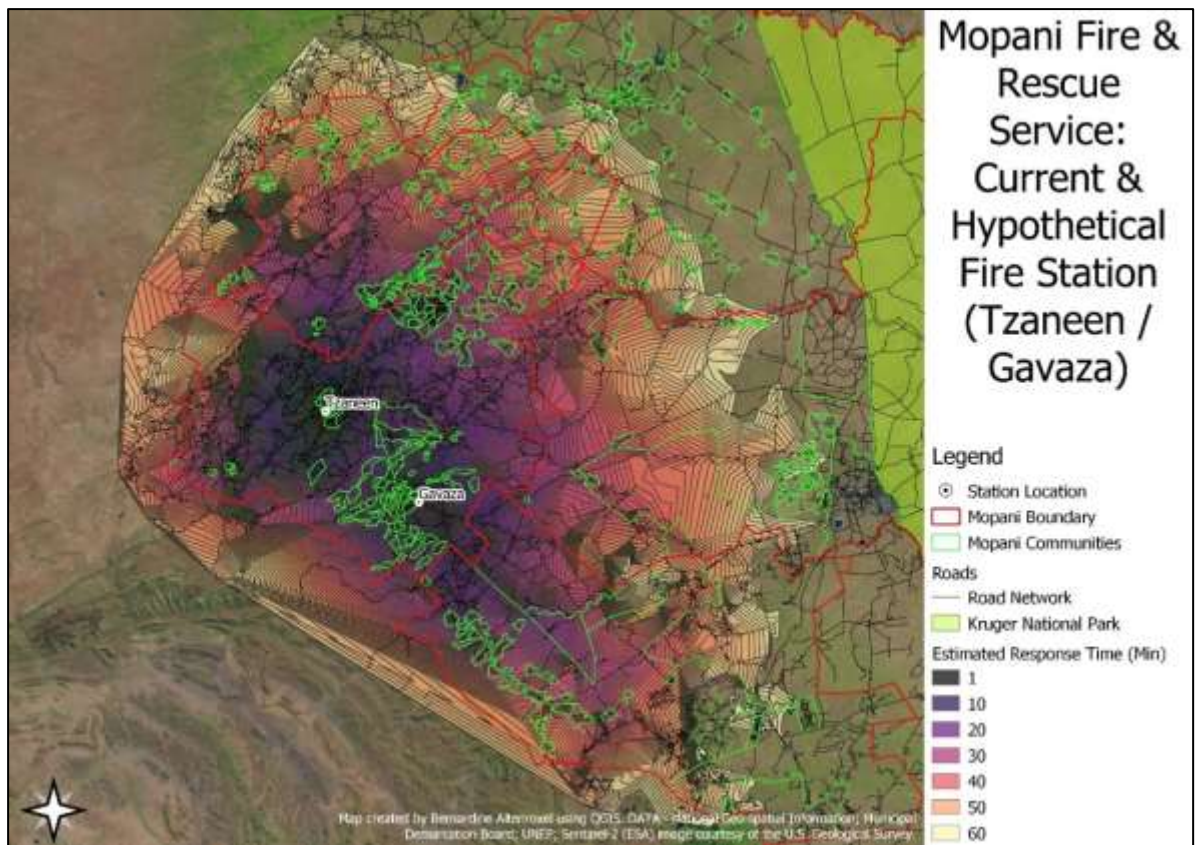


Figure 4-79: Areas within the estimated 60-minute reach of the Tzaneen Fire Station and proposed Gavaza Fire Station

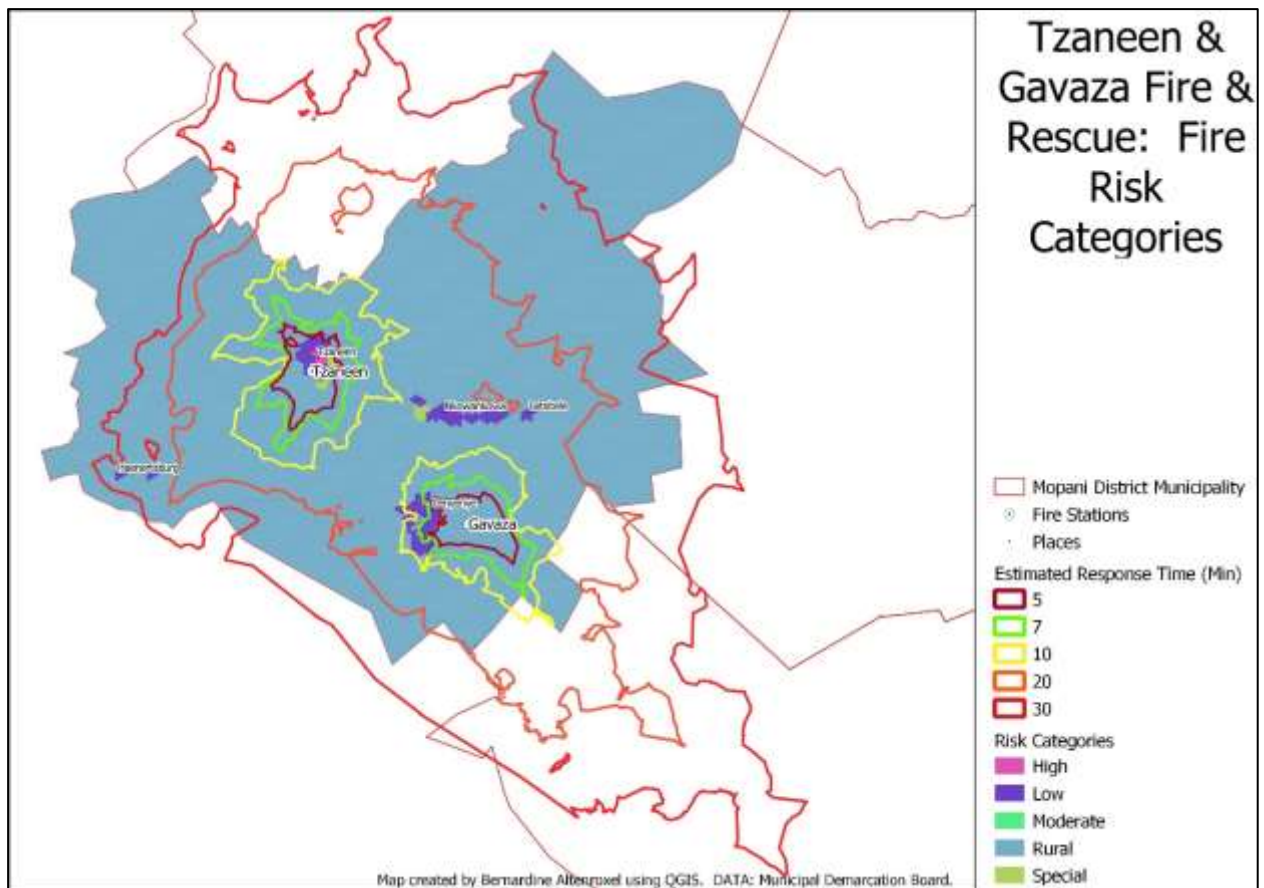


Figure 4-80: Areas within an estimated 5-, 7-, 10-, 20- and 30-minute reach of the Tzaneen Fire Station and proposed Gavaza Fire Station

