# *The Effects and Efficacy of Large-Scale Motorway Development: A Case Study of Wellington, New Zealand*

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# Abstract

Large-scale motorway development is a common response to traffic issues such as congestion and inconsistent trip times. It is a tool used to alleviate these pressures, which are commonly caused by increasing urban populations and changing urban form. Although best practice motorway development should occur pre-emptively to address these issues, it often occurs instead as a reaction to these effects. Poor motorway planning can have a wide range of adverse effects such as congestion, changes in land use, and an impact on people's wellbeing.

This research addressed large-scale motorway development in the case study of Wellington, New Zealand. A number of key drivers of motorway development, such as congestion and growth, are present in the Wellington Region. The Wellington Smart Motorway and Kapiti Expressway have also recently opened, and Transmission Gully is still in the construction phase. To determine the value of large-scale motorway development the research addressed three research objectives: to investigate current international approaches; to establish and identify the main effects of large-scale motorway development; and to evaluate the efficacy of large-scale motorway development.

The research found that large-scale motorway development can be used to address the effects and impacts of increased vehicle usage. A range of positive impacts were identified, including improved safety, increased road capacity, minimised congestion and improved free-flow speed. Conversely, negative impacts of large-scale motorway development in New Zealand included impacts on urban form, adverse effects for the receiving environment, and impacts on the road user.

It was concluded that large-scale motorway development is an effective tool for managing the effects and impacts of increased vehicle usage. Further, the research is valuable for the NZTA, MoT, GWRC, WCC, PCC and KCDC due to their role as key stakeholders. The research will assist them in making better decisions in the future regarding large-scale motorway development.

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## *List of Abbreviations*

| | |
|---|---|
| GWRC | Greater Wellington Regional Council |
| KCDC | Kapiti Coast District Council |
| MoT | Ministry of Transport |
| NPS | National Policy Statement |
| NZTA | New Zealand Transport Agency |
| PCC | Porirua City Council |
| RMA | Resource Management Act |
| TOD | Transit Orientated Development |
| VSL | Variable Speed Limit (signs) |
| WCC | Wellington City Council |

# 1 - Introduction

## *1.1 Introduction*

Motorways allow citizens to move quickly and efficiently from one point to another. They are also essential to a city's economic viability, as they are a part of freight networks and provide transportation routes for people from home to work. By 2050, at least 70% of the world's population will live in cities, so motorway planning is becoming a significant field of research (Zhao, 2010). Poor motorway planning can result in congestion, changes in land use, and it can adversely affect people's wellbeing. As a result, the effects of large-scale motorway development need to be properly understood and the efficacy of motorway development as a planning response determined.

Motorway development can occur as a reaction to issues, such as congestion, or it can be pre-emptively developed before such issues arise. Good motorway design and development will enable users to travel from one point to another smoothly and efficiently. The ability to maintain free-flow speed for the duration of the journey makes this possible (Deardoff, Wiesner & Fazio, 2011). Further, good motorway design is able to address the pressures it faces during peak hours and ensure reliable and consistent trip times. As a result, the design is another important aspect of motorway development (Strömgren, 2011). Improved efficacy can occur through development and tools, such as adding lanes, or the addition of smart technologies, such as variable speed limit signs (VSL) and computer control systems (Sun et al., 2014). This kind of infrastructure development usually requires a substantial investment. However, the sole introduction of smart technologies can cost substantially less than a large-scale motorway development. This research compared the efficacy of the Wellington Smart Motorway with a traditional motorway development.

In the context of New Zealand, rising populations in major cities such as Auckland, Hamilton and Wellington have placed significant vehicle pressure on

existing motorways. Already, 86% of New Zealand's citizens live in urban centres (Early, Howden-Chapman & Russell, 2015). Contributing to this is New Zealand's dependence on private transportation. As a country, New Zealand possesses the fourth highest rate of private car ownership in the OECD world. Individuals favour private vehicles over public transportation due to the freedom and convenience offered by private transportation (Jakob, Craig & Fisher, 2006). On top of this, congestion in the Auckland region is considered to be a national problem, as congestion is estimated to cost the New Zealand economy about 1% of GDP from lost income, time and pollution (Sankaran, Gore & Coldwell, 2005). The impact to New Zealand's GDP demonstrates the need to find a congestion solution.

The Wellington region is made up of a series of cities interconnected through land use, transportation, housing, infrastructure and the environment. As a consequence, large-scale infrastructure developments that affect one of these cities will affect other cities and could provide co-benefits (Early, Howden-Chapman & Russell, 2015). Pressure has gradually been building on Wellington's roading network with its growing population. Wellington's unique and restricting topography means options are limited. To address this pressure, a Smart Motorway has been developed between Aotea Quay and Ngauranga, construction has finished on the Kapiti Expressway north of MacKays Crossing, and Transmission Gully is currently under construction, which joins these two developments. These developments aim to alleviate the pressures caused by the increasing population in the Wellington Region.

The development of Wellington's motorway network will have significant impacts on the economic vitality of the region, and it will also have impacts at a national scale. By looking at Wellington as a case study, other centres around New Zealand facing similar pressures may be able to implement their own large-scale motorway development. Congestion is an issue as it can have economic and societal impacts (Sankaran, Gore & Coldwell, 2005). This thesis addresses the drivers, effects, and efficacy of large-scale motorway development in the case study context of Wellington, New Zealand.

## *1.2 Research Context*

The chosen case study location for this research is the Wellington Region due to the presence of large-scale motorway developments that have been constructed recently or are near completion. Furthermore, the region is currently experiencing population growth. The population of the Wellington Region is 471,315, which is an increase of 22,356 since the 2006 census. Dwellings in the Wellington region now sits at 193,914 with 1,020 under construction, demonstrating the significant growth that has occurred (Statistics New Zealand, 2013b). Consequently, large-scale motorway development is required to address the increasing volume of private cars due to this population increase.

Public transportation routes historically dictated the location of motorway development in Wellington. This also influenced the development of surrounding suburbs (Dodson & Mees, 2003). However, in the 1960s, the Wellington Foothills motorway was developed, demonstrating a shift in popularity of private motor vehicles. Motorway developments have been constructed and planned due to the strategic significance of the Wellington motorway network and increased roading pressure. Wellington has developed a Smart Motorway into/out of the CBD up to Ngauranga, is currently building a large $850 million road of national significance (RONS) that joins the Smart Motorway (Transmission Gully), and construction has finished on the Kapiti Expressway which joins onto the end of the Transmission Gully development and heads north.

As a result of Wellington's substantial growth, commuting became normalised with citizens of the region needing to access Wellington city for work and educational purposes (Early, Howden-Chapman & Russell, 2015). The effects of this were minimalised, to begin with, as Wellington has the country's highest usage of public transportation for both rail and bus networks. However, significant congestion has become characteristic on some of Wellington's main motorways during peak commuter periods (Greater Wellington Regional Council, 2015).

Wellington needs large-scale motorway development, as the growing population of the region has resulted in changes to its urban form and increasing pressure on the pre-existing motorways (Early, Howden-Chapman & Russell, 2015). This thesis researched the new Smart Motorway between Aotea Quay and Ngauranga, the under-construction Transmission Gully and the recently completed Kapiti Expressway. Chapter Four of this thesis goes into more detail as to the location of these motorways.

## *1.3 Research Aims and Objectives*

The aim of this thesis is to provide insight into the effects, efficacy, and value of large-scale motorway development. This is of value to key stakeholders including the Greater Wellington Regional Council (GWRC), the Wellington City Council (WCC), the Porirua City Council (PCC), the Kapiti Coast District Council (KCDC), the New Zealand Transport Agency (NZTA), and the Ministry of Transport (MoT). The value of this research to territorial authorities is in providing an increased understanding as to how large-scale motorway development will positively or negatively affect their area of authority. Further, this research is valuable to the NZTA and MoT as it provides them with a clearer understanding of the efficacy of large-scale motorway development. Table 1 displays the aim of this thesis research and the three research objectives.

**Table 1: Thesis aim and research objectives.**

| **Aim: To determine the value of large-scale motorway development in our urban areas.** | |
|---|---|
| **Objective 1** | To investigate current international approaches for managing increasing road user pressure via large-scale motorway development. |
| **Objective 2** | To establish and identify the main effects of large-scale motorway development in New Zealand. |
| **Objective 3** | To evaluate and assess the efficacy of large-scale motorway development in the case study of Wellington, New Zealand. |

This thesis addresses three research objectives to answer the aim of this thesis. Research objective one is focussed on identifying the international approach to managing increased roading pressure. Chapter Three discussed this

in the context of the literature review. Key themes analysed in this chapter include: benefits of motorway development; the effects of motorway development; motorway typology; and motorway policies and tools. By conducting a wide-ranging literature review, it is possible to gain an understanding of large-scale motorway development from an international context.

Research objective two aimed to establish and identify the main effects of large-scale motorway development in New Zealand. Chapter Five of this thesis addresses this research objective with the literature analysed in Chapter Two informing these findings. The primary methodology employed for this objective was Key Informant interviews. To address this objective, the chapter analysed the effect on urban growth and development, economic effects, the effect on the implementation and creation of policy and plans, and other effects including improved resilience.

Finally, research objective three is focussed on evaluating and assessing the efficacy of large-scale motorway development in the case study of Wellington. Chapter Six discusses this objective and is informed by a mixed methodological approach. This included Key Informant interviews and graphical analysis of information provided by the NZTA. To assess the efficacy of large-scale motorway development this chapter discusses Wellington's existing motorway network, the efficacy of the current motorway network, approaches to improve motorway efficacy further, and future motorway developments.

By addressing the three key research objectives, this research answers the thesis aim, which is to determine the value of large-scale motorway development in our urban areas. This research is of value to the key stakeholders as it assists them to implement and manage the effects of large-scale motorway development. The research also contributes to the existing body of literature on large-scale motorway development.

## *1.4 Key Concepts and Definitions*

This thesis uses many key concepts and definitions. It is important to understand the utilisation of these concepts and definitions in the context of this research. This section provides information about the use of: effects; efficacy; free-flow speed; and road capacity.

In the context of this thesis research, effects can be both positive and negative. It is important to establish this, as a large volume of international literature focuses on effects through a negative point of view. Further, effects are important for this thesis research due to its link to research objective two. Due to the large variety and range of effects associated with large-scale motorway development, it is important to consider them in both a positive and negative light. The interpretation of effects in this thesis is thus meant to be broad.

Research objective three for this thesis discusses assessing the efficacy of large-scale motorway development. Efficacy is related to the efficiency of a system or tool, which in the case of this thesis is related to the efficiency of motorways. Efficacy for this thesis is about improving vehicle flow rates, congestion reduction, the removal of bottlenecks, and improved safety. These features are all considered necessary to improve the efficacy of a large-scale motorway development.

This thesis frequently discusses free-flow speed. Free-flow speed is important when discussing the efficacy of motorways. It is the ability for a vehicle to travel at the posted speed limit, with surrounding vehicles not influencing its speed (Chiou, Huang & Lin, 2012; Deardoff, Wiesner & Fazio, 2011). This thesis discusses free-flow speed due to its maintenance often being the primary goal of motorway development.

Road capacity is also discussed frequently when assessing motorway developments and their efficacy. Motorway developments often increase road capacity. The capacity of a motorway is considered to be the volume of vehicles that can traverse a given distance in the space of an hour under normal flow conditions (Daniel & Maina, 2011). Increasing capacity occurs by adding lanes,

which ensures normal flow can be maintained even with an increase in vehicle numbers.

## *1.5 Thesis Structure*

The purpose of this introductory chapter, ***Chapter One***, was to explain the research problem and provide detail about the research aims and objectives of this thesis. ***Chapter Two*** contains the Literature Review, which offers an insight into the current and historical knowledge that exists pertaining to the value of large-scale motorway development, its efficacy and its effects. In particular, the literature review addresses the history of motorway development, the benefits of motorway development, the effects of motorway development, motorway typologies, and motorway policy and tools. The methodology utilised is then discussed in ***Chapter Three***. This contains details of the approach employed, reasoning as to why a mixed methodology was selected, as well as limitations to the approach. ***Chapter Four*** provides the geographic and urban context for the thesis research, detailing specific features associated with the case study site of Wellington. Subsequently, ***Chapter Five*** identifies the main effects, both positive and negative, of large-scale motorway development, with a narrower focus on the effects as observed in Wellington. In ***Chapter Six***, the efficacy of large-scale motorway development is analysed and discussed. This chapter focuses on the efficacy of large-scale motorway development within the case study of Wellington. Finally, ***Chapter Seven*** concludes the thesis research while suggesting areas for future research.

# 2 - Literature Review

## 2.1 Introduction

This research is focussed on the effects and efficacy of large-scale motorway development. This chapter identifies relevant international and New Zealand literature. Motorway developments have the potential to minimise the impact on communities of increasing traffic demand and reduce the environmental impact of these vehicles (Frank *et al.*, 2008). There are many studies focused on specific aspects of motorway development, such as congestion, safety, and new technology (Cheu & Ritchie, 1995; Lighthill & Whitham, 1955; Nissan & Koutsopoulosb, 2011). In particular, this literature review assesses: motorway construction and development, including the benefits and effects of these developments; motorway typology and the types of motorways present in New Zealand; and the motorway policies and tools present in New Zealand, followed by a summary and conclusion.

Throughout the literature review it became evident that there is an abundance of mathematical and engineering literature regarding motorway features, such as flow rates; however, this is not relevant to this thesis. Instead, literature was selected based on how relevant it was to motorway planning and the effects of motorway developments for managing increasing road user demand. The purpose of this chapter is to identify, analyse, summarise and reflect on literature that is relevant to motorway development.

## 2.2 Motorway Construction and Development

Internationally, motorway construction and development have occurred as a response to increasing volumes of private car ownership with the aim of reducing the impacts of these vehicles on the environment and the surrounding urban form (Featherstone, Thrift & Urry, 2005; Gunder, 2002). This section looks at the international history of motorway development, identifies the purpose and drivers behind motorway development, and then discusses the

environmental effects of motorway development. This section provides a comprehensive understanding of motorway development, which can be used to understand motorway development occurring in New Zealand and assist in answering the key aims and objectives of this thesis research in relation to the Wellington case study.

### *2.2.1 International History of Motorway Development*

As a primary mode of transportation, cars are becoming more prevalent in our modern society and are attached to a person's social image (Featherstone, Thrift & Urry, 2005). With increasing car use has come increasing demand for roads to accommodate these vehicles. Consequently, motorway development has occurred to manage traffic flow and demand (Litman, 1995). Historically, this increase in private vehicle ownership occurred in the 1950s and 1960s. As a result, cities sought to find a solution to address the pressure posed by mass car ownership (Gunn, 2011).

Published in 1963, the Buchanan Report had a focus on abolishing England's rising traffic issues by suggesting an approach that would see the establishment of the new motor age (Gunn, 2011). Planning and architecture groups in England identified it as one of the most significant planning documents of the twentieth century at its time of publication. It went against the ideals of planners, such as Jane Jacobs, who was concerned about the destruction of urban space due to automobile dependence. Specifically, Jane Jacobs was concerned about the destruction of urban space in New York City due to the 'Urban Renewal Plan' of Robert Moses that prioritised private vehicle use (Jacobs, 1961). Many planners shared this view during this period.

Due to the increasing political impact of traffic, countries such as England and America undertook large motorway construction projects to address rising congestion. Motorway development occurred through increased spending and allocation of government budgets on roads (Gunn, 2011; Taylor, 1995). In England, American-style urban highways became the favoured approach, which was also the approach taken in New Zealand (Gunder, 2002; Gunn, 2011). The American system focused on the origin and the destination and then established

the quickest line to achieve this link. This approach was criticised because it ignored the role that other modes of transportation could have in the new urban city, and the impact these developments may have on existing communities (Litman, 1995). Critics are of the opinion that motorway development has resulted in disjunct cities that adversely impact on the social, psychological and aesthetic wellbeing of existing communities (Taylor, 1995). Further, during this period the adverse effects of motorway development were ignored. These effects included: sprawl; socio-economic segregation; loss of native vegetation; loss of agricultural land; and an increase in individual car dependency (Barrett & Rose, 1999).

While governments were encouraging motorway development, the investigation of alternative modes of transportation was stopped. In California in the 1970s this resulted in the 'Freeways Revolt Movement' (Taylor, 1995). This movement was the citizen movement against freeway development, in favour of more multi-model metropolitan transportation plans. In California, this movement dramatically impacted and curtailed freeway development (Taylor, 1995). Disruption also occurred in New Zealand due to the planning link between the two countries (Gunder, 2002).

In New Zealand, similar plans were commissioned to address increasing road demand. These plans included the 1955 Master Transport Plan, and then the De Leuw Cather reports for Wellington, Auckland and Dunedin (Gunder, 2002). Through these reports, New Zealand adopted the northern hemisphere concept of high-speed highways, with multiple lanes and limited access points (Gunder, 2002). These promoted the development of unused land on the outskirts of existing cities, enabling the people of New Zealand to pursue the dream of a 1/4 acre section (Foster, 1979). By building motorways in the manner employed in America, social benefits of the city were going to be unlocked (Gunder, 2002). However, the forecast year for these New Zealand reports was 1986. Traffic demand has since exceeded what these reports planned for (Foster, 1979). Now, congestion is a prevalent issue in New Zealand cities due to increasing traffic demand caused by rising populations. This thesis discusses current motorway

development as experienced in Wellington City and identifies ways to improve these developments.

### *2.2.2 The Purpose of Motorway Construction*

Perera (1990) analysed the primary purpose of investment into motorway development and found that maintaining the quality of service, or improving the transportation service, was the primary goal. Specifically, highway users would benefit from a reduction in travel time, a decrease in vehicle running costs, less congestion, and an improvement of road safety (Carey & Semmens, 2003; Perera, 1990). Motorway development could also benefit road users indirectly. This can occur through an improvement of travel time reliability (de Jong & Bliemer, 2015). The consideration of improvements to travel time reliability is not found in a traditional cost-benefit analysis.

Another purpose of constructing motorways is to improve the accessibility of an area (Linneker & Spence, 1996). Through new motorway development, areas that were previously inaccessible may become more desirable. This can also result in economic activities being highly concentrated in specific areas due to the accessibility of the motorway network (Yu *et al.*, 2016). This is an indirect benefit of motorway development as discussed by Carrey and Semmens (2003). Further, the study by Yu et al., (2016) found that significant improvement of the motorway network might also facilitate spatial dispersal. This research is interested in whether accessibility improvements have occurred within the Wellington Region because of large-scale motorway development.

A study by Poelmans and Van Rompaey (2009), found that at a regional level motorways can be a positive driver for built-up land. By strategically planning where motorways go, and which areas they service, they can impact on urban form. Motorways can encourage main transportation routes to and from strategic destinations, they improve convenience and reliability of freight networks, and can encourage industrial land use to occur on the fringes of cities (Poelmans & Van Rompaey, 2009). Motorways are a tool that can influence built form. Through motorway development, an authority's vision for an area may be achieved.

### *2.2.3 Drivers of Motorway Development*

Motorway development may occur for a variety of reasons. Severe congestion, regardless of whether it's at a morning or afternoon peak, can be a significant driver for motorway development and is commonly addressed through adding additional lanes (Goldberg, 2010). This approach, however, can be flawed. Mackie (1996) found that a small change in the total volume of traffic could have an impact on the benefits derived from investment into motorway development. To assess the benefit of potential motorway developments in the United Kingdom, an approach is employed where they considered large, or minimum, intervention situations under different network scenarios to establish the worth of the work (Mackie, 1996). However, while it is possible to use this approach as part of a cost-benefit analysis, it is difficult to accurately establish the volume of induced traffic that could impact on this development (Goldberg, 2010). If the costs outweigh the benefits, then the development may not go ahead.

Congestion is another issue addressed through the development of new motorways. A method used to understand the congestion pressure put on a road is the 'speed-flow curve'(Goodwin, 1997). This relationship links the volume of traffic on the road to the speed at which it can travel. When the volume of traffic reaches the capacity of the road, a breakdown in flow occurs, resulting in congestion and impeded vehicle travel (Goodwin, 1997). To reduce the demand on existing roads and add capacity to the network, new motorway developments occur (Handy, 2005). This was a key driver in the development of Spain’s motorways. Congestion was at unsustainable levels, so motorway development occurred to address this congestion (Holl, 2011). As a result, congestion is a key driver of new motorway development.

Increasing accessibility to remote areas can also be a driver of motorway development. A study by Grimes and Liang (2010) analysed the net economic benefits of extending the Auckland Northern Motorway from 1995-2000. Land prices rose and increased development around the new motorway corridor was also observed (Grimes & Liang, 2010). Further, population and employment increased at a more rapid rate than observed in the wider Auckland region.

Grimes and Liang (2010) concluded that motorway development increased opportunities and productivity. In relation to this research, a key area of interest is if this will occur in the Wellington Region.

## *2.3 Positive Effects of Motorway Development*

As previously acknowledged, motorway development can have a range of benefits. These benefits include travel time reliability, reduction in congestion and improved safety (Goodwin, 1997; Handy, 2005). They can also be indirect, such as increasing land prices and encouraging development in the surrounding areas (Goldberg, 2010; Grimes & Liang, 2010). The next section discusses the benefits of motorway development.

### *2.3.1 Safety*

Cheu and Ritchie (1995) classify motorway incidents as infrequent events such as: car accidents; vehicles becoming disabled; spilt vehicle loads; temporary maintenance and construction; issues arising with malfunctioning technology; and other such unique and one-off events. It is any event which may disrupt the normal flow of traffic or cause a significant delay to the road user (Cheu & Ritchie, 1995). All of these factors can impact on safety and can result in a disruption to normal traffic flow. In the United States of America, incidents on motorways result in 50-60% of total delays (Cheu & Ritchie, 1995; Dia & Rose, 1997). The direct link between accidents and congestion demonstrates the importance of improved motorway safety as part of motorway development.

Other ways to improve safety on motorway developments include widening road lanes and increasing sight distance. Both of these can be achieved through new motorway development, and decrease the probability of vehicle incidents (Daniel & Maina, 2011). With vehicles now being able to reach higher speeds, the design characteristics of the road are a primary constraint on vehicle speed (Dumbaugh & Rae, 2009). By widening and straightening sections of a road, there is an increased stopping sight distance for the road user that can improve safety (Daniel & Maina, 2011; Dumbaugh & Rae, 2009).

As a result, design considerations of a new motorway development can have an impact on safety (Daniel & Maina, 2011). Dumbaugh and Rae (2009), found that the development of arterial roads and freeways can both reduce congestion and improve safety. This study also identified a link between population density and crash risk, crediting an increase in risk to an increase in road users (Dumbaugh & Rae, 2009). However, the study by Daniel and Maina (2011) identified that through motorway development, such as increasing roadway capacity, there is a reduction in crashes and improved safety. In the safety literature, frequent disputes occur around the importance of design, capacity and topography. In Wellington, the topography restricts the new motorway developments from being in straight lines. Instead, Wellington's motorway developments have been designed to avoid significant topographical barriers that mean visibility may be limited at times. This could hinder safety (Dumbaugh & Rae, 2009). However, the developments have also increased the road's capacity, which could result in increased safety (Daniel & Maina, 2011).

### *2.3.2 Improved Free-Flow speed*

Motorways flow at their best when they can flow at their free-flow speed. Free-flow is considered to be the theoretical speed where the density and flow rate on a section of motorway are both zero. This means the preceding vehicle does not influence the following driver's speed (Deardoff, Wiesner & Fazio, 2011). This is an understanding of free-flow speed shared by a number of previous studies, and a term utilised by transportation engineers (Chiou, Huang & Lin, 2012; Deardoff, Wiesner & Fazio, 2011; Gupta & Katiyar, 2005). The development of new motorways means the road user will ideally be able to achieve and sustain this free-flow speed for the duration of their journey. Figure 1 displays a graphic representation of free-flow characteristics. It is evident that when the volume of traffic passes the point of critical accumulation, congestion occurs.

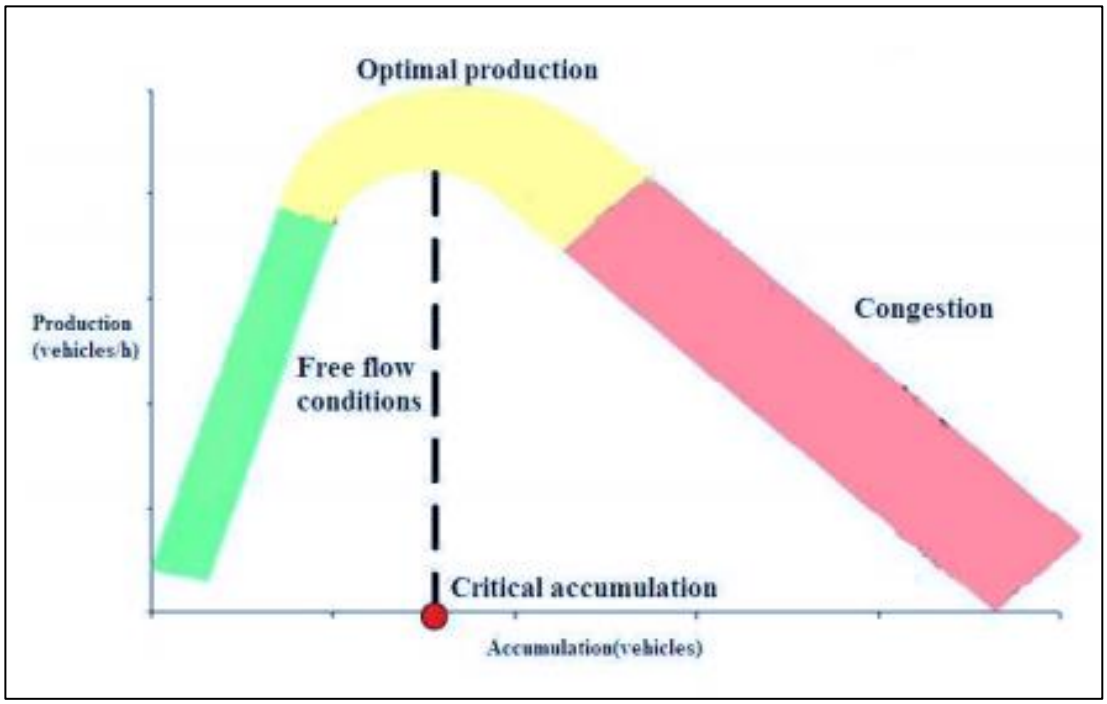


**Figure 1: Diagram of typical free-flow speed characteristics for a section of a motorway (Xu *et al.*, 2013).**

Motorway developments aim to achieve a capacity at which, in most normal traffic situations, the free-flow speed is achievable for the road user. However, achieving this free-flow speed becomes difficult during periods of peak traffic movements, such as during morning and evening commuter windows (Deardoff, Wiesner & Fazio, 2011). The ability to achieve the free-flow speed is compromised during these periods, unless the motorway development is a significant size. This ensures the maintenance of free-flow speed (Gupta & Katiyar, 2005). By ensuring that the motorway development is at a sufficient scale, or has enough lanes, it is possible to attain this free-flow speed at all times (Gupta & Katiyar, 2005). This results in a quicker journey and more travel time reliability for the motorist.

Chiou et al., (2012) argue that as vehicle numbers increase, speed variations are more likely. This is due to disruptions to the traffic's uniform flow and can cause gridlock. As a result of this, the maintenance of free-flow speed is critical for ensuring a motorway development improves the flow of traffic (Chiou, Huang & Lin, 2012). This requires discussion on how the maintenance of free-flow

speed could be used to assess the efficacy of Wellington's motorway developments. This is discussed in more detail later in this thesis.

### *2.3.3 Increased Roadway Capacity*

Another primary purpose of motorway developments is to increase road capacity. This can alleviate traffic congestion through increasing capacity on main arterial roads and motorways that are considered critical commuter routes (Dumbaugh & Rae, 2009). The increase of motorway capacity has been the focus of multiple studies. Methods include sophisticated modelling, analysis of the geometric shape of the motorway, and vehicle counts (Chiou, Huang & Lin, 2012; Daniel & Maina, 2011; Frank *et al.*, 2008; Strömgren, 2011). Daniel and Maina (2011) defined capacity as:

> *"The capacity of a roadway facility is defined as the maximum hourly rate at which persons, or vehicles, reasonably can be expected to traverse a point or a uniform section of a lane or a roadway during a given time period under prevailing roadway, traffic and control conditions" (Daniel & Maina, 2011, p. 318).*

This definition for capacity by Daniel and Maina (2011) establishes the key factors a motorway development needs to meet to increase its capacity. Increased capacity can occur through introducing additional lanes. Another benefit of increasing a motorway's capacity is to facilitate the economic and social development of a city or urban centre (Zhao, 2010). This can result in increased productivity of the city or region. Zhao (2010), did place a significant emphasis on the vital role that roads can play in the development of an area. However, in Zhao's (2010) research there was little acknowledgement given to how congestion can arise as a result of motorway development.