4.3.2.1.1 Potential for improved response to fire

In Table 4-22 below, potential estimated response times with the additional fire station at Gavaza, are considered for the different risk categories. To understand any possible gains which could be made, the potential estimated response times are compared against the estimated response times for the Tzaneen Fire Station alone (Table 4-23). This indicates the potential improvement in response times for the low risk classification from 68.42% to 77.19%. The greatest benefit could potentially be to those living within the rural risk category, with a potential improvement from 68.71% to 87.20% of fires reached within the recommended response times. Figure 4-81 provides an overview of the historic fire sample for the Tzaneen Fire Station and how this would correspond to the improved footprint potentially created by an additional station located at Gavaza. This also indicates the types of fires typically dealt with in and around the Ritavi and Maake area which the Gavaza Fire Station would serve, and can inform station resource needs. Based on the data, it can be seen that the predominant fire types in Ritavi and Maake are house fires, structural fires and vehicle fires.

Table 4-22: The estimated number of fires which could potentially be reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	77.19%	22.81%
Moderate	7 Min	0.00%	100.00%
Rural	20 Min	87.20%	12.80%
High	5 Min	100%	0.00%

Table 4-23: The estimated number of fires which could potentially be reached within the recommended response time compared against performance by the current station at Tzaneen on its own

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN
Low (Gavaza & Tzaneen)	10 Min	77.19%
Low (Tzaneen)		68.42%
Moderate (Gavaza & Tzaneen)	7 Min	0.00%
Moderate (Tzaneen)		0.00%
Rural (Gavaza & Tzaneen)	20 Min	87.20%
Rural (Tzaneen)		68.71%
High (Gavaza & Tzaneen)	5 Min	100%
High (Tzaneen)		100%

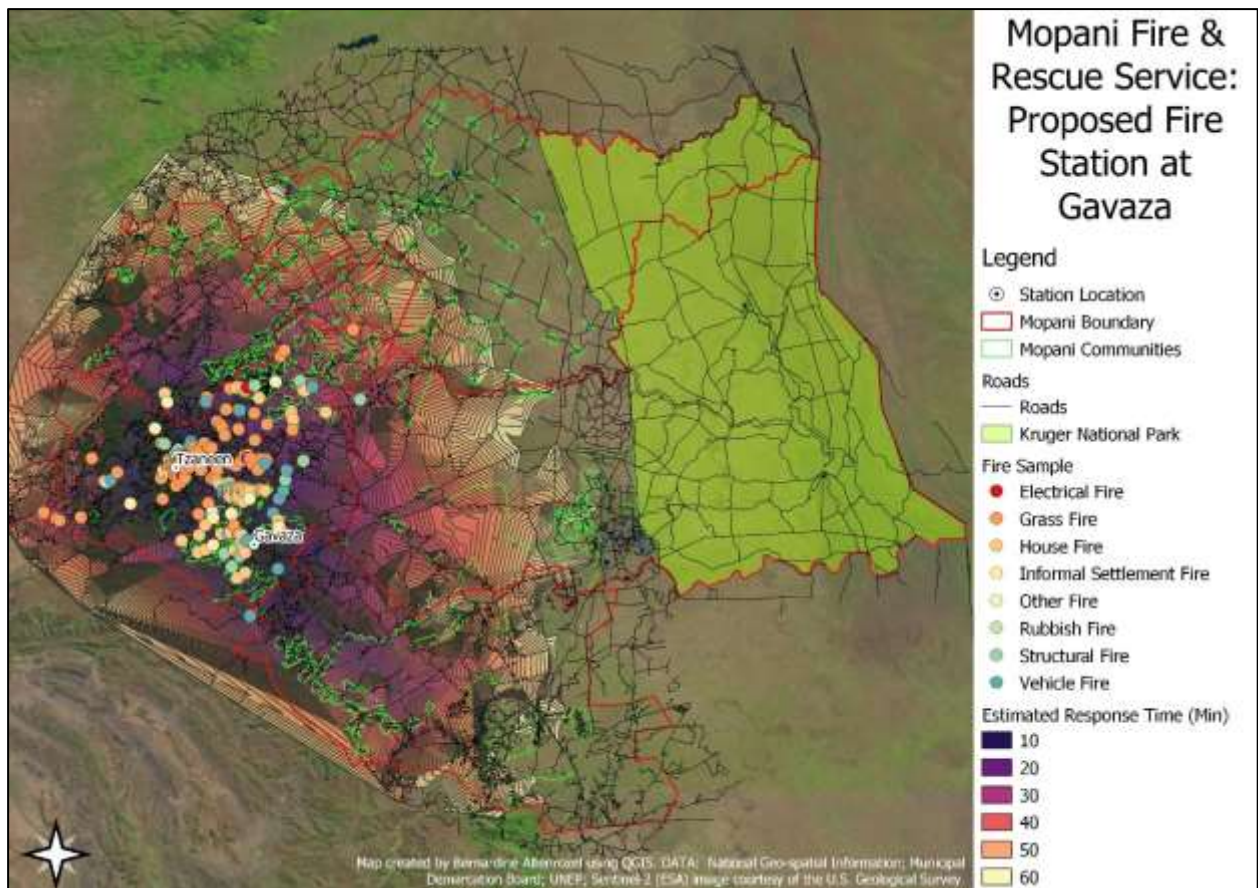


Figure 4-81: Areas within the estimated 60-minute reach of the Tzaneen Fire Station and proposed Gavaza Fire Station and historic fires dealt with between 2016 and 2019

Figure 4-82 below provides an overview of the sampled fires against estimated potential response time and risk categories. The difference in estimated response time in terms of the low classification is considered in Figure 4-83. Although this does not quite reach the target of 90%, it does create a potential overall reduction in response time from 22 minutes to 18 minutes. Figure 4-84 for the rural risk classification shows a similar potential overall reduction in response times to potentially reach close to 90% of fire-related incidents within the recommended response time.

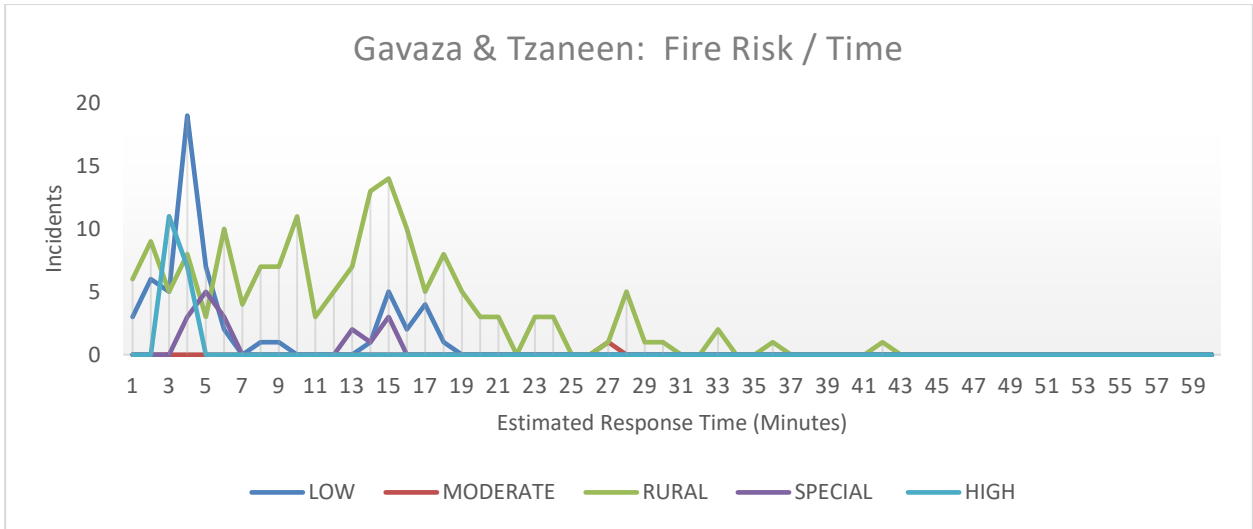


Figure 4-82: Sampled fires plotted per time interval and risk type for Gavaza and Tzaneen

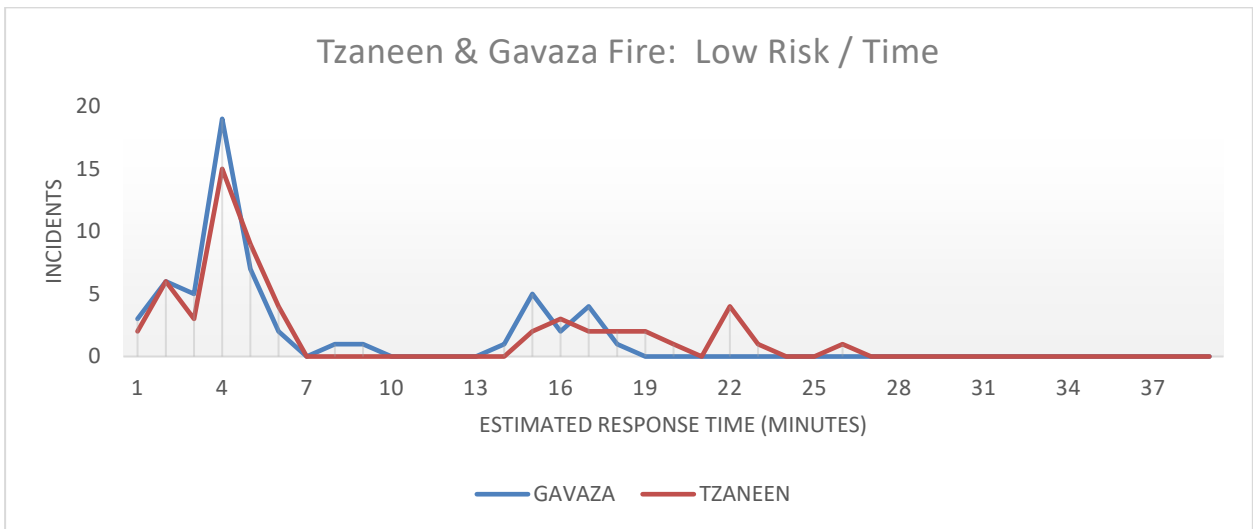


Figure 4-83: Sampled fires plotted per time interval and low risk type for Gavaza and Tzaneen

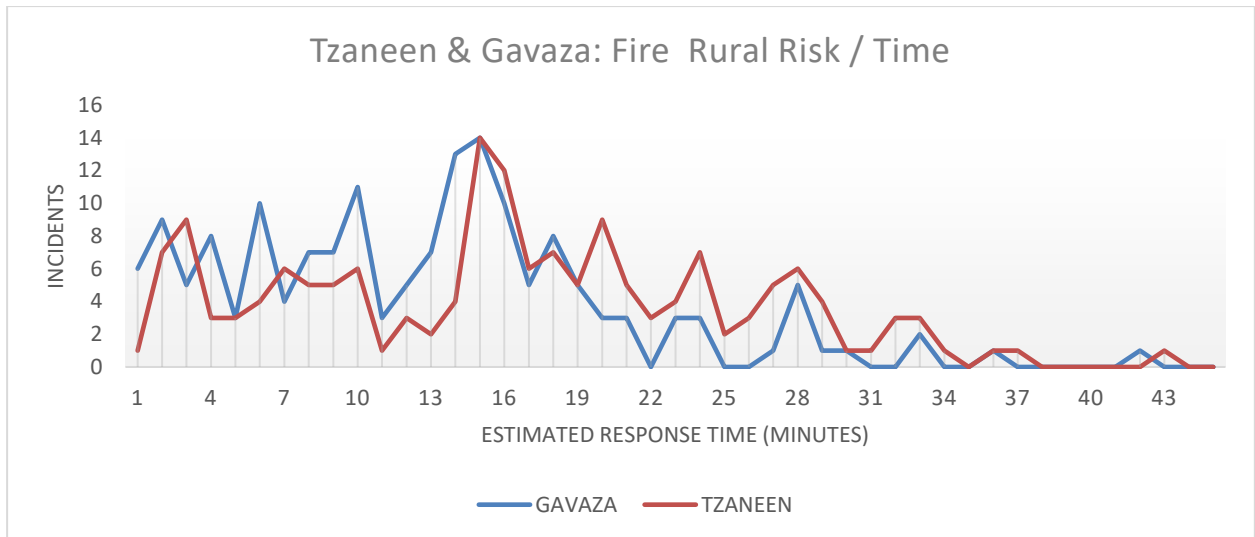


Figure 4-84: Sampled fires plotted per time interval and rural risk type for Gavaza and Tzaneen

4.3.2.1.2 Potential for improved response to rescue

The placement of a new station at Gavaza to supplement the service provided by the Tzaneen Fire Station could potentially lead to a similar improvement in service delivery in terms of response times to rescue incidents (Figure 4-85). As in the case of fire-related incidents discussed in Section 4.3.2.1.1 above, resource needs for the proposed Gavaza Fire Station can be informed by the historic incident data, which indicates that motor vehicle accidents and taxi accidents are the predominant rescue-related incident types in the Ritavi and Maake areas. Table 4-24 below provides an overview of potential response times to rescue-related incidents for the Tzaneen Fire Station supplemented by the proposed station at Gavaza. Table 4-25 compares estimated response times against risk categories for the Tzaneen Fire Station, as well as the combined effect of the proposed station at Gavaza and the Tzaneen Fire Station. This indicates very good improvements in estimated response times for the low and rural risk categories, reaching close to the desired 90% reached within the recommended response time for both categories.