A motorway's physical features can contribute to its capacity. These can include introducing additional lanes, widening lanes, and increasing the width of the shoulder (Daniel & Maina, 2011). Primarily, these features increase capacity by increasing the volume of driving surface available to motorists. A study by Strömgren (2011), found that the gradient of the road could even contribute to the road's capacity. The impact that gradient can have on large and heavy vehicles in the traffic flow was credited as the reason (Strömgren, 2011). The

impact that heavy vehicles could have on the Wellington motorway developments is considered to be outside the scope of this thesis and will not be assessed. By looking into some of the physical contributing factors to motorway capacity, Strömgren's (2011) study was important in that it moved into analysing real-world examples. This, compared to studies carried out on capacity by authors such Zhao (2010), is a more practical approach to utilise, as it moves away from conceptual modelling and into the realm of realised motorway developments. Thus, the study by Strömgren (2010) validates the use of Wellington as a case study approach for this thesis. By using the Wellington motorway developments as a real-world case study, this thesis is able to accurately measure the benefits these developments have had on vehicle capacity and how physical characteristics may contribute to this.

This thesis assesses the capacity of Wellington's new motorway developments by using a vehicle counts approach, similar to the method employed by Daniel and Maina (2011). Counts are made possible through access to the New Zealand Transport Agency's (NZTA) Traffic Monitoring System (TMS). Counts enable this research to assess if the Wellington motorway developments have resulted in increased capacity.

### *2.3.4 Reducing Vehicle Shockwaves*

Research has identified that there is an empirical relationship between both vehicle speed and traffic density (Richards, 1956). When traffic jams occur due to a breakdown of the road's free-flow, or by exceeding the road's capacity, the road user becomes disrupted in their journey. Shockwaves are variations in the speed of the regular traffic flow (Chiou, Huang & Lin, 2012). Lighthill and Whitham (1955) observed that a vehicle shockwave is when a driver has to adjust their speed as a direct result of the behaviour of a vehicle in front of them. This can occur because the driver observed the vehicle in front begin breaking (Lighthill & Whitham, 1955). While the article written by Lighthill and Whitham may be dated, the point they raise around driver behaviour and the characteristics of shockwaves is still valid on today's motorways. This understanding of vehicle shockwaves is reflected in more recent research by

authors such as Chiou, Huang and Lin (2012), Hegyi, De Schutter and Hellendoorn (2005), and by Nissan and Koutsopoulosb (2011). These authors reflect that the understanding around vehicle shockwaves has not changed (Hegyi, De Schutter & Hellendoorn, 2005b; Nissan & Koutsopoulosb, 2011). New motorway developments have the potential to minimise the presence of shockwaves. Lighthill and Whitham described vehicle shockwaves as:

> *"A driver experiences such a wave whenever he adjusts his speed in accordance with the behaviour of the car or cars in front of him – for example, on observing a brake light, or an opportunity to overtake" (Lighthill & Whitham, 1955, p. 319).*

Figure 2 displays a flow curve with the point of flow breakdown highlighted. This shows that as vehicle concentration increases on a section of road, the movement of vehicles can decrease. Through new motorway development, capacity is added to the motorway, enabling a higher vehicle concentration (Chiou, Huang & Lin, 2012). This then increases the flow curve and the volume of capacity required to cause a vehicle shockwave (Lighthill & Whitham, 1955). Motorway development results in the reduction of shockwaves, and the road user's driving experience is improved.

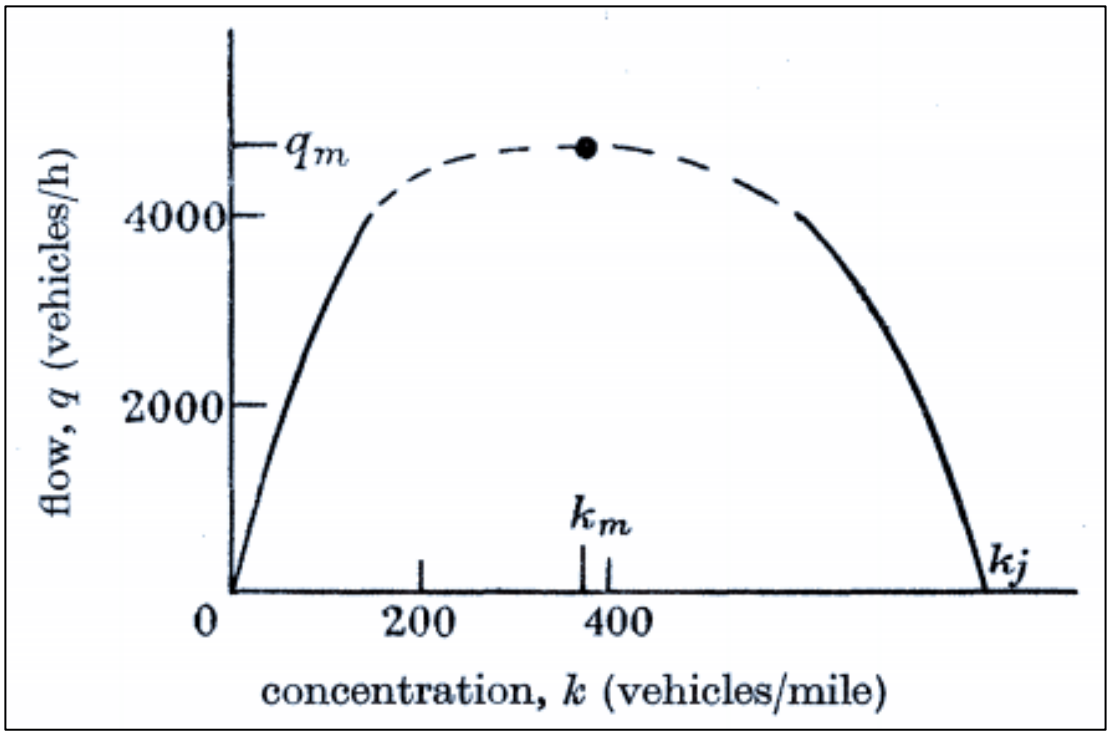


**Figure 2: Flow curve showing the breakdown in vehicle flow as vehicle concentration increases (Lighthill & Whitham, 1955).**

Understanding the characteristics of vehicle flow is important for this thesis. This is because it is possible to predict the volume of vehicle concentration required for a breakdown in free-flow conditions to occur. Increased vehicle concentration can occur through developing additional lanes and increasing roadway capacity. This can be a result of large-scale motorway development.

### *2.3.5 Minimised Congestion*

The reduction of congestion is another benefit of motorway development. This is because the distribution of traffic can occur over a larger area (Carey & Semmens, 2003). So whilst some of the adverse effects of motorway development may not be addressed, they are spread out over a wider geographical area. It is also important to acknowledge the impact that the road layout can have on congestion (Lighthill & Whitham, 1955). While existing motorway developments may experience congestion because of this, new motorway developments can avoid its occurrence through sound design principles. Design can also improve the time required for a new motorway

development to recover from a period of congestion (Strömgren, 2011). This, however, goes beyond the scope of the present thesis research.

In Figure 3, the impact a motorway development can have on traffic volume due to increased supply is displayed. Due to motorway construction, congestion is decreased from an increase in roading supply (Handy, 2005). Motorways can then accommodate a larger volume of vehicles while decreasing demand on other roads. Figure 3 also displays how the increase of supply could result in a shorter travel time due to a reduction in demand.

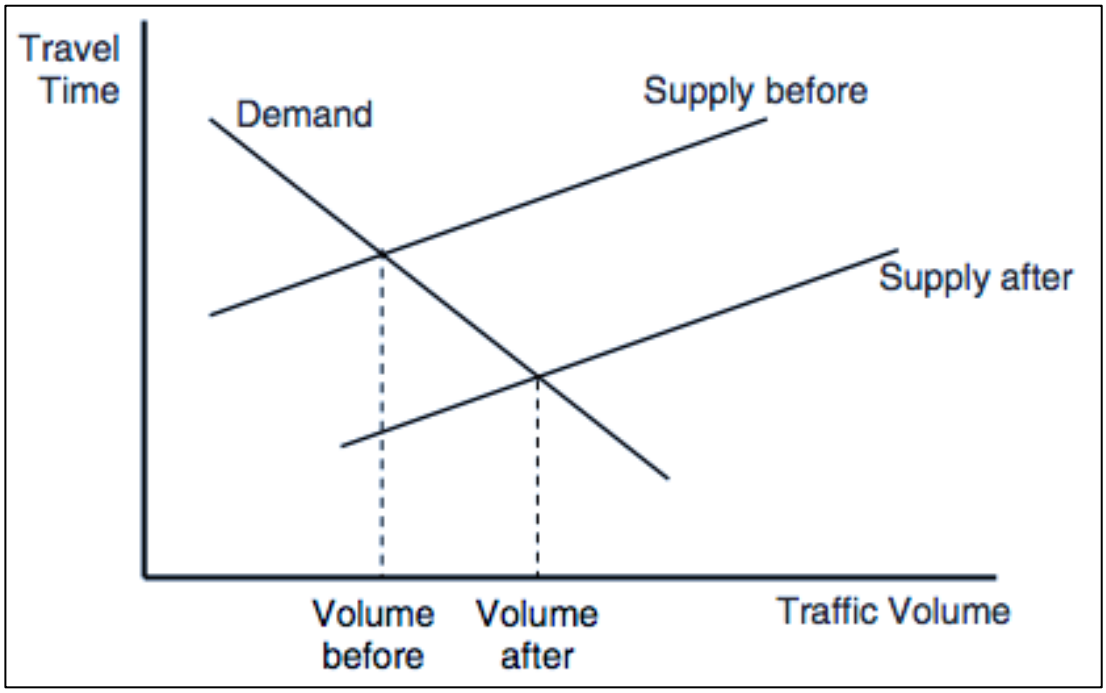


**Figure 3: A visual representation of how a shift in road supply can impact traffic characteristics (Handy, 2005).**

Motorway congestion can also have a social cost, which is harder to measure (Brueckner, 2000). This is commonly overlooked in transportation studies as most focus on improving traffic flow, technology, climate change and safety. Societal impacts could include, but should not be limited to: impacts on health and wellbeing; time spent commuting; loss of income through loss of time; and climate change. The study by Brueckner (2000) acknowledged that there is a societal cost associated with congestion. However, the societal cost of congestion was not the focus of this study. Societal cost is thus a gap that exists in the literature. However, with new motorway developments minimising the impacts

of congestion, these social costs may, in fact, be reduced (Brueckner, 2000). This is another benefit of large-scale motorway development.

Motorway development can reduce the volume and frequency of bottlenecks. Lighthill and Whitham (1955) acknowledged the role the receiving environment plays in creating bottlenecks. Motorway development often does not alter the receiving environment. However, motorway development can reduce or remove bottlenecks that are caused by motorway features, such as a reduction in lanes to go through a tunnel. Improving the capacity of the motorway will, in turn, improve these flow conditions (Lighthill & Whitham, 1955). This ensures that the motorway's vehicle capacity should not be exceeded, meaning that cars are less likely to crawl or end up in a bottleneck. Constructing motorways results in a reduction in traffic and congestion (Carey & Semmens, 2003). Consequently, bottlenecks in urban areas are more likely to be reduced due to a decrease in local traffic arising from motorway development.

As discussed above, a variety of factors of motorway development all come together to reduce congestion. The manner in which these factors may influence congestion recovery varies. However, they all assist in either preventing congestion or speeding up the motorway's recovery post congestion. In relation to this, this research addresses congestion within the context of the Wellington Region's case studies.

### *2.3.6 Economic Benefits*

Motorway development can have a significant impact on the price of land in an area (Carey & Semmens, 2003). A reduction in travel times is the reason for this. This can result in higher property prices occurring along the motorway corridor, as the land becomes more desirable to developers (Carey & Semmens, 2003). Further, motorway development may make it more feasible for commercial and residential development to occur in areas further away from major centres (Handy, 2005). As a result of this, motorway development is a tool that can encourage urban growth and can have positive economic benefits on land prices.

> *"In sum, the evidence suggests that highways influence land prices, population, and employment changes near the project, and that the land use effects are likely at the expense of losses elsewhere"* (Handy, 2005, p. 152).

This quote by Handy (2005) demonstrates the clear linkage that exists between motorway development and land prices. However, this quote does also acknowledge some of the effects of motorway development that are discussed later in this literature review. Figure 4 displays the importance of investment in transportation networks and their influence on land development patterns. While this could result in sprawl due to motorway development, it can also open up new land for development (Handy, 2005). This then positively impacts on the price of land due to transportation investment. Thus, the economic benefits of motorway development improve the accessibility of previously remote areas.

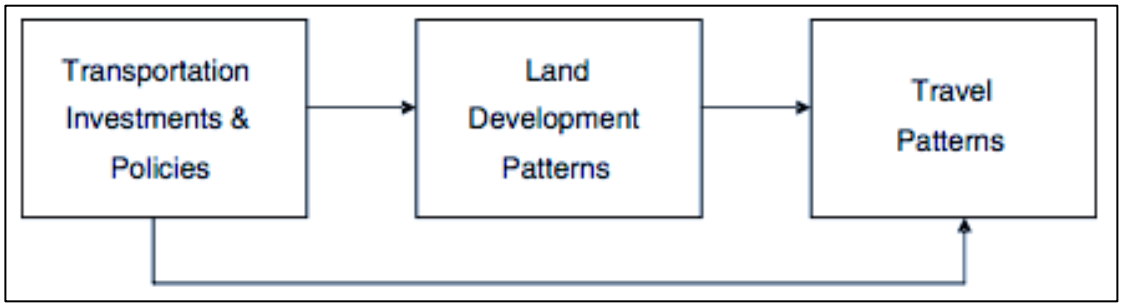


**Figure 4: Links that exist between transportation and land use (Handy, 2005).**

Two approaches can gauge accessibility to a motorway. The price of the land surrounding motorway developments, and the amount of growth that has occurred due to a motorway development (Handy, 2005). Economic theories also link the amount of development a particular area may receive, versus its accessibility compared to other regions (Gunder, 2002). Zhao (2010) argues that transportation is essential for the development of megacities. This is similar to the research by Handy (2005) in that it places transportation and transportation developments as a primary driver for the economic growth of an area. Poelmans and Van Rompaey (2009) found that in the United States of America the location of motorways and their entrance/exit points were necessary for the development of newly urbanised areas. As a result of the above points, the introduction of a motorway development can result in positive economic development of a previously remote area due to increased accessibility.