Table 4-24: The estimated number of rescues which could potentially be reached within and outside the recommended response time

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN	OUTSIDE
Low	10 Min	88.24%	11.77%
Moderate	7 Min	0.00%	0.00%
Rural	20 Min	88.84%	11.16%
High	5 Min	100.00%	0.00%

Table 4-25: The estimated number of rescues which could potentially be reached within the recommended response time compared against performance by the current station at Tzaneen on its own

RISK CATEGORY	EXPECTED RESPONSE TIME	WITHIN
Low (Gavaza & Tzaneen)	10 Min	88.24%
Low (Tzaneen)		76%
Moderate (Gavaza & Tzaneen)	7 Min	0.00%
Moderate (Tzaneen)		0.00%
Rural (Gavaza & Tzaneen)	20 Min	88.84%
Rural (Tzaneen)		78.14%
High (Gavaza & Tzaneen)	5 Min	100%
High (Tzaneen)		100%

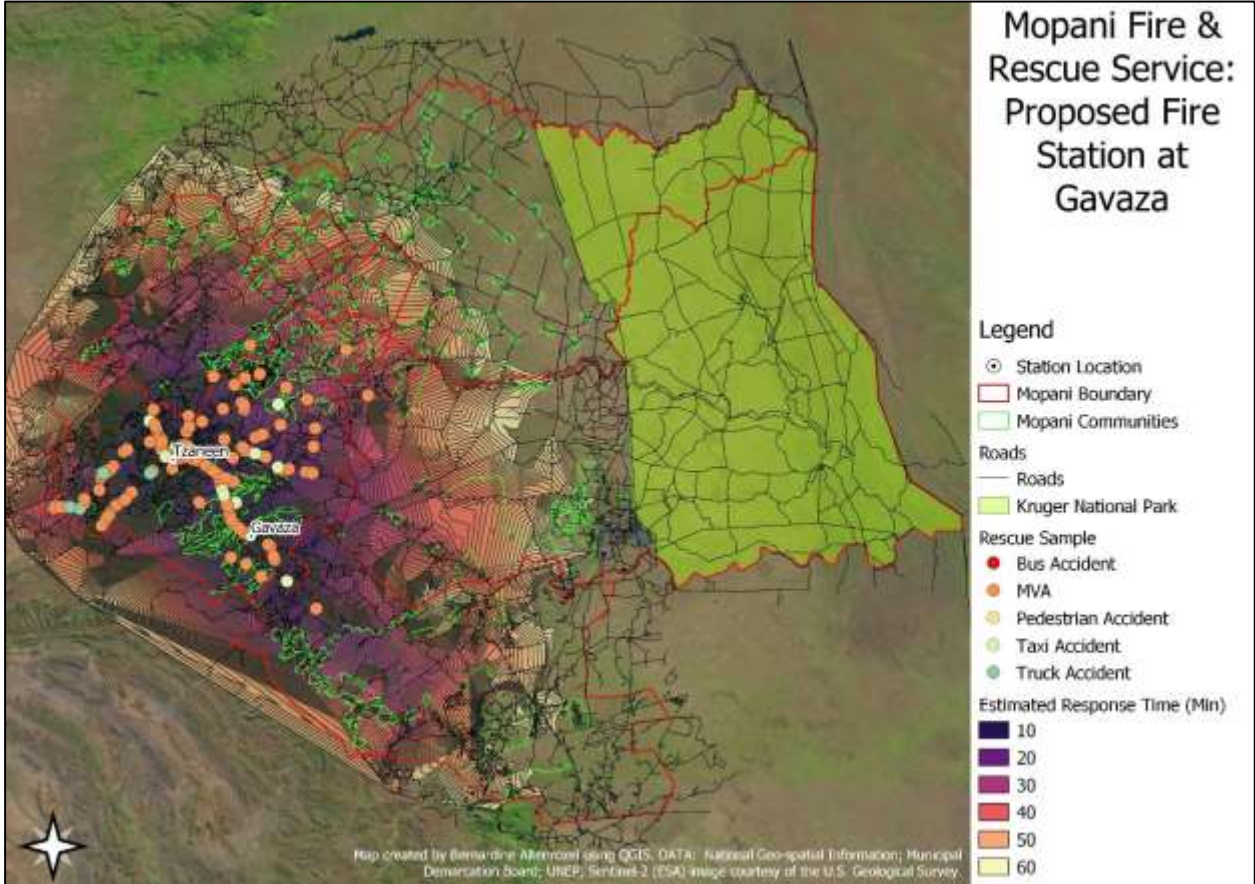


Figure 4-85: Areas within the estimated 60-minute reach of the Tzaneen Fire Station and proposed Gavaza Fire Station and historic accidents dealt with between 2016 and 2019

Figure 4-86 below provides an overview of the estimated response times per risk classification for Tzaneen and Gavaza Stations combined. The gains which can be made in reducing estimated

response times within the low risk classification (Figure 4-87) are clearly evident, as well as those within the rural risk classification (Figure 4-88).

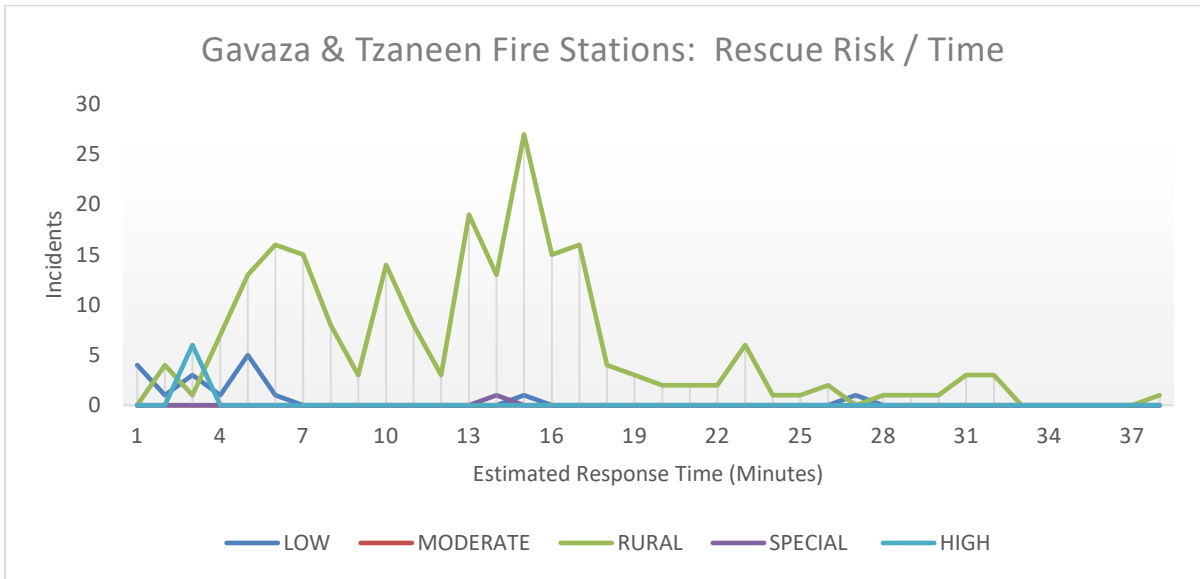


Figure 4-86: Sampled rescues plotted per time interval and risk type for Gavaza and Tzaneen