Brueckner (2000) discussed how sprawl, a by-product of motorway development, can be viewed from a supply and demand context. Sprawl may occur when a developer is willing to pay more for the parcel of land than an agricultural user would. The developer does this as they theorise that the land could have a greater economic contribution in a developed state (Brueckner, 2000; Poelmans & Van Rompaey, 2009). Comparatively, productive agricultural land is more expensive and is less likely to be susceptible to sprawl. This emphasises the positive economic impact that accessibility due to motorway development can have. How the Wellington motorway developments may result in economic growth and development is analysed in this thesis through interviewing Key Informants.

## *2.4 Adverse Effects of Motorway Development*

Whilst the previous section acknowledged some of the benefits of motorway development, it is also important to consider the effects that could arise due to motorway development. The adverse effects that motorway development could have include: impacts on the receiving environment; effects on the road user; effects on climate change and air pollution; impacts on urban form; and health effects (Frank *et al.*, 2008; Litman, 1995; Newman & Kenworthy, 1989). A discussion about these adverse effects follows.

### *2.4.1 Impacts on the Receiving Environment*

Often the result of motorway development is that the capacity and flow of a motorway is improved. However, if the local roads are unable to receive this improved capacity efficiently, then congestion and bottlenecks will still occur (Frank *et al.*, 2008). Increased vehicle volumes can be an unintended consequence of motorway development, with congestion in the urban core then occurring. This is what Frank et al., (2008) found in their study in Puget Sound. If the receiving environment has topographical constraints, such as tunnels or limited capacity local roads, then the increased flow of motorway traffic can not be efficiently distributed amongst the receiving environment (Handy, 2005). Topographical constraints could result in gridlock within the receiving environment itself. Literature pertaining to the impact motorway development

may have on the receiving environment is, however, limited. The establishment of a theoretical link to the Wellington Region case study is thus limited.

Motorway developments have a detrimental effect on their surrounding environments. This can be through poor air quality, urban sprawl or lower quality of life (Müller, Steinmeier & Küchler, 2010). Whilst Muller et al., (2010) looked at some of the urban issues associated with motorway development, Gunder (2002) discussed some of the impacts on the original environment of New Zealand. In New Zealand, motorway development has occurred at the expense of native species, vegetation, forests and agricultural land (Gunder, 2002). This demonstrates some of the detrimental effects of motorway development as observed in New Zealand.

Often, the largest group opposing motorway development are the property owners surrounding these developments. This is because they believe that they will be significantly adversely affected by the environmental impacts of the motorway development, such as noise and air pollution (Carey & Semmens, 2003). They often do not consider the lower transportation cost that could benefit them due to the motorway development (Carey & Semmens, 2003). By weighing up the positives and the negatives of the development, those who remain opposed to motorway development are of the opinion that they could be significantly adversely affected by the development going ahead. This can be an issue with such developments, and these groups can often advocate against these developments (Taylor, 1995).

An increase of private vehicles within the city due to motorway development can also have adverse effects. In Wellington City, increasing volumes of private vehicles within the city were causing negative environmental effects (Dodson & Mees, 2003). Further, new motorway development can cause induced demand. This can result in more individuals deciding to use their private motor vehicle to commute, instead of alternative methods of transportation (Handy, 2005). When this occurs, the receiving environment is impacted, with more pressure faced by the local roads. The Wellington motorway developments may cause adverse effects on the receiving environment of Wellington City. To assess this, GIS and

Key Informant interviews were undertaken to understand what impacts these developments have had, or are likely to have, in Wellington City.

### *2.4.2 Adverse Effects on Transportation Users*

Research on how new motorway developments can impact on an individual's travel behaviour has previously been insufficient (Frank *et al.*, 2008). Whilst studies have previously addressed built form, and how transportation projects such as motorways may create change, they have not focused on how these projects would influence people's travel behaviour. Litman (1995), found that increased traffic through a community can have negative impacts on the community's behaviour. This includes creating a dispersed urban form, encouraging non-active modes of transportation, decreasing patronage at local businesses, and can have significant impacts on the community's most vulnerable individuals (Litman, 1995). Other effects can include community disruption, visual intrusion, noise, and the symbolic threat of a motorway development (Dunt, Abramson & Andreassen, 1995). The study by Litman (1995) focused on how people may change their transportation patterns because of a new motorway project. And the study by Dunt et al. (1995) had more of a focus on health impacts. However, they each noted that changes to urban form, as a result of motorway developments, may change people's travel behaviour and that the surrounding environment could be affected (Müller, Steinmeier & Küchler, 2010). This could have further negative societal impacts and is discussed later in this literature review.

The other impacts and effects that motorway development may have on the user are harder to measure. These other potential impacts include, but are not limited to added convenience for the user's journey, provision of easier access for emergency services to carry out their work, and comfort improvements from smoother travel surfaces (Carey & Semmens, 2003). Acknowledging these other benefits of motorway development is essential. This thesis assesses the impacts that motorway developments may have on road users through conducting Key Informant interviews.

In the study by Frank et al., (2008) a link was identified between a person's willingness to use public transportation and time. Frank et al., (2008) identified this, as changes to a person's trip time were found to have the biggest impact on a person's desire to use public transportation, instead of changes to the fare. As a result, it can be noted that the most important aspect of a person's journey is time (Frank *et al.*, 2008). If a new motorway development reduces the time it takes for an individual to carry out their trip, then it is possible that new motorway developments could encourage more private vehicle use. However, it is unknown how much of a time reduction would need to occur for this shift to happen. Through analysing vehicle counts before and after the completion of Wellington's motorway developments, it is possible to assess the impact they have had on the transportation user. This fills a gap that exists in the current literature.

### *2.4.3 Climate Change, Air Pollution and Health*

Broad academic acknowledgement exists surrounding the link of motor vehicles to climate change. Further, the effect that motor vehicles have on air pollution, health and other environmental effects have also previously been identified, with some studies identifying the adverse environmental effects of car usage (Dunt, Abramson & Andreassen, 1995; Grumert, Ma & Tapani, 2015; Newman & Kenworthy, 1989). Induced demand was identified as a potential issue of motorway development; increasing volumes of private vehicles could contribute to the above-mentioned climate issues.

The use of motor vehicles has led to air pollution issues through emissions of respirable particulates such as sulphur dioxide, nitrogen dioxide and carbon monoxide. In small doses, these are unlikely to pose health hazards (Dunt, Abramson & Andreassen, 1995). Previous research into the health impact of motorway developments has had a narrow focus. Studies have looked into the impacts of the development on one health issue, not a comprehensive overview of all health effects (Dunt, Abramson & Andreassen, 1995). Grumert, Ma and Tapani (2015), have linked car usage and emissions to air pollution. This research did not extend into looking at the health impacts of motorway

development and increasing vehicle use (Grumert, Ma & Tapani, 2015). This link between transport planning and health studies is an area that warrants future research.

Ozone pollution from a motorway development will only occur on the urban scale. This is much larger than if it was localised and only occurred on the neighbourhood scale (Dunt, Abramson & Andreassen, 1995). Noise pollution is also a major environmental effect of motorway development. In particular, noise pollution can cause ill health-related effects mainly due to the disturbance it may cause to an individual who lives close to the developments (Dunt, Abramson & Andreassen, 1995). The study by Dunt et al., (1995) had a heavy environmental focus. This discussed both the impacts on the surrounding environment of motorway development but also a wider perspective regarding the impact on climate change. So whilst some of the effects of motorway development may be local, they can also impact on a much broader environment.

The effective execution of spatial planning can influence travel choice through urban form. If a city is more walkable, people might walk. If a city has an effective public transportation network, people could utilise it for their commuting (Dodson & Mees, 2003; Litman, 1995). Effective urban form thus limits $CO^2$ emissions (Grazi, van den Bergh & van Ommeren, 2008). Newman and Kenworthy (1989) have also noted this. In their study, they identify that both re-urbanisation and a reorientation of a city's transportation priorities could result in reduced gasoline consumption and reduced automobile dependence (Newman & Kenworthy, 1989). A combination of both effective public transportation and more efficient road developments could attain this reduction. By utilising this approach, there could be a reduction of greenhouse gas emissions through a reduction in traffic congestion.

In previous studies, such as the research undertaken by Grazi, Bergh and Van Ommeren (2008), there was an emphasis on how important and influential sound policy for urban form could be on greenhouse gas emissions. This is necessary for future transport planning and policy creation. Motorway developments may result in more vehicles being used by individuals due to the

perceived benefits (Frank *et al.*, 2008). This could lead to increased emissions and air pollution, an issue that Grazi, Bergh and Van Ommeren (2008) did not acknowledge. The impacts that motorway development may have on climate change, air pollution and health have been identified by the literature. However, they are considered to be outside of the scope of this thesis. Whilst Key Informants may wish to discuss these effects as a part of the new Wellington motorway developments they are not considered to be significant.

### *2.4.4 Impacts on Urban Form*

Motorway developments can have a significant impact on urban form. This can come in many forms, such as development along the new road corridor, urban sprawl, and urban infill (Brueckner, 2000; Carey & Semmens, 2003; Handy, 2005; Munoz, 2003). Further, this change to urban form may also influence transportation. Understanding how new motorway developments could impact on urban form is an aspect being considered by this thesis.

Development can occur along the fringe of urban areas due to motorway development. These areas, along the urban periphery, have received increased urban development as a direct result of motorway development (Munoz, 2003). Land and house values can also be significantly affected (Carey & Semmens, 2003). Both Munoz (2003) and Carey and Semmens (2003), acknowledged that there was a link between urban development and motorway development. This link occurred primarily because of a change of land price, but also through increased urban development. Many of the articles analysed for this literature review acknowledged that link between motorway development and changes in land value, as discussed previously (Carey & Semmens, 2003; Munoz, 2003).

The combination of a variety of variables is used to measure urban sprawl. These often include density, land use mix, the degree of centring, and street accessibility (Ewing, Pendall & Chen, 2003; Kasanko *et al.*, 2006). Sprawl is a natural expansion of the metropolitan area due to population growth, or it can occur as unplanned growth. It is also worth considering the influence that city-specific topography can have on its form (Catalán, Saurí & Serra, 2008; Müller, Steinmeier & Küchler, 2010). A study undertaken by Catalan, Saurí and Serra

(2008) found that city-specific geography can significantly impact sprawl. This includes rivers, harbours, mountains, lakes, hills and coastline. Catalan, Saurí and Serra (2008) reached this conclusion through analysing aerial photographs of Mediterranean cities. Topography could be a significant driver as to where urban development occurs in Wellington. GIS and Key Informant interviews are used to assess this.

Definitions of sprawl vary significantly, each slightly different from the other depending on the author. Müller (2010) defined sprawl as:

> *"The physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas" (Müller, Steinmeier & Küchler, 2010, p. 3).*

This quote is effective with how it captures both the physical change to the city's urban form, by discussing the expansion out from the urban area. The quote also identifies the receiving environment of that land expansion. Academics often primarily focus on what form the metropolitan area could take, versus considering what area the city is sprawling into (Brueckner, 2000; Ewing, Pendall & Chen, 2003; Poelmans & Van Rompaey, 2009). The study by Müller (2010) is critical in the breadth of analysis used to assess sprawl. This views sprawl as a process involving a multitude of interconnected factors.

Litman (1995) acknowledged that automobiles possess an active link to urban sprawl and changing landform. This is due to the amount of urban land required for both roads and parking, which results in the degradation of the urban environment and the development of low-density housing at the urban periphery (Litman, 1995). Academics have tried to define sprawl in the way it changes landform. Handy (2005) describes sprawl as dispersed auto-dependent development, which can occur outside of both compact urban and village centres, and instead forms along highways and in the rural countryside (Handy, 2005). This demonstrates that the development of motorways can significantly impact on urban form, and can cause cities or urban centres to actively sprawl. Zhao (2010) identified that there is a relationship between changes in the form of land use and that it can have a significant impact on transportation. This is

shown in Figure 5, which demonstrates the relationship between urban form, socioeconomic factors and attitudes to transportation. As a result of sprawl, long-distance transportation is required along key routes to reach the city centre (Zhao, 2010). Unlike Handy (2005), Zhao (2010) acknowledged the need for transportation routes because of sprawl, whereas Handy (2005) identified transportation as a driver of sprawl.

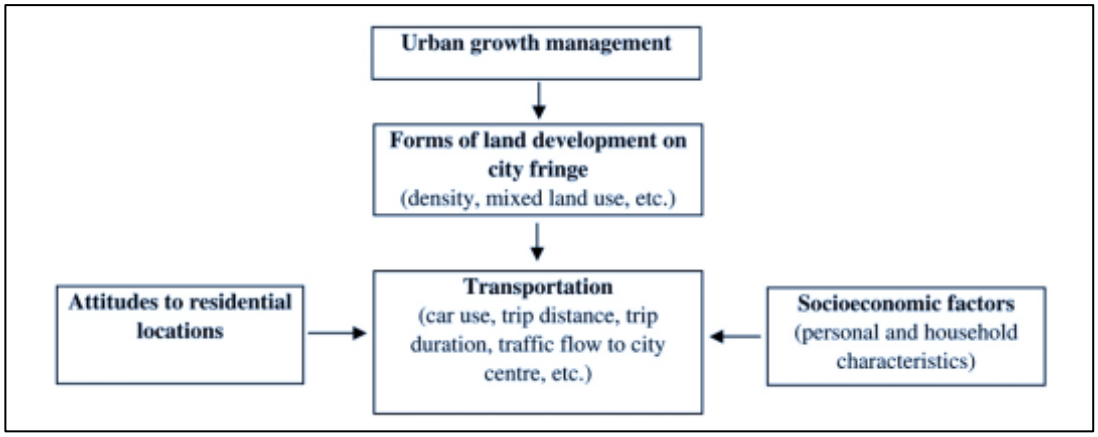


**Figure 5: The link between urban growth management, land development, and transportation (Zhao, 2010).**

Brueckner (2000), argues that urban sprawl, or urban spatial expansion as the author refers to it, is driven primarily by growing populations, rising incomes and falling commuting costs. Consideration of both rising incomes and falling commuter costs places more of an emphasis on the influence the nation's economy could have on sprawl (Brueckner, 2000). Further, commuter costs will fall as a result of motorway development (Brueckner, 2000). This could result in more people commuting from new suburbs due to a decrease in commuting cost as a result of motorway development.

Sprawl is also an intrinsic urban process which is related to the economic maturity of the city studied (Catalán, Saurí & Serra, 2008). Catalán (2008) is, however, alone on this reasoning. The majority of authors have cast sprawl in a negative light (Brueckner, 2000; Kasanko *et al.*, 2006; Zhao, 2010). This is primarily as a result of poor planning and policy development resulting in poor urban form and unintended consequences. Through the case study of Wellington,

it is possible to identify in what manner Key Informants view urban sprawl and if it is a positive or negative of the region's urban form.