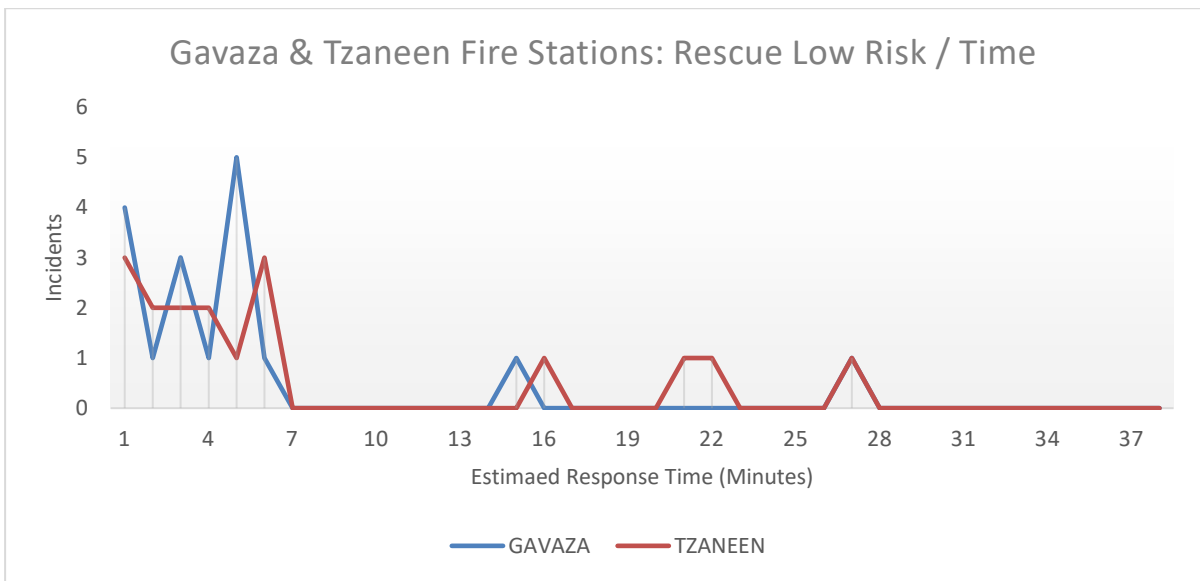


Figure 4-87: Sampled rescues plotted per time interval and low risk type for the proposed Gavaza Fire Station and Tzaneen Fire Station combined, compared to the Tzaneen Fire Station on its own

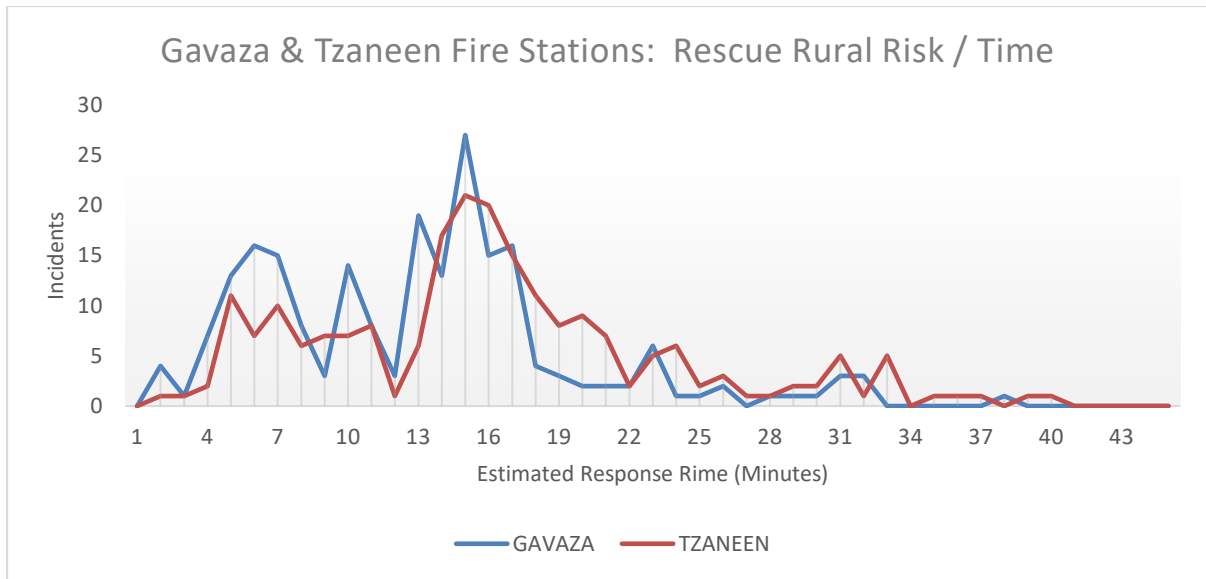


Figure 4-88: Sampled rescues plotted per time interval and rural risk type for the proposed Gavaza Fire Station and Tzaneen Fire Station combined, compared to the Tzaneen Fire Station on its own

4.3.3 The role of the PIER system

Capacity building can take many forms, such as raising awareness and training the community on aspects related to fire prevention and the activation of emergency services. Mopani Fire and Rescue Services indicated that they have adopted the PIER program primarily as a method of raising awareness in the community regarding fire. As highlighted by Dlodla, the eThekweni Metro also makes use of the PIER program for improved public awareness and reduced fire risk (Dlodla, 2016:75). Schools are frequently visited as part of the Mopani PIER program and a participative approach is undertaken, according to Respondent 1. Promotional materials are also usually provided and scholars are later quizzed to ensure they have been adequately capacitated on how to act appropriately in the event of a fire or crash. At workplaces, training on fire extinguishers and basic fire prevention is provided. The PIER program is proactive, encouraging home and workplace safety, and can be developed in conjunction with disaster management awareness activities.

4.3.4 Collaborative networks and road traffic crashes

Accident location data is frequently sourced through the Mopani RIMS network (discussed in Section 2.6.1). This provides the opportunity to feed the fully-analysed data back into the network for strategic decision-making on issues related to road safety. From the data collected from Mopani Fire and Rescue Services, it is evident that road traffic crashes are a pervasive problem

in all five local municipalities within the Mopani District. GIS provides the opportunity to better visualise the occurrence of accidents over different periods of time, to identify problem areas and problem roads for targeted intervention, similar to the interventions resulting from the study by Osidele (2016). In BPM, for example, the majority of crashes involved light motor vehicles and relatively few heavy motor vehicles (trucks). However, in the GTM and GLM, a larger number of heavy motor crashes can be noted. In effect, this means that any approach towards greater road safety for heavy motor vehicles would best be targeted in the GTM and GLM.