Handy (2005), identified that in the United States of America there is a clear link between motorway/freeway development and urban sprawl. Through increasing road capacity, territorial authorities were using these motorway developments as a method for encouraging sprawl and development on the urban periphery (Handy, 2005). Zhao (2010) also observed this in a case study of Beijing in China. International examples show how sprawl is encouraged through motorway developments. As a result, it is an effect of motorway development (Zhao, 2010).

The literature on sprawl rarely discusses the relationship between urban form and transportation outcomes. An issue with sprawl is that whilst sprawling regions can have a positive impact on the transportation network by dispersing congestion, they create more vehicle miles that have to be travelled by the residents. This can negate some of the positive benefits of this form of urban dispersal (Ewing, Pendall & Chen, 2003). If inhabitants of these sprawled neighbourhoods were encouraged to use alternative forms of transportation, such as public transportation, then the impact of this would be mitigated (Munoz, 2003). Munoz (2003) contends that motorway development encourages private car use instead of public transportation. This is because they have more convenient access to the motorway network and their final destination. Handy (2005) agrees, stating that with easier access to a motorway development, people are more likely to use their cars as a result of induced demand. This similarity between both of the previously mentioned authors demonstrates the clear link that exists between urban form and demand for transportation.

There is limited literature on how motorway development can contribute to urban infill. A study by Munoz (2003) attributed motorway development as having significant impacts on pre-existing densely compact Mediterranean cities. These cities initially encouraged dense infill as the predominant urban form; motorway development has resulted in diffuse urban sprawl (Munoz, 2003). However, these motorway developments have also led to people making more

use of the land that previously existed within urban centres (Munoz, 2003). The article was divided on how motorway development contributed to or hindered urban infill. One method for assessing how motorway development can impact on urban form is to use the 'with and without test'. This offers an insight into the indirect impacts that a motorway development may have on an area and its associated urban form (Litman, 1995). By discussing changes to urban form due to Wellington's motorway developments with Key Informants, a variation of the with or without test is carried out. This offers an insight into what territorial authorities expect development to be like, with or without the Wellington motorway developments.

Motorway development influences urban form in New Zealand. This is visible in Auckland, where motorway development occurred at the expense of mass transit development. Auckland's significantly dispersed urban form is because of motorway development (Gunder, 2002). This linkage between the development of motorways and urban form has been a frequently acknowledged issue amongst some studies (Carey & Semmens, 2003; Müller, Steinmeier & Küchler, 2010; Taylor, 1995).

Policy can be utilised to mitigate the impacts that motorway development may have on urban form. Through policy, it is possible to encourage sustainable growth, or to control unplanned growth and to mitigate some of the effects of this (Hickman & Banister, 2007; Zhao, 2010). In Beijing, it is a policy approach being used to attempt to manage unplanned sprawl with increased car and gas usage being by-products of this (Zhao, 2010). Whilst the study by Zhao (2010) was assessing policy that was reacting to a change in urban form due to motorway development, Hickman and Banister (2007) questioned the effectiveness of attempting to predict these issues through modelling. This questions the efficacy of other studies that utilise a modelling approach, with real-world case studies carrying more weight and significance. Consequently, the case study approach of Wellington being used by this thesis is the most effective methodology. This enables the efficacy and effects, both positive and negative, of large-scale motorway development to be determined within the Wellington Region case study.

## *2.6 Motorway Development as a Planning Problem*

During the 1950s, motorway developments utilised an American approach. This included European countries sending their planners to America to learn the American approach and then translating freeway development manuals (Knoflacher, 2007). There was no consideration as to how the American method would impact on other countries' existing urban structure (Knoflacher, 2007). In Europe, this shifted many centres from focusing on active modes of transportation to more reliance on private motor vehicles. The American approach burdened many urban centres with incorrect approaches to transportation planning, which then impacted on their built urban form (Knoflacher, 2007). As a result, the American style of motorway planning has led to dispersed urban form, congestion, environmental effects and has impacted on the motorways' receiving environments (Brueckner, 2000; Dunt, Abramson & Andreassen, 1995; Frank *et al.*, 2008; Litman, 1995). Through the application of the American planning approach, motorway development in New Zealand has been burdened by these adverse effects.

Motorway development also encouraged unsustainable transportation. High private motor vehicle use combined with the provision of more motorways in cities has resulted in cities having high car and energy consumption (Kenworthy, 2006). These motorway developments can lead to an indiscriminate use of private motor vehicles. This is because citizens can live in a detached environment, away from their place of work, and rely on convenient access to work by their private car on the motorway network (Munoz, 2003). Kenworthy (2006) found that in the United States of America, those cities with the highest volume of private motor vehicles had the highest length of freeways per person. This increased usage of private motor vehicles due to motorway development is another planning issue that is faced by motorway developments. It has also occurred in the Wellington Region. The motorway developments that this research focuses on could, in fact, lead to an indiscriminate use of private motor vehicles and a desirability to commute over longer distances.

Motorway developments also create a planning problem due to the impact that they have on urban form. Motorway development can result in dispersed

urban form, such as sprawl (Carey & Semmens, 2003). With sources acknowledging a strong link between urban development and motorway development, it is important that motorway development considers the impact it could have on urban form (Carey & Semmens, 2003; Munoz, 2003). In both the United States of America and the Mediterranean, articles have been published linking motorway development to dispersed urban centres and sprawling regions (Catalán, Saurí & Serra, 2008; Handy, 2005). As a result, motorway developments have a significant impact on urban form. To understand the impact of motorway development within the Wellington Region, Key Informants were asked questions about how they perceive motorway developments as a planning problem. This will offer a greater insight into motorway development as a planning problem within the Wellington Region and contributes to a wider understanding of international motorway development.

## *2.7 Motorway Tools*

To improve the efficacy of motorways, a range of tools is available to any motorway development. These tools often integrate new forms of technology with existing motorway developments to improve the motorway's efficacy. Improved efficacy is possible through improving the free-flow speed and traffic characteristics of an existing motorway. To understand the range of tools available, this section discusses smart motorways, smart technologies, VSL, computer control programs such as METANET, and the possibility of technological disruption.

### *2.7.1 Smart Motorways*

Smart motorways are another motorway approach utilised in New Zealand to ensure high-quality motorway development. Smart motorways are only made smart by the technology that they possess. Harmonised traffic flow is possible through implementing smart technologies, safety is increased, and information is gathered (Chiou, Huang & Lin, 2012; Dia & Rose, 1997; Nissan & Koutsopoulosb, 2011). Programs such as METANET can be utilised to control the flow of traffic or run simulations. Tools such as VSL can also be used to control the flow of traffic. It is this combination of tools that make a motorway 'smart'.

### *2.7.2 Smart Technologies*

Smart motorways are only considered smart because of the technology they possess. Technology includes VSL, traffic detection systems, computer algorithms, vehicle activated signs, incident detection systems and ramp metering systems (Cheu & Ritchie, 1995; Dia & Rose, 1997; Grumert, Ma & Tapani, 2015; Hegyi, De Schutter & Hellendoorn, 2005a). These technologies all possess the ability to monitor, control and react to real-world situations along a stretch of motorway. Numerous studies have been undertaken to assess the effectiveness of these technologies for controlling the flow of traffic and for assessing if they mitigate motorway issues such as congestion and accidents.

Smart technology can also mitigate the adverse environmental effects of motorway development and private vehicle usage. VSL achieve this by ensuring a consistent control over the network speed. As a result, the need to accelerate erratically is removed, ensuring fewer greenhouse gas emissions (Grumert, Ma & Tapani, 2015). The discharge of greenhouse gas emissions is high along motorway corridors, but VSL can reduce these emissions. Through the utilisation of VSL, vehicles are more likely to maintain a smooth and consistent speed (Grumert, Ma & Tapani, 2015). The result is a harmonised and consistent traffic flow that should produce fewer greenhouse gas emissions.

One new technology that is present on new motorway developments is incident detection systems. Combined with a traffic detection system and an advanced algorithm, this can result in smoother and quicker responses to motorway incidents, lessening the impact they may have on the wider roading network (Dia & Rose, 1997). Incident identification is important, as the quick response to an incident, and the time it takes to return the motorway to its normal rate of flow, is a primary objective of most motorway control centres (Cheu & Ritchie, 1995). This detection of incidents is also incredibly important for the control centre to formulate a response to the incident. Responses can include dispatching emergency services, controlling and rerouting traffic around the incident, providing road users with real-time information and sending out incident removal crews (Cheu & Ritchie, 1995). Dia and Rose (1997) identify the importance of these systems due to the high volume of congestion in the United

States of America caused by traffic incidents. Incident detection systems could minimise incident disruptions on Wellington's motorways if employed.

Vehicle activated signs are another tool employed by smart motorways for controlling the speed of road users. As a tool, they are widely used to reduce speeding in high incident areas. Further, they have an acknowledged track record of reducing both the number and severity of accidents in areas in which they are installed (Jomaa *et al.*, 2016). A vehicle activated sign is activated when a set series of events or criteria occur, such as the vehicle travelling too fast for a corner (Jomaa *et al.*, 2016). Whilst an important tool, the distribution of these signs tends to be on roads rather than on motorways, with none being present on the motorway developments this thesis is analysing. Other technology being utilised by smart motorways includes VSL. The discussion around the importance of VSL will occur next.

### *2.7.3 Variable Speed Limit Signs*

The distribution of VSL occurs along the length of smart motorways. The purpose of VSL is to make drivers aware of the actual speed conditions of the road, which can result in a decrease in accidents and an increase in the efficiency of traffic (Grumert & Tapani, 2012). As a tool, VSL has been identified as effective when densely distributed along an intelligent motorway network (Chiou, Huang & Lin, 2012). When combined with a monitoring system and artificial control system such as METANET, the system becomes capable of predicting traffic behaviours and patterns. In this instance, VSL is then capable of mitigating congestion by pre-emptively changing the speed limits before congestion occurs (Sun *et al.*, 2014). Other benefits of VSL include harmonised traffic flows, more homogenous headways, and decreased variance in speed (Grumert & Tapani, 2012). To assess the effectiveness of VSL, Chiou et al., (2012) looked at both the efficiency of a section of road and also the safety characteristics of a section of road. This is an approach that has been used by some other studies, and is modified and used in this thesis.

A study undertaken by Nissan and Koutsopoulosb (2011) found that VSL is most effective when traffic volumes are 15-20% below the capacity of the

highway. Reaching the capacity of the motorway results in VSL struggling to control and manage traffic appropriately. An analysis of the wider literature confirmed this issue (Chiou, Huang & Lin, 2012; Grumert & Tapani, 2012; Nissan & Koutsopoulosb, 2011). By increasing a motorway's capacity, VSL could be more effective, which could be the case with the addition of a northbound lane on the Wellington Smart Motorway. The previous research did not address the effectiveness of VSL for flow recovery. However, the study by Morries et al., (2011) did find that in the United Kingdom it was used as a tool for improving motorway congestion recovery time. This study was limited because the VSL did not adjust to traffic conditions, only to the time of the day in a fixed cycle.

Traffic incidents can have negative impacts on the roading network through reducing roadway capacity and creating shockwaves. VSL has become widely used as a tool to enhance safety and network efficiency at high incident sites (Chiou, Huang & Lin, 2012; Grumert, Ma & Tapani, 2015; Grumert & Tapani, 2012). In countries such as Germany, research on VSL has acknowledged it as enabling harmonised traffic flows while reducing speed differences in the traffic stream (Geistefeldt, 2011). Through the effective utilisation of VSL, the adverse impacts of vehicle incidents and congestion can be mitigated, ensuring greater network efficiency. Further, the use of dynamic speed limit signs can significantly reduce the road's congestion and result in lower time spent travelling for road users (Hegyi, De Schutter & Hellendoorn, 2005a). The study by Geistefeldt (2011), is useful in that Germany has a wide range of VSL controlled motorways and their drivers are used to this technology. This could mean the benefits that Geistefeldt found in their study could apply to other such smart motorway networks, such as in Wellington. This was further backed up by research carried out by Grumert and Tapani (2012), who found that VSL had many traffic and congestion benefits, with their research looking at active smart motorways in the United Kingdom and the Netherlands.

VSL as a tool can benefit the motorway system by leading to a decrease in accidents, as drivers are driving to the road conditions, and increase traffic efficiency (Grumert & Tapani, 2012). A method that is utilised by VSL is to incrementally drop the speed limit in 10km/h increments to improve safety and

efficiency (Hegyi, De Schutter & Hellendoorn, 2005b). This is an approach similar to what is occurring in Wellington. Attaining the motorway's critical speed and reducing shockwaves is possible through the utilisation of a program like METANET. The research also suggests that shock wave reduction is most effective when VSLs are placed every one kilometre (Hegyi, De Schutter & Hellendoorn, 2005b). This shows the link that exists between these smart technologies being utilised on motorways and motorway capacity and congestion features as discussed previously. To analyse the efficacy of VSL as a smart motorway tool, this thesis examined the traffic flow and capacity of Wellington's smart motorway and asked Key Informants questions about the efficacy of VSL.

### *2.7.4 Metanet*

Motorway traffic management occurs through the detection and processing of traffic characteristics such as speed and traffic flow which, when analysed by a system such as METANET and combined with tools such as VSL, can result in harmonised and efficient traffic flow (Nissan & Koutsopoulosb, 2011). Systems, such as METANET replace the need for human controlled traffic centres and utilise a wide variety of sensors and tools to create a harmonised and smooth traffic flow. Depending on the level of programming, METANET type systems possess the ability to forecast and predict traffic events and respond accordingly through the use of smart technologies such as VSL (Dia & Rose, 1997).

The primary purpose of a program such as METANET is to create uniform traffic flow and improve traffic mobility and safety. METANET is a prediction modelling tool that attempts to behave proactively by predicting issues, such as congestion, before they occur (Sun *et al.*, 2014). However, there are not many studies published that look at METANET as a tool for controlling smart motorways. Instead, it is often used as a tool for studies to map traffic flows and run flow simulations for new sections of motorways (Chiou, Huang & Lin, 2012; Hegyi, De Schutter & Hellendoorn, 2005a; Sun *et al.*, 2014). These three studies found METANET to be an efficient and accurate tool for running traffic simulations, but none of them utilised METANET in a real-life setting. So whilst it

is widely being used as a tool for running simulations, research is limited as to the actual application of METANET in a motorway control environment. It is important to note here that the Wellington Smart Motorway is utilising a system similar to METANET that they have created. This research accesses the effectiveness of computer systems for traffic control through the Wellington Smart Motorway case study.