4.4 In summary

The allocation of specific resources to fire stations improves capacity by ensuring that appropriate equipment and vehicles are provided, which meet individual fire station needs and profiles. Individual fire station profiles were mostly revealed through a thorough analysis, including spatial analysis of historic incident data collected from the Mopani Fire and Rescue Service through disaster management information management, and an analysis of the IDP documents. In Section 4.2, the predominant incident types per fire station were revealed through the analysis of historic incident data. This analysis, for example, indicated that the Tzaneen Fire Station deals with a far larger number of fire-related incidents compared to other stations in the Mopani District, while the Phalaborwa Fire Station deals with more rescue-related incidents in the form of accidents. The Tzaneen Fire Station would thus benefit from the allocation of more vehicles and equipment to deal with fire, while the Phalaborwa Fire Station would require more rescue-related equipment and possibly additional rescue units (vehicles). After undertaking network analysis per fire station and combining this with the different fire risk categories and historic incident data, perspectives of Respondents is considered to explain the results of the quantitative analysis. The results indicate how GIS can be used as a tool in service delivery, as well as fire station location and resource needs. Network analysis to estimate response times against historic incident data reveals where improvements can potentially be made in meeting community needs. It is through these types of interventions that capacity can be enhanced, leading to the development of strategic disaster risk reduction measures. The discussion and findings will be discussed in Chapter 5 which follows.

CHAPTER 5: DISCUSSION AND FINDINGS

5.1 Introduction

The detailed exploration of the use of GIS and information management for the Mopani Fire and Rescue Service was undertaken in Chapter 4. Using historic incident data collected from the five fire stations located in the Mopani District Municipality, GIS was tested as a tool to build a better understanding of the operating environment of each fire station. The intention of the detailed analysis in Chapter 4 was to explore how GIS and information management could be coupled to be used as a tool for the development of disaster risk reduction strategies (Objective 1). Furthermore, the use of GIS was explored as a tool which could be used to support decision-making for improved service delivery, fire station location planning and resource needs for Mopani Fire and Rescue Services (Objective 2). Input from senior management from Mopani Fire and Rescue Service was also sought and presented in Chapter 4 to generate a deeper understanding of the results of the GIS analysis. The first two research objectives set in Chapter 1 were thus met in Chapter 4. In this Chapter (Chapter 5), a discussion of the findings primarily in terms of the fourth research objective, to consider how information management can support decision-making in the Mopani District Municipality, is undertaken.

5.2 Discussion of findings

The discussion of the findings that follow below outline the application of information management for disaster management and fire and rescue services. The identification of resource needs for Mopani Fire and Rescue Services is discussed, as well as the feasibility of a new fire station at Gavaza, and suggestions for the use of the analysed data for the benefit of the PIER system and RIMS collaborative network and discussed. In conclusion, a summary of the key findings is presented.

5.2.1 Overview of Mopani Fire and Rescue Services and identification of resource needs

Once sufficient incident data has been collected from individual fire stations, and incident locations verified against station records, remotely-sensed fire data or RIMS records, the type of analysis seen in Section 4.2 of Chapter 4 can be applied. Kernel density mapping aids in visualising historic incident data in such a way that problem areas can be easily identified. In the context of the study on Mopani Fire and Rescue Services, kernel density mapping provided a clear indication of where high-density incident areas are located in the Mopani District Municipality for both fire- and rescue-related incidents. For fire, the majority of fire-related incidents are located

in or around the more heavily urbanised areas of the district where human activity is the greatest, such as in Tzaneen, Maake, Ritavi and Sekororo. Further assessment of the data to determine other trends or patterns, clearly indicates that the Tzaneen Fire Station deals with the highest number of fire-related incidents and needs to be sufficiently capacitated to deal with these. The Modjadjiskloof and Phalaborwa Fire Stations also deal with a fair number of fires and also need to be appropriately capacitated. The analysis serves to guide management decisions on resource needs for individual fire stations to ensure that enough resources are provided to meet demand. This may include the procurement of additional water tankers, rescue equipment, major pumpers and / or skid units, where necessary, to meet individual station needs. This clearly demonstrates how GIS can be used as a tool to inform decision-making on individual fire station resource needs. In using GIS to visualise the SANS requirements in terms of fire risk classification against estimated response times (made possible through network analysis), combined with historic incident data, an additional advantage is provided in understanding where service delivery can be improved. The outcome of the spatial analysis of Mopani Fire and Rescue Services' individual fire stations provided the opportunity for improved planning in future fire station placement.

In terms of rescue-related incidents, the overwhelming majority of which were light motor vehicle crashes, it was revealed that the Phalaborwa Fire Station deals with the highest number of rescues in the district. The Giyani Fire Station, on the other hand, encountered the most serious injuries on crash scenes and the Tzaneen Fire Station dealt with the highest number of fatalities. Serious injuries and fatalities in accidents are an indication of the seriousness of accidents dealt with by these two fire stations – an indication of the need for specialised rescue equipment for extrication. The statistics on crashes related to these three fire stations (Phalaborwa, Giyani and Tzaneen Fire Stations) thus indicate that sufficient rescue equipment is required for all three stations. Furthermore, kernel density mapping is also useful to determine where high density accident areas are located on different roads and can be further analysed to determine crash type i.e. light motor vehicle, heavy motor vehicle, taxi or bus. This will inform resource management for each of the fire stations to cater for specific needs. For example, with the Tzaneen and Modjadjiskloof Fire Stations receiving the most accidents involving trucks, sufficient heavy-duty rescue equipment is thus required for each station in addition to regular rescue equipment. In rendering the data as a series of maps, heatmaps and graphs, specific sections of road can be targeted for intervention through collaboration with other RIMS role players in the field of law enforcement and road safety. The data rendered can also be used for disaster management activities, including disaster risk assessment and disaster risk management planning. Where deemed necessary, a road inspection by engineers can be requested through the RIMS structures, or reports on problem areas can be submitted to the relevant road authority for

consideration. Additionally, MOUs with neighbouring district municipalities can be sought where there is overlap in response to incidents, as highlighted in the case of Maruleng where more than 10% of accidents sampled occurred in neighbouring Sekhukhune and Ehlanzeni District Municipalities. Also of note are the problems noted for each of the fire stations in terms of poor access roads as well as the steep terrain (in the case of the GTM and GLM). In these cases, careful consideration of appropriate vehicles for the terrain type are required. Poor water supply identified in the more rural areas means that sufficient water tankers must be available for each fire station to ensure that bulk water can be driven to sites of fires where traditional water reticulation is insufficient or not available.

5.2.2 Additional fire stations and disaster risk management

The study has given a clear indication that the planned satellite fire station at Gavaza will be beneficial and will assist in attaining the provisions of the SANS regarding meeting appropriate response times, and can improve service delivery. In the analysis undertaken in Section 4.3.2.1 to determine how effective the planned station may be, it was demonstrated that the proposed Gavaza Fire Station has tremendous potential in reaching future incidents within significantly reduced response times. In particular, a significant potential decrease in estimated response times is indicated for fires in the rural risk classification. Potential reductions in estimated response times to fires in the low risk category are also possible. In terms of rescue-related incidents, estimated response times can potentially be improved significantly (close to the desired 90%) in the low and rural risk categories. It was conceded by Respondents from fire and rescue services that an additional fire station will be beneficial to service delivery.