### *2.7.5 Technological Disruption*

Motorway developments did not previously acknowledge how important private vehicles were going to be for people and their identity. When planners focused on the provision of public transportation, such as trams and buses, they failed to take into account the popularity of the private motor vehicle (Gunder, 2002). This means motorway developments are playing catch-up to meet the demand of private vehicle use that outgrew existing motorways. It is essential for transport planners to consider the role that new technology could play in motorway development now and into the future.

In the future, it is also worth considering what disruptions could occur to the demand for roads and transport through changes to technology. Ride-sharing applications such as Uber and Lyft have disrupted the demand for taxi services. This means that technology could still further disrupt the way people interact with roads and use motor vehicles (Chaube, Kavanaugh & Perez-Quinones, 2010; Feeney, 2015). These systems work on the basis of a sharing economy, whereby individuals can share the benefits of fewer resources. Ride-sharing can also lessen issues, such as the environmental impacts of private car usage, by encouraging people to share rides (Feeney, 2015). This possesses the potential to lower vehicle-related emissions and also to decrease the volume of traffic on roads, a point argued by both authors.

## *2.8 Motorway Development and Typology*

There are a variety of motorway typologies in use around the world, such as: ring roads; freeways; highways; toll roads; and interstates (Papageorgiou & Kotsialos, 2000; Pearce, 1974). It is worth noting here that freeways, motorways

and highways are the same road typology. However, depending on the nation of origin they are referred to by different names (Federal Highway Administration, 2017).

Ring roads have the potential to minimise the impacts of commuter vehicles within cities by reducing the distance of travel, reducing congestion and increasing trip speed (Pearce, 1974). Ring Roads circumvent the slow, central area of a city with a higher-speed route (Pearce, 1974). The literature identified that by diverting traffic on a ring road, instead of through a city, air quality is improved (Caselli *et al.*, 2010). Freeways were originally implemented to provide increased mobility for road users (Papageorgiou & Kotsialos, 2000). The uninterrupted free-flow of vehicles in both directions separated by a physical barrier makes this possible (Federal Highway Administration, 2017). In America, a motorway fits the same definition as a freeway (American Association of State Highway and Transportation Officials, 2001). So whilst the terminology is different, the operation is the same.

Toll roads can present a number of benefits and issues. For one, toll roads offer the government the opportunity to raise funds from road users to pay for the development and maintenance of road development. However, toll booths can create congestion, as it is very complicated to predict the waiting time to pay a toll at a toll booth (Richards, 1956). To pay the toll, an interruption of traffic flow has to occur (Federal Highway Administration, 2017). Since toll roads work on a user-pays system, fewer people may be inclined to use them for their commute (Richards, 1956). Aside from the paying of tolls, the Federal Highway Administration (2017) claims that they function similar to freeways.

## *2.9 Motorway Typology in New Zealand*

Motorway development in New Zealand has also historically been influenced by how motorway development occurs in the United States (Gunder, 2002). The De Leuw Cather Reports carried out in the 1960s show this American approach (Dodson & Mees, 2003). The American approach utilised freeways with multiple lanes and few exits, with weight afforded to increasing capacity and improving

traffic flow (Taylor, 1995). In New Zealand, motorway developments include toll roads, expressways and motorways.

Three types of motorway typologies are present in New Zealand. These are motorways, expressways and toll roads. In New Zealand, expressways are considered to be dual carriageways with a focus on providing for through traffic. Access can be restricted to achieve this purpose, and these expressways do not face any operational restrictions (New Zealand Transport Agency, 2010). Motorways are sections of roads where specific rules have been applied to provide the best vehicle-operating environment. These restrictions include no stopping, and a ban on pedestrian and cycling traffic along these roads (New Zealand Transport Agency, 2010). The last typology of motorways present in New Zealand is the toll road. Toll roads are a section of road or motorway that requires the driver to pay a fee to utilise a faster and safer route to their destination. By New Zealand law, a viable free alternative route to a toll road must be available (New Zealand Transport Agency, 2010). This thesis will analyse the Kapiti expressway, which is an expressway, and Transmission Gully and the Wellington Smart Motorway, which are both motorways.

### *2.9.1 Issues with Motorway Development in New Zealand*

The World Bank uses New Zealand as an example of good transport planning, yet New Zealand as a country has sustainability issues when it comes to its transportation planning (Dodson & Mees, 2003). This is primarily credited to a heavy reliance on American style motorway development from 1965 that occurred in Auckland, Wellington, Christchurch and Dunedin (Gunder, 2002). Development saw existing tram networks and public transportation networks downsized in favour of a more automobile-dependent society and transport planning documents prepared by American firms (Dodson & Mees, 2003; Foy, 2014). As a result, private motor vehicles are the primary transport provider for New Zealand, and to cope with growing demand and pressure, more motorways are required (Dodson & Mees, 2003).

With at least 85% of New Zealand's population being urban, and 30% of this population residing in Auckland, significant pressure exists on motorways

around these densely populated centres (Lee & Rivasplata, 2001). These motorways were primarily two-lane roads outside of major centres with significant motorways previously only existing outside of Auckland and Wellington (Lee & Rivasplata, 2001). This shows the regionally specific nature of motorway development as a planning issue within New Zealand. Further, the limited capacity of motorways outside of these main centres demonstrates that motorways were ill-equipped to handle increased road capacity that has occurred in New Zealand through increasing populations (Early, Howden-Chapman & Russell, 2015). In Auckland, congestion from increasing road use and poor motorway planning has been estimated to cost the New Zealand economy 1% of its GDP (Sankaran, Gore & Coldwell, 2005). As a result, motorway development in New Zealand needs to focus on increasing capacity in order to manage effects such as congestion.

In cities like Wellington and Auckland, effects caused by poor motorway planning and development can have a multitude of impacts. These include congestion, climate change, impacts on urban form and impacts on the receiving environment (Grimes & Liang, 2010; Sankaran, Gore & Coldwell, 2005). In Wellington, the issue with current motorway developments is that the links between arterial roads, local roads and motorways are vulnerable to disruption. Disruptions occur because of congestion, construction and weather (Yu *et al.*, 2016). Due to having a vulnerable network, Wellington requires motorway development to meet future demand (New Zealand Transport Agency, 2017). This thesis also further explores how motorway developments may cause issues in New Zealand through the execution of Key Informant interviews and GIS.

### *2.9.2 Motorway Policies in New Zealand*

In New Zealand, a variety of tools and policies are being utilised to achieve high-quality motorway development. Implementation of transportation policy occurs through four separate Acts: The Resource Management Act; Land Transport Act; Transit New Zealand Act; and the Local Government Act (Lee & Rivasplata, 2001). A variety of tools are also in wide use throughout New Zealand in order to attain high-quality motorway development. These include smart motorways that deploy a range of smart tools to improve traffic flow (Nissan & Koutsopoulosb, 2011). This section discusses motorway policies and tools in use in New Zealand and how they ensure that motorway developments can manage high volumes of vehicles.

The creation of policy is one method used to control and direct motorway development. Policy thus ensures the mitigation of effects. Previously, reports were commissioned to provide options for New Zealand's motorway options from external firms, such as the De Luew Cather reports (Dodson & Mees, 2003). In recent years this approach has shifted to be more focused on the provision of roads through either government agencies, regional authorities, and/or local authorities. In Figure 6, the planning and policy framework for transportation planning in New Zealand is displayed. This displays the four key statutes in place that then flow into policies and planning documents (Lee & Rivasplata, 2001). Under the RMA, the intended purpose is to promote sustainable management. For transportation, this means providing high-quality transportation networks (Lee & Rivasplata, 2001). However, under the RMA, effects such as vehicle emissions must be ignored.

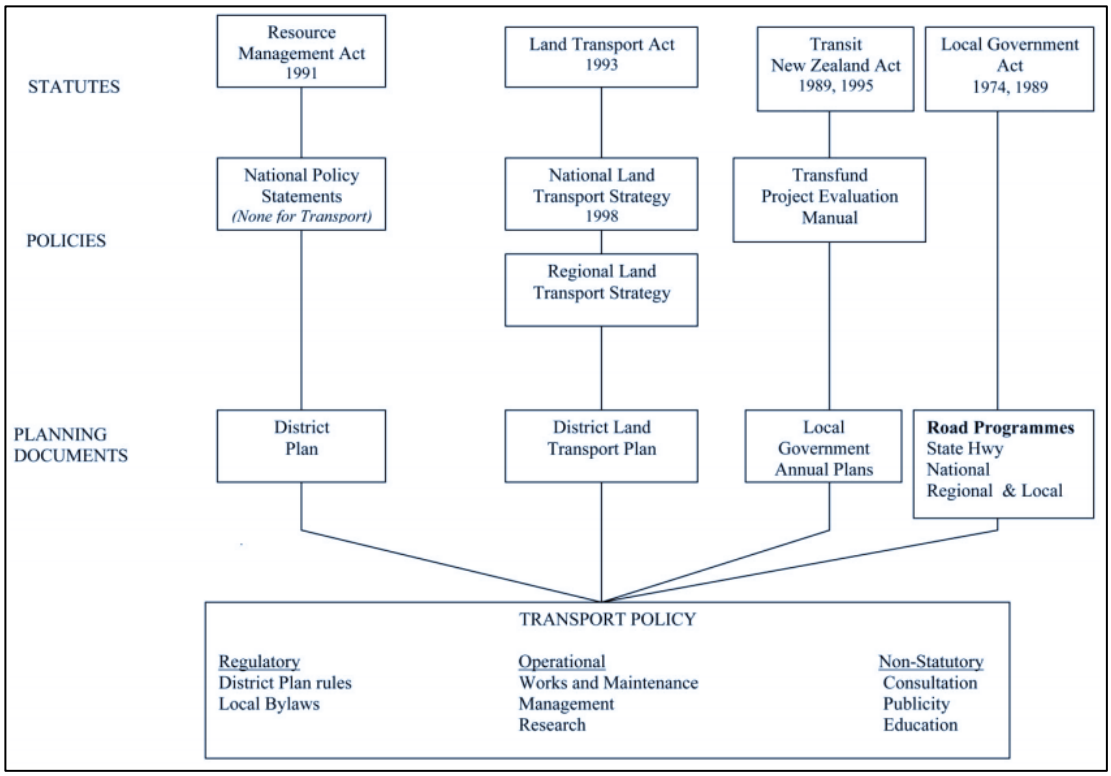


**Figure 6: The Policy framework for transportation planning in New Zealand (Lee & Rivasplata, 2001).**

The Transit New Zealand Amendment Act divided up the responsibilities of authorities when managing transportation and roads. The New Zealand Transport Agency is responsible for the development and operation of the state highway network, regional councils are in control of regional transportation and public transportation, whilst local authorities, such as district councils, are responsible for the local road network (Lee & Rivasplata, 2001; McDermott, Toleman & Lee, 1997). The multi-agency approach has seen a separation of responsibilities for road management to ensure quality and to also separate transport funding agencies from the providers of urban transportation (Watson & Brennand, 1996). Through this process high quality, efficient motorway development can occur. It also enables authorities to sustainably react to demand caused by increasing motor vehicles.

## *2.10 Summary*

This chapter has analysed the literature that exists surrounding motorway development, discussed the benefits and effects of motorways, identified the

different motorway typologies that exist and discussed the different motorway policies and tools that are in use. The thesis research has been discussed during this review so as to identify how this thesis assesses the efficacy of motorway development. This approach established links between the existing literature and the thesis research. Further, this literature review satisfies one of the aims of this thesis, which is to investigate current international approaches for managing changes to urban form via large-scale motorway development. This thesis utilised the literature review to expand the existing understanding of the effectiveness of large-scale motorway development, and it assessed the efficacy of large-scale motorway development as a planning approach.

Overseas approaches influence motorway development in New Zealand, especially the approach employed in the United States of America (Gunder, 2002). Original motorway developments in New Zealand were not suited to the particular regions and areas where they were built because of this. As a result, adverse effects arose. However, there is now a need for more motorway development as rising populations have resulted in increased congestion and disrupted traffic flow (Goldberg, 2010; Mackie, 1996). Benefits of large-scale motorway development were found to include improved road safety, better free-flow speeds, increased road capacity, a reduction in congestion, and wider economic benefits (Cheu & Ritchie, 1995; Deardoff, Wiesner & Fazio, 2011; Dumbaugh & Rae, 2009; Handy, 2005; Lighthill & Whitham, 1955). The literature review also identified some detrimental effects that arise due to large-scale motorway development. These included impacts on the receiving environment, effects on road users, climate change, health impacts, and impacts on urban form (Brueckner, 2000; Dunt, Abramson & Andreassen, 1995; Frank *et al.*, 2008). Through Key Informant interviews, this thesis is able to assess and understand the effects of the motorway developments in Wellington.

The literature review then identified the different motorway typologies that exist around the world before narrowing the focus to those typologies present in New Zealand. The review found that in New Zealand the motorway typologies present are toll roads, expressways and motorways (New Zealand Transport Agency, 2010). Through understanding the types of motorway typologies

present in New Zealand, a better understanding of the Wellington motorway developments is attained. Finally, this literature review identified the key tools and policies utilised for motorway development. Whilst policy in New Zealand is limited, the RMA ensures that motorway development occurs in a sustainable manner (Lee & Rivasplata, 2001). Primary tools in use now are smart technologies, with numerous studies being focused on the effectiveness of tools such as VSL for improving flow (Piao & McDonald, 2008; Sun *et al.*, 2014). This thesis addresses the gaps in smart technology knowledge in the case study of the Wellington Smart Motorway.

This literature review informs the findings of this thesis. Specifically, this thesis addresses the efficacy of large-scale motorway development as a tool for managing increasing roading pressures arising from changes in urban form. Whilst literature exists surrounding specific aspects of motorway developments and changes to urban form, there is no literature that attempts to look at it as a planning problem in such a comprehensive manner. The next chapter of this thesis discusses the methodology employed by this thesis to answer the key research aims.

# 3 - Methodology

## 3.1 Introduction

The previous chapter has acknowledged the theoretical framework for this research by analysing relevant literature. Large-scale motorway development has been found to be effective for managing increasing road user demand in an international context. This research seeks to understand the New Zealand experience of large-scale motorway development.

To determine the value of large-scale motorway development in our urban areas, this thesis research employs a mixed methodological approach. Research methods employed included conducting Key Informant interviews, GIS analysis, and graphical analysis for primary research and a literature review for secondary research. This chapter discusses the research design employed, the positionality of the research, ethical considerations and then discusses both the quantitative and qualitative research methods employed. Discussion of the research limitations follows. Identification of these limitations occurred through applying the research methodology. Finally, there will be concluding remarks.