The GIS analysis method used in the analysis on the potential reduction in response times for the proposed Gavaza Fire Station proved effective in demonstrating how institutional capacity can be enhanced. Other options may also be considered for future fire station placement if development and demand for services increase in years to come, particularly on the western areas of the Greater Letaba Municipality and through the Sekororo area of Maruleng Municipality. The feasibility of the proposed stations at Ga-Kgapane and The Oaks can be explored, should the demand in Greater Letaba and Maruleng Municipalities continue to grow. The potential benefits of each of these stations can be evaluated using the same method used in evaluating the potential benefits of the development of the Gavaza Fire Station. The development of additional stations has the potential to provide more equitable access to fire and rescue service across the Mopani District.

Additional stations will build the capacity of Mopani Fire and Rescue Services by improving resource and service availability in the community. The goal would be to reach incidents within reduced response times and to offer an improved service, thus strengthening institutional capacity. With improved institutional capacity, through strengthened systems combined with appropriate skills and resources, new stations would effectively result in reduced risk. In the context of the Mopani Fire and Rescue Service study, it has been demonstrated that the incident data gathered and analysed through the disaster management information management process also aids in hazard identification. At the same time, Geographic Information Capacity (GIC) is also improved. In turn, this feeds into disaster risk assessment and disaster risk reduction activities, as envisaged by the NDMF and NDMA (57 of 2002), as amended. Known hazards can thus be identified easily and dealt with appropriately.

5.2.3 Input for the PIER system

The analysis and spatial visualisation of historic incident data can add strength to the PIER program by identifying specific areas that can be targeted to raise awareness. In using the spatial analysis of the historic incident data to inform decisions on the application of the PIER program, a strategic advantage is created. This focused approach builds capacity to reduce risk in affected communities. In the Greater Tzaneen Municipality (GTM), for example, the analysis of historic incident data indicated that grass fires tend to occur more around Tzaneen, while house fires are typically encountered in more rural communities, including Ritavi and Maake. Similarly, in the GTM, house fires tend to occur more in the rural areas. These spatial analysis results can be applied for the development of a well-structured awareness program. Coupling information management and GIS for use in identifying target areas for awareness can thus serve as an effective additional tool for strategic disaster risk reduction. Furthermore, the PIER program can be used as a medium through which information about a new fire station, such as the proposed Gavaza Fire Station, can be communicated to the community once it has been established, including activation procedures and introduction of personnel.

5.2.4 Collaborative networks

Besides the benefit provided through association with the RIMS network in verifying incident location data, benefit can potentially be provided back to the RIMS system through the spatial analysis of historic rescue (accident) data. Since fire and rescue services can do little to address the problem of road-traffic crashes, the data can be shared through the already-established collaborative RIMS network to aid in finding solutions and to reduce disaster risk. Chakwizira (2019) highlighted the link between disaster risk reduction and transport in South Africa, noting

the need for collaboration between different spheres of the government and economic sectors (Chakwizira, 2019:6). The analysis of spatial data on road traffic crashes provides the ideal opportunity to collaborate with the transport sector in seeking solutions, as noted by Respondent 2. Of note is how this can be done, not only in the interest of collaboration and improved road safety, but also for the potential extended use of GIS and information management as tools for the development of disaster risk reduction strategies. Through collaborative networks, such as RIMS, identified problem areas can be investigated and corrective measures applied to reduce the risk of crashes. Linking with community-based groups, such as neighbourhood watches and Community Policing Forums (CPFs) can serve to further enhance the existing RIMS network. It is this type of collaborative effort and exchange of information that is encouraged by the NDMF.

5.3 Summary of key findings

The relative benefits of routinely using GIS as part of the disaster management information management process were demonstrated in the study on the Mopani Fire and Rescue Services. Using historic incident data and spatial analysis techniques in GIS proved beneficial as tools for strategic decision-making related to improving service delivery, location planning for a fire station and the identification of specific resource needs for each fire station. This capacity building serves to reduce disaster risk. Additionally, information management was indicated to be beneficial in the identification of target areas for the application of additional disaster risk reduction strategies through collaborative efforts within the PIER and the RIMS networks. The Mopani District Municipality can thus benefit from the continued development of a disaster management information management system which can be used to support decision-making.

The process of extending the use of GIS as a tool for decision-making in fire station location planning to optimise the delivery of a fire and rescue service to the community was also demonstrated. The Gavaza site has already received Council approval for development, according to Respondent 1 and Respondent 2. Using GIS and sampled historic incident data from the Tzaneen Fire Station, the potential of the proposed Gavaza Fire Station to reduce response times was tested. The data and analysis from this study was successful in indicating good potential for the reduction of response times through the Maake and Ritavi areas for both fire- and rescue-related incidents. It was also indicated that the historic fire and rescue incident data within the Maake and Ritavi areas can be used to guide resource needs for the proposed Gavaza Fire Station in terms of vehicles and equipment.

Aside from showing how the data can be used to establish the effectiveness of a possible site for fire and rescue services, other opportunities for capacity building through already-established

collaborative networks were identified. The PIER program capacitates communities on issues related to fire prevention, while the RIMS network provides avenues for collaboration on improving road safety. Through these partnerships, it is evident that the use of GIS as a decision-making tool can be extended for greater effect and enhanced capacity at multiple levels. The combined use of GIS and disaster management information management thus provides for focused decision-making and the development of strategic risk reduction strategies.

In Chapter 6 below, recommendations will be put forward based on these findings.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Chapter 1 of this study set out the problem statement, key research questions, research objectives, basic literature review and the research design used in the study. In Chapter 2, a full literature review was undertaken to develop the theoretical and legal framework which would be used to guide and build the study. The literature review covered topics which included the guiding framework and legislation for disaster management, the role of information management in disaster risk management, guiding legislation for fire and rescue services, and the use of GIS as a tool to support decision-making. The link between disaster risk management and fire and rescue services was also discussed. The research methodology was explained in Chapter 3, and included a description of the area under study, an explanation of the explanatory sequential research design used in the study and the step-by-step process followed in applying the research design.

In Chapter 4, the analysis of the data related to the study on the Mopani Fire and Rescue Service was discussed in detail, while the discussion of findings was outlined in Chapter 5. These two chapters presented the ways in which GIS analysis techniques can be applied to identify resource and fire station location needs for improved institutional capacity and reduced disaster risk. In coupling GIS and information management, a strategic advantage is provided for the development of targeted and appropriate disaster risk reduction strategies. In this chapter (Chapter 6), the conclusion and recommendations of the study are put forward.

6.2 Information management as support for decision-making and strategic risk reduction

The explanatory sequential research design provided the opportunity to thoroughly explore the historic incident data from Mopani Fire and Rescue Service quantitatively, while also considering the views of the participants through qualitative data collection. The study illustrated the wealth of information which can be generated from historic incident data. Furthermore, it became clear that the careful application of GIS and disaster management information management is vital to inform decision-making for disaster risk reduction at multiple levels. Following the detailed analysis of the historic incident data collected from the Mopani Fire and Rescue Services incident record books, the potential for reduced emergency response times through the establishment of a new fire station at Gavaza could be tested.