## 3.2 Research Design

When planning to undertake research, the research design plays a fundamental role. It provides an insight into the direction of the research while also identifying the data collection method, the data analysis method, and ensuring the success of the research questions (Bickman & Rog, 2008). Further, for applied research, there needs to be significant efforts made to ensure that the context of the study and stakeholders' perspectives is adequately understood (Bickman & Rog, 2008). To ensure this, the methodology is an important initial step of the research process to ensure high-quality research.

All of the qualitative research undertaken for this thesis has a basis in grounded theory. Primarily, grounded theory is achieved through systematic

data acquisition and analysis to inform the creation of theories (Strauss & Corbin, 1994). The creation of theories occurs by utilising an open theory coding approach to all of the Key Informant interviews (Bickman & Rog, 2008). Consequently, the theories and codes for the Key Informant interviews were not decided on before the interviews. This enabled discussion and emphasis on key issues to develop organically versus being constrained by a specific academic theory (Strauss & Corbin, 1997). The generation of theories occurs from the research undertaken when using the grounded theory. Theories are thus not influenced by previously identified theories (Strauss & Corbin, 1994). With the Wellington motorway developments being new projects, and little literature existing on these types of developments, grounded theory enables new theories and ideas about these developments to be generated through Key Informant interviews.

This research employed a mixed methods approach. This is known as triangulation, which is the mixing of methods to gain a more in-depth understanding of the objectives of the study (Olsen, 2004). Triangulation as a methodology improves the validity of the data gathered (Fielding & Fielding, 2008). This provides researchers with the ability to understand a research problem at a deeper level than would be possible with traditional research approaches (Olsen, 2004). As an academic research approach, many credit Denzin in the 1970s for providing a description about triangulation that acted as the starting point for it as a research method (Olsen, 2004). This ensures the methodology answers all of the research questions. Literature critiques the use of advanced theories as it narrows down the research, and results may miss critical information (Tolich & Davidson, 2011). Academics do still critique the triangulation approach to research. Often, this is due to the perception that mixed methods are fundamentally different, and that attempting to combine different methods can result in conflicting results (Bryman, 2015). For this research, a mixed methodological approach is considered relevant due to the complexities of the research being carried out. The researcher utilised Key Informant interviews, GIS and graphical analysis.

By employing the triangulation approach, two research theories become important. They are the ideas of inductive research and deductive research (Tolich & Davidson, 2011). Inductive research is the approach present throughout the literature review and Key Informant interviews. This method sees observations, from a study of existing literature, coded into a variety of themes in which theory and results are then generated (Tolich & Davidson, 2011). Further, the inductive approach provides researchers with an understanding of a broad and complex subject matter. Talking to key stakeholders ensures this understanding occurs (Bickman & Rog, 2008). This is also considered a critical aspect of research undertaken in the grounded theory school of thought (Bickman & Rog, 2008). Deductive research, on the other hand, is present in the GIS and graphical analysis in this thesis. This approach is commonly associated with quantitative information and enables the validity of Wellington as a case study to be tested. The deductive approach places emphasis on seeing if general principles of the relevant theories are present in case study observations (Tolich & Davidson, 2011). Through utilising a deductive approach, the researcher can then create visual aids that assist in displaying the information found by the research (Bickman & Rog, 2008). The combination of inductive and deductive research carried out by this thesis strengthens the results and conclusions made.

Johnson and Onwuegbuzie (2004) ascertain that by utilising a mixed methods approach it is possible to emphasise the strengths of various approaches while minimising the weaknesses that are present with these approaches. This occurs through combining methodologies to emphasise the techniques as a greater good (Tolich & Davidson, 2011). Figure 7 shows a visualisation of the research design. This displays the four different research methods used to answer this thesis' research questions.

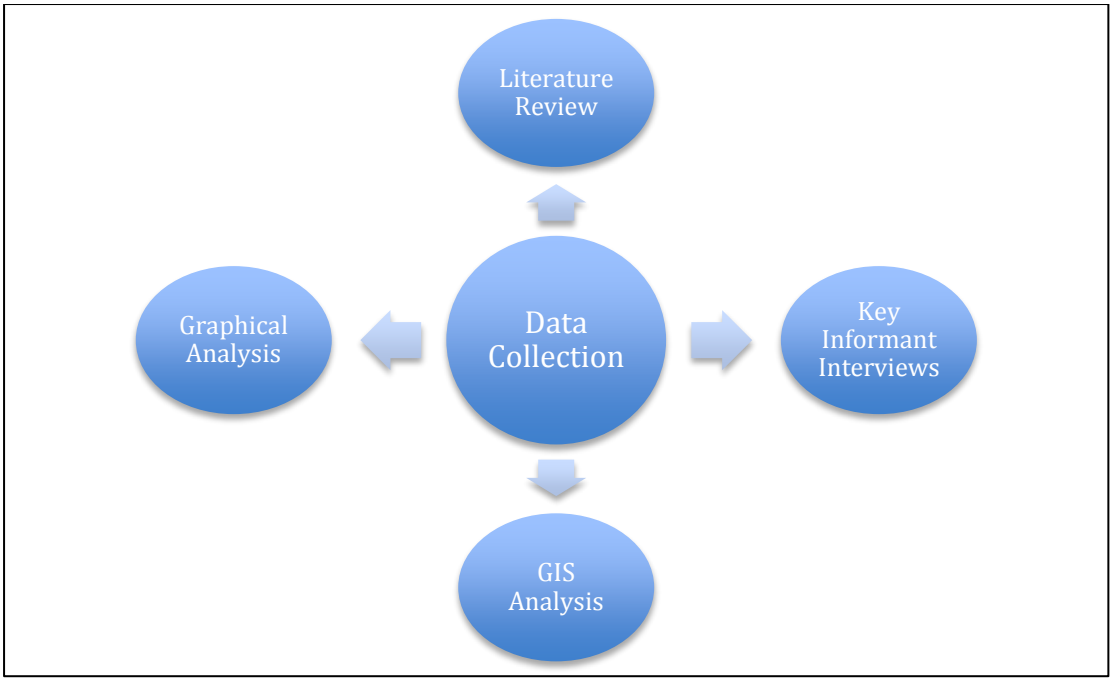


**Figure 7: Research methods employed in this thesis .**

The first research method used in this thesis was to carry out a literature review. This offers a broader understanding of the thesis topic and provides an insight into international case studies and examples (Hart, 1998). The Literature review provides an analysis of secondary data for this research, with the Key Informant interviews, GIS and graphical analysis all being primary research. Key Informant interviews were then carried out to gain an understanding of the research within the case study context of Wellington. This was an inductive approach to research based in grounded theory (Strauss & Corbin, 1997; Tolich & Davidson, 2011). Following this, GIS analysis and graphical analysis was carried out to form the deductive quantitative aspect of this research. This provided the research with quantifiable results presented in a spatial context (Phua & Minowa, 2005). All of the sections mentioned above are discussed in more specific detail later in this methodology chapter.

A case study was also chosen for this research, as they offer the researcher with the opportunity to experience, or observe, a vast volume of information. Otherwise, the research might fail to observe this information (Flyvbjerg, 2006). This opinion on the validity of case studies was further emphasised by Stake (1995), who stated:

*"Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995, p. xi).*

The case study approach employed was the evaluative case study assessment approach. This method offers the researcher the ability to understand a complex attribute, or range of attributes, in a geographical context (George & Bennett, 2005). Further, through the use of a case study the researcher can test the validity of a concept or an idea within this setting (George & Bennett, 2005). This then can contribute to the author persuading the thesis reader that the research is, in fact, valid and the findings are sound (Siggelkow, 2007). In this thesis, a case study has been used to test the efficacy of large-scale motorway development and to establish what causes such developments. If the Wellington motorway developments are found to be an efficient tool for addressing increasing road user pressure, then the use of a case study is justified and the research presented will be validated.

For this reason, Wellington was chosen as the case study for this thesis as it offered an insight of an activity within relevant circumstances. Recently, work has been completed on two major motorway projects (the Smart Motorway and the Kapiti Expressway), and a third (Transmission Gully) is currently under construction. These motorway projects have faced some obstacles such as Wellington's unique topography and its susceptibility to natural hazards. Further, Wellington's regional population is continuing to expand and rise with new development and the threat of unplanned sprawl is an imminent risk to the region's urban form. Ensuring roads can manage this increasing demand is a significant regional issue. As a result, the author has chosen the Wellington Region as the case study for this thesis research.

## *3.3 Positionality*

With any study, it is important to consider the positionality of the researcher undertaking the work (Sultana, 2007). It has been acknowledged by Ganga and Scott (2006) that positionality can have an impact on both qualitative and quantitative research. Further, the concept of positionality is not fixed, and can change due to its dynamic nature according to Sultana (2007). Factors such as

gender, class and generation can influence research and can result in an imbalance between the researcher and Key Informants when attempting to establish a rapport during interviews (Ganga & Scott, 2006). Further, Bourke (2014) states that:

> *"The nature of qualitative research sets the researcher as the data collection instrument" (Bourke, 2014, p. 2).*

This shows how the researcher themselves is an important aspect of the research process, and that their positionality can influence the data that they attain. As a result, careful consideration is given to the researcher before any research is undertaken (Bourke, 2014).

The researcher grew up in Wellington City, attending both primary and secondary schools within the city. As a frequent road user and resident of Wellington, the researcher became interested in these roading developments due to the high frequency of use by the researcher. Further, a shift in the location of the researcher's family to the Wairarapa meant that they became daily users of these roads to commute into Wellington. Through executing a robust evaluative research process, the information gathered shall be objective and not influenced by any perceived experiences the researcher may have had when permanently living in the Wellington Region. As a result, the researcher is considered to be neutral, so the researcher's positionality or subjectivity should not hinder the researcher's field work (Sultana, 2007). All of the above factors mean that the researcher can undertake the research while maintaining, and researching from, an objective stance.

## *3.4 Ethical Research*

When conducting research, it is also important that ethical considerations should pervade throughout the thesis and its associated research. Further, this needs to be in the researcher's mind when researching in the field (Sultana, 2007).

Studies have found that for research to be considered ethical it should aim to meet five ethical principles. These principles are: voluntary participation;

informed consent; do no harm; avoid deceit; and provide confidentiality or anonymity (Tolich & Davidson, 2011). This was used as a guide when designing the research approach for this thesis, and was adopted to ensure that all research would not breach ethical practice.

Throughout this research, all efforts have been made to ensure that the research is ethical. Ethical research is possible by following the University of Otago's Ethics B guidelines and then submitting an ethics application. Ethical approval for the thesis research was granted on 24/5/17. By following the University of Otago's ethics process, all ethical considerations of the research were analysed and approved by a departmental approved assessor.

Further, during the undertaking of Key Informant interviews, participants were provided with an information sheet detailing the scope of the thesis and information on their selection. The researcher also provided informants with an outline of the key questions, and a consent form that they had to sign before the interview could commence. The information sheet, participant consent form and outline questions are attached in Appendix A, Appendix B and Appendix C.

## *3.5 Research Methods*

Both primary and secondary methods were utilised to attain data for this research. Secondary research was carried out through conducting a review of relevant literature whilst primary research was carried out through Key Informant interviews, GIS and graphical analysis. From this, the methods can be considered either quantitative or qualitative. The specific methodology employed was also informed through the findings of the literature review. In particular, this influenced the methods employed for assessing the efficacy of large-scale motorway development through quantitative methods.

### *3.5.1 Quantitative Research*

To portray and accurately represent the complexities surrounding the Wellington motorway developments, an approach with both GIS and graphical analysis was utilised, alongside the qualitative methods. GIS was an important research tool as it enabled the researcher to situate the research spatially.

Further, by utilising GIS, additional information from data analysis can be derived (Phua & Minowa, 2005). The analysis of graphs also offers the research the ability to understand if a relationship exists between the motorway developments and vehicle flow characteristics (Tolich & Davidson, 2011). By using two quantitative methodologies for this thesis, the efficacy of Wellington's large-scale motorway developments is able to be understood.

Both graphical and GIS analysis were considered appropriate due to the availability of data to the researcher. The data was primarily sourced from the NZTA's Traffic Monitoring System (TMS) as the researcher had access to this system from the NZTA. The TMS collects information on state highways, such as vehicle counts and average vehicle speeds. This data was downloaded and then graphed using Microsoft Excel. Graphs constructed focused on: daily vehicle counts; yearly growth; hourly average; vehicle incidents; average vehicle speed; and vehicle fatalities. For these graphs, it was also possible to locate the actual location of the monitoring station in ARC GIS. These positions were selected based on a number of criteria. They were either locations mentioned explicitly during Key Informant interviews, were areas identified through media reports as suffering significant congestion, were located or affected by the new motorway developments, and had been operating for a period longer than a week, ensuring another data was available.

The utilisation of vehicle count information to assess the flow, capacity and characteristics of the new motorway developments was an approach adapted from Daniel and Maina (2011). This study demonstrated that vehicle counts offered an insight into the efficacy of motorway developments through presenting information about the realised traffic characteristics of a motorway (Daniel & Maina, 2011). By having access to similar information, it was possible to mirror some of the methods employed. This contributed to the validity of the overall methodology that was employed.

Whilst the GIS database contained aerial imagery of New Zealand, it was found to be out of date. To accurately display what was occurring, new satellite imagery was required. By downloading up to date images from Google Earth and

then georeferencing these images to the ARC GIS layer, the imagery was updated. This process created new images that displayed the new motorway developments.

Whilst the graphical analysis offered an insight as to what was occurring on these roads, GIS also contributed significantly to providing an insight into what was occurring based on its geographical location. GIS provides the researcher with the ability to cross-reference highly specific information with a location, and then compare it with information from another location. As a result, it is frequently utilised in transportation planning (Bateman *et al.*, 2002). Research also uses a longitudinal method. This enables a comparison of data from multiple situations at their respective points in time (Phua & Minowa, 2005). For this thesis research, the combination of graphical and GIS analysis occurring through a longitudinal approach means that a comparison of motorways at a set point in time can occur.

In summary, the quantitative methodology included the following components:

1. Plotting new motorway developments on GIS.
2. Locating and displaying locations of NZTA TMS monitoring sites.
3. Updating aerial imagery through georeferencing.
4. Displaying built form surrounding motorway developments.
5. Graphing vehicle characteristics at these locations, including: daily vehicle counts; yearly growth; hourly average; vehicle incidents; average vehicle speed; and vehicle fatalities.
6. Comparing vehicle characteristics with other motorway locations.