6.3 Summary of methods used to address the research objectives

In the section below, the methods used to achieve the research objectives are outlined:

6.3.1 Research objective 1: To explore the use of GIS coupled with information management as a tool for developing disaster risk reduction strategies

In Chapter 4, the analysis of historic incident data was undertaken in GIS to reveal the spatial significance of different incident types. The identification of areas of high incident density can be used to inform public awareness campaigns for disaster risk reduction in the identified areas, including through the PIER program and other collaborative efforts. The theoretical framework which guided this approach is located in Section 2.5 and Section 2.6 of Chapter 2.

6.3.2 Research objective 2: To explore the use of GIS as a tool for decision-making in service delivery, location and resource needs for Fire and Rescue Services

The individual fire stations were discussed at length under Section 4.2 of Chapter 4, including the analysis of their historic incident data in GIS. Visualising historic incident data in GIS and classifying the data into different categories reveals which areas require specific resources e.g. the Tzaneen and Modjadjiskloof Fire Stations deal with a lot of grass fires during the annual fire season. Sufficient vehicles suitable for fire-fighting and which can cope with the terrain are thus required. The Tzaneen and Modjadjiskloof Fire Stations and, to a lesser degree, the Maruleng Fire Station, deal with the most truck accidents due to the steep mountain passes located at the Strydom Tunnel on the R36, the Buffelsberg Pass on the R81, the Magoebaskloof road (R71) and the George's Valley road (R528). This means that these three fire stations require sufficient heavy-duty rescue equipment. The spatial arrangement of historic incidents indicates demand for specific incident types. Displaying these against the different risk categories and estimated travelling time provides a clear indication of areas which can benefit from new stations as well as how these stations should be equipped.

An understanding was developed of the socio-economic environment and spatial characteristics for each of the local municipalities based on insights gained from their respective IDP documents. This is necessary to understand where rapid development is occurring and thus where the greatest need is for additional services – specifically in terms of fire stations. The potential benefit of the first site already identified for additional fire station development was tested in Section 4.3.2.1 of Chapter 4 using historic incident data against estimated response times. The potential improvements in response times were compared and the relative gains which could be made per identified fire risk category.

6.3.3 Research objective 3: To make recommendations for the use of GIS in the development of disaster risk reduction strategies

The study has illustrated the advantages of using GIS in the development of disaster risk reduction strategies by highlighting specific areas that are prone to specific incident types. Of the five stations in the Mopani District, it is the Tzaneen Fire Station, for example, which deals with the most fire-related incidents, however, the Phalaborwa Fire Station deals with the most rescue-related incidents. This was outlined in the data analysis overview of Mopani Fire and Rescue Services in Section 4.2 of Chapter 4 and discussed in Section 5.2.1 of Chapter 5. In applying GIS analysis techniques, the information generated can thus be used to guide strategic risk reduction strategies by focusing on specific areas where particular incident types are commonly found. This provides scope for the development of targeted strategies for raising awareness and other intervention strategies in identified communities. In Section 6.4 of Chapter 6, recommendations are put forward for the continued use of GIS for the development of disaster risk reduction strategies.

The PIER program as an effective approach to fire risk reduction was discussed in Section 2.4.1.2 of Chapter 2. In Section 5.2.3 of Chapter 5, the way in which the results of the GIS analysis of historic incident data can be applied to PIER program to the benefit of disaster risk reduction through capacity building was outlined. The role of GIS and collaborative networks in disaster risk reduction was outlined in Section 2.6.1 of Chapter 2.

An understanding of risk, hazard, vulnerability and capacity was generated in Section 2.3, including the role each of these play in overall disaster risk management.

6.3.4 Research objective 4: To consider how information management can support decision-making in fire and rescue services.

Information management formed the backbone of this study and illustrated how the collection and analysis of appropriate data can be applied for more informed decision-making in fire and rescue services. The outcome of the GIS analysis of historic incident data undertaken in Chapter 4 provided practical examples of how specific resource needs per fire station could be identified, resulting in a solid foundation upon which decisions can be made.

The theoretical and legislative framework, from international down to national and local level, were discussed in Section 2.4 of Chapter 2. The link between disaster management and fire and rescue services was detailed through the legislative (Section 2.4.2) as well as theoretical framework (Section 2.2 and Section 2.5).

6.4 Recommendations

Based on the outcome of the analysis presented in Chapter 4 and the findings discussed in Chapter 5, the following recommendations are made:

- An assessment should be undertaken of specialised equipment and vehicles for each fire station in the Mopani District Municipality to determine if sufficient resources are available to meet demand. The possible need for additional vehicles and equipment was highlighted in the analysis of individual fire stations under Section 4.2 of Chapter 4 and in the discussion of the findings in Section 5.2.1 of Chapter 5.
- The development of the new fire station at Gavaza should continue along with appropriate resource allocation. The potential benefit of the establishment of a fire station at Gavaza was tested in Section 4.3.2.1 of Chapter 4 and a discussion of the findings outlined in Section 5.2.2 of Chapter 5;
- The analysis of areas of high incident-density be considered as strategic input for the rollout of the PIER system in the Mopani District Municipality, as discussed in Section 5.2.3 of Chapter 5;
- The ability to analyse the data collected from Mopani Fire and Rescue Services creates the possibility to extend the project to add value to the work undertaken by other disaster risk management role players through collaborative networks. Involvement in structures such as RIMS provides ideal opportunities for the enhancement of meaningful links with first responders through which disaster risk reduction can be sought. The existing collaborative networks in the Mopani District should continue to be built and developed for ease of information flow. In Section 2.6 of Chapter 2 and Section 4.3.4 of Chapter 4 the role of collaborative networks was discussed, with particular emphasis on RIMS. Section 5.2.4 of Chapter 5 outlined how collaborative networks can be used as an additional opportunity for capacity building and risk reduction;
- The information management system for the MDM DMC should continue to be developed;
- The continued development of GIS, coupled with information management, should be applied for improved decision-making, location planning and the development of disaster risk reduction strategies.

6.5 Conclusion

The proper use of information management for disaster risk management by the MDM DMC has been thoroughly explored in the study on Mopani Fire and Rescue Services. It has been demonstrated how proper information management can aid in informed decision-making for

improved institutional capacity, strategic planning in fire and rescue services as well as disaster risk management, the allocation of appropriate resources and fire station location planning. Incorporating the benefits of collaborative networks was also discussed, and how this can feed into and derive benefit from the disaster management information management process. Proper information management has thus been proved to be beneficial at a number of different levels, including the provision of support to disaster risk management role players through already-established collaborative networks. The development of an information management system is in keeping with international best-practice. The further development of the MDM DMC information management system, in conjunction with the application of data display and analysis techniques in GIS should thus form the foundation of a system which can contribute to improved decision-making.

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