#### *3.5.1.1 Quantitative Data Analysis*

With the quantitative aspects of this research having two main components, a robust and fair data analysis method was required. As previously mentioned, an approach similar to that carried out by Daniel and Maina (2011) was utilised to assess the efficacy of these new motorway developments through using vehicle counts. Whilst this study originally focused on relating motorway capacity to

safety, it has been slightly modified to reflect capacity and efficacy. This information is displayed in graphs linked to the monitoring site's geographical location.

A key component of this research was the graphical analysis that was carried out. This was made possible by plotting the vehicle count characteristics against a specific time series. Time series varied from hours, to days to years depending on the graph's information. By plotting the vehicle counts against a specific time series, it was possible to see when vehicle volumes were at their peak. Through yearly growth comparisons, it was also feasible to measure the increased demand and volume of road users on a section of these motorways. By visually presenting this information it was then possible to compare the vehicle volume characteristics with other monitoring locations to assess what differences occurred. The literature and Key Informant interviews influenced the conclusions reached surrounding differences in characteristics.

The other component of the quantitative data analysis was the GIS. Through GIS it was possible to locate the site that gathered vehicle information on the analysed motorways. Determining the information geographically was important to understand what external factors could affect or contribute to the vehicle characteristics (Phua & Minowa, 2005). By locating the TMS monitoring site it was possible to see if the section of road faced geographical constraints, was near residential areas, was located on/before/after one of the new motorway developments, and what the road's characteristics were at a set location. Key Informant interviews also influenced this by speaking about specific locations facing significant issues, which would affect the flow of motorway traffic. Through GIS it was possible to then locate these areas.

### *3.5.2 Qualitative Research*

The other method employed by this research was to utilise qualitative research. This attains findings through methods other than statistical approaches or those that attempt to quantify research (Strauss & Corbin, 1990). The nature of the research can result in a qualitative approach being more effective. It can also be because of the preference of the researcher (Strauss &

Corbin, 1990). It was found that transportation planners favour qualitative research methods and techniques. This is because they can gauge the opinions of the public and gain an insight into the potential problems and solutions (Clifton & Handy, 2003). When Strauss and Corbin (1990) considered the effectiveness of qualitative methodologies, they stated:

> *"In addition, qualitative methods can be used to obtain the intricate details about phenomena such as feelings, thought processes, and emotions that are difficult to extract or learn through more conventional research methods" (Strauss & Corbin, 1990, p. 11).*

This quote by Strauss and Corbin (1990) demonstrates the level of detail that is attainable by employing a qualitative methodology. For this thesis, it offered the ability to understand people's feelings, thoughts and emotions about the motorway projects whilst also providing their expert opinion. The qualitative research consisted of carrying out Key Informant interviews.

Key Informant interviews were an important part of this thesis research. Key stakeholders were contacted and then interviewed in a semi-structured interview. These interviews began with broad questions to encourage the interviewee to discuss information they believed to be relevant to the thesis and themselves (Curtis & Curtis, 2011). Table 2 identifies the Key Informants that the researcher consulted. Key Informants were selected based on whether their authority would be affected by these motorway developments, organisations that were active stakeholders, and individuals with significant planning experience surrounding motorway development. The value of interviews for research lies in the fact that they can provide rich and situational responses to research specific questions (Clifton & Handy, 2003). Due to the benefits of carrying out Key Informant interviews, this method was one of the key methods used for this thesis research.

**Table 2: Key Informant numbers and their associated organisations that participated in Key Informant interviews.**

| Organisation | Key Informant |
|---|---|
| New Zealand Transport Agency, Expert 1 | KI1 |
| Local Elected Representative | KI2 |
| Wellington Planning Specialist | KI3 |
| Independent Transportation Specialist | KI4 |
| Wellington City Council | KI5 |
| Porirua City Council | KI6 |
| Kapiti Coast District Council | KI7 |
| New Zealand Transport Agency, Expert 2 | KI8 |

When conducting Key Informant interviews, it is important to ensure that the questions will result in answers to the key research objectives. Yin (2006) identifies that questions can be either isolated or integrated. Figure 8 demonstrates this questioning approach. The researcher chose an integrated question approach. This was because an integrated approach enabled flow-on questions, whereas an isolated approach would have come across in interviews as more fragmented and disjointed (Yin, 2006).

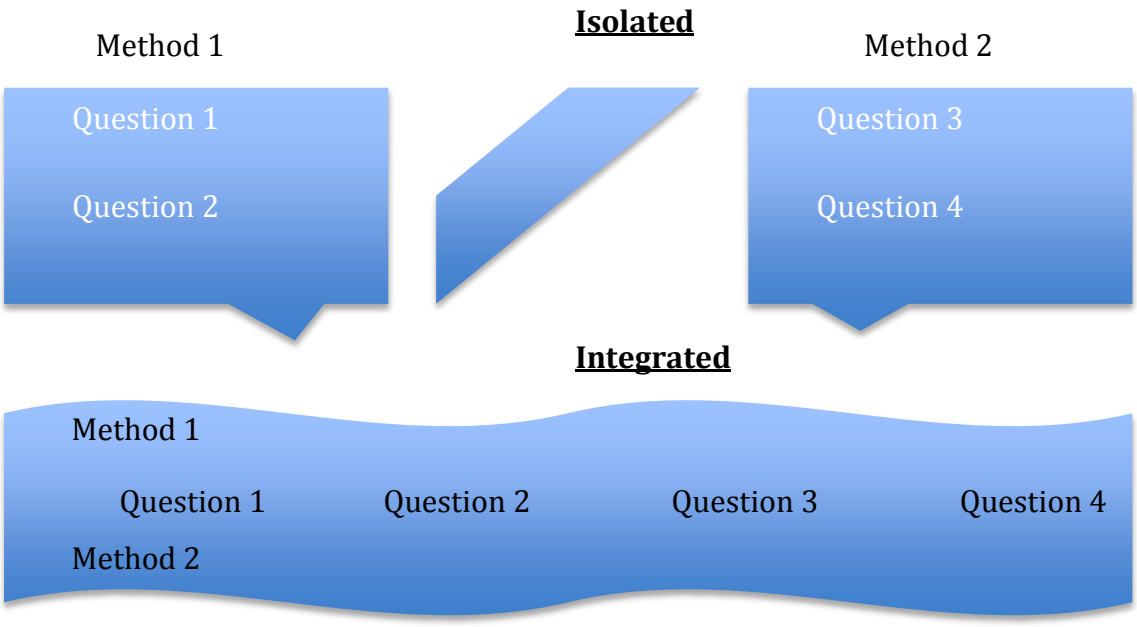


**Figure 8: Two methods for designing research questions for key informant interviews. Adapted from Yin (2006).**

Across all questions, there were a number that did not vary between interviewees. In other circumstances, different questions were created to be more relevant to the organisation interviewed. This enabled a more in-depth understanding and line of questioning to be executed. These questions were all written before the interview and provided to the interviewee before the day of the interview. This was important as it enabled the interviewee time to consider the questions and, where uncertain of answers, ask appropriate members of their organisation for assistance.

#### *3.5.2.1 Qualitative Data Analysis*

All of the Key Informant interviews were audio recorded and transcribed at a later date. This transcribing is important, as throughout the interview the interviewer should be actively encouraging the interviewee to share as much relevant information as possible. This could be unintentional or intentional (DiCicco‐Bloom & Crabtree, 2006). However, an issue that arises with transcribing is:

> *"Transcribers often have difficulties capturing the spoken word in text form because of sentence structure, use of quotations, omissions and mistaking words or phrases for others. Because often people speak in run-on sentences, transcribers are forced to make judgment calls. The insertion of a period or comma can change the meaning of an entire sentence (DiCicco - Bloom & Crabtree, 2006, p. 318).*

During the transcribing process, all efforts were made to ensure that the transcription was accurate and reflected the opinion of the interviewee. The researcher used contextual queues when the transcription was confusing.

Coding is another method that was utilised to make sense of the qualitative data gathered. When undertaking qualitative research, coding can be seen as the primary analytical process used by the researcher to interpret collected information (Corbin & Strauss, 1990). It is also a process carried out to conceptualise, reduce and elaborate on Key Informant interviews that have been conducted (Strauss & Corbin, 1990). However, an issue with coding is the time that it can take to do (Bazeley, 2006).

For this research, coding was used to analyse all Key Informant interviews, which identified key themes. Table 3 displays these themes below. Themes were chosen to capture the broad range of topics discussed in the interviews, and also to answer the key research objectives.

**Table 3: Themes used for coding the Key Informant interviews.**

| | |
|---|---|
| Issues with the existing network | Existing road developments |
| Future road developments | Changes to urban form |
| Policy issues | Alternative modes of transportation |
| Regional specific issues | Possible solutions |
| User experience | Commercial users |

By dividing the Key Informant interviews based on these codes, it was easier to identify similarities and contrasting opinions between the Key Informants. This meant that it was also possible to identify which themes were more important, dependent on the views of the Key Informants. These themes and quotes are discussed further in this thesis with the results.

## *3.6 Limitations to the Methodological Approach*

Some limitations arose through the quantitative aspects of this thesis research. These are primarily due to the use of a single case study, limited TMS data sets and old aerial photography. These limitations need to be acknowledged so that the reader is not misinformed when reading the results of this thesis.

A case study can provide an important example of a theory and phenomena occurring at a set place, however, the choice of using only one case study is a research limitation. There is some debate in social sciences about the case study approach when only one case study is used (Flyvbjerg, 2006; Yin, 2006). However, Flyvberg (2006) argues that a single case study may, in fact, be a valid academic approach to research. This is through analysing other studies where a single case study was utilised and then applied to other locations effectively. Whilst Wellington is not as large as Auckland, the sprawling nature of Auckland could accommodate motorway development as analysed by this thesis. Further, Wellington is larger than Hamilton, Christchurch and Tauranga, meaning that

these smaller cities may become more like Wellington as their population increases (Early, Howden-Chapman & Russell, 2015). This is an area that would benefit from further research.

The TMS data was also a limitation of the research that was carried out. Whilst providing a comprehensive suite of measurement locations, data sets were frequently inconsistent and lacked continuity. This created difficulties when attempting to compare different locations, as for some locations it was not possible to present data with the same time characteristics. When this occurred, the closest dataset to the desired time was located and presented instead. This means that some information is not at a consistent timescale with other monitoring locations, limiting the results from this information. Another issue with the TMS data was regarding what the measuring stations measured. Some stations were equipped to measure speed; others focused on only one lane whilst the rest gathered information from the whole road. To circumvent this, this research prioritised those monitoring stations that monitored the entire road.

With the GIS analysis, a limitation also arose with the base maps available in ARC GIS. The researcher attained more recent satellite imagery from Google Earth, but it still was not as up-to-date as the researcher desired. As a result, imagery used in GIS may not accurately reflect the progress made with the Wellington motorway developments, specifically Transmission Gully. The thesis research did not analyse aerial imagery, yet it can be seen as a limitation because the GIS imagery is not accurately reflecting the current situation.

Whilst the previous paragraphs addressed the limitations of the quantitative research, it is also important to acknowledge the limitations of the qualitative research. An issue faced during the data collection was attaining enough reliable Key Informants. Consequently, the number of Key Informants interviewed is a limitation. Whilst many organisations could be affected by these roading developments, few wanted to partake initially in the research. A standard response received was to direct the researcher towards a specific government agency whom they believed should be able to answer every question on the

research. This was potentially a result of the organisation initially not understanding the research proposed. However, with perseverance, only one stakeholder was unable to be interviewed.

The coding approach used to analyse the Key Informant interviews is another limitation. This is because only ten themes were selected to code for. As a result, coding could have missed important messages from Key Informants. The researcher felt that ten codes were sufficient, as more codes could have resulted in an overly complex results section. Further, this could have meant that the main issues raised by Key Informants became diluted amongst the large volume of alternative codes and information.

## *3.7 Conclusion*

To carry out high-quality research, this thesis research has been based on grounded theory to ensure appropriate thematic coverage from Key Informant interviews, and has employed a mixed methodology. The mixed methodology consisted of quantitative research methodologies, which included GIS and graphical analysis, and qualitative research mythologies, which included Key Informant interviews that were coded. The secondary information about international motorway development practice was attained by carrying out a literature review. A quantitative methodological approach assessed the efficacy or large-scale motorway development as a response to increasing roading pressures within the case study of Wellington. Qualitative research was then carried out to assist with this key research aim, as well as to provide an insight into the drivers of large-scale motorway development within the context of Wellington. By utilising a combined methodology, the research has answered the research aims and objectives comprehensively.

This chapter has also discussed the limitations that exist with this particular research approach. These limitations were focussed on the validity of the case study approach, TMS data availability, and the number of Key Informants. Whilst they were limitations, the author believes that they should not significantly detract from the findings of this thesis. The following chapter discusses the geographic context of the case study of the Wellington Region for this thesis. The

context chapter provides an insight into the validity of the Wellington Region for a motorway case study.

# 4 - Geographic and Urban Context

## *4.1 Introduction*

The topography of Wellington has influenced motorway development. As a result, it is important to understand the geographic and urban context for motorway development for this thesis. The Wellington region is composed of a number of cities which are connected by transportation routes and links (Early, Howden-Chapman & Russell, 2015). The CBD of Wellington itself is only possible due to land reclamations (Lets Get Wellington Moving, 2016). Due to its diverse topography, Wellington is limited when it comes to providing transportation options. The compact development of Wellington has resulted in restricted opportunities to improve capacity of the transportation network, and that limited capacity between motorways and arterial roads can result in network disruptions (Lets Get Wellington Moving, 2016). Consequently, the geographic and urban context of Wellington needs to be understood to fully understand factors that may influence the case study use of the Wellington Region.

The purpose of this chapter is to identify and discuss how the geography and urban form of Wellington may influence large-scale motorway development. Next, this chapter outlines the history of motorway development in the Wellington Region, including existing motorway developments. Finally, this chapter identifies the study area for this thesis with a focus on the specific locale selected for analysis. Following this, Chapter Five discusses the main effects of large-scale motorway development.

## *4.2 Geography and Urban Form*

Topography has influenced Wellington's development. This is mainly due to the presence of the Wellington harbour and surrounding steep hills. As a result, topography has restricted the location of important infrastructure and

transportation routes. Further, difficulties arise when attempting to provide new infrastructure services (Early, Howden-Chapman & Russell, 2015). Wellington has high-density central city development, but also sprawling surrounding suburbs such as Johnsonville. The development of suburbs in the 1970s occurred due to cooperation of the Wellington Council with the Housing Division of the Ministry of Works (Dodson & Mees, 2003). Development also saw the establishment of Porirua on Wellington's periphery. The region's dispersed urban form means there is already substantial commuting occurring for work and educational purposes (Early, Howden-Chapman & Russell, 2015). Figure 9 displays the Wellington Region.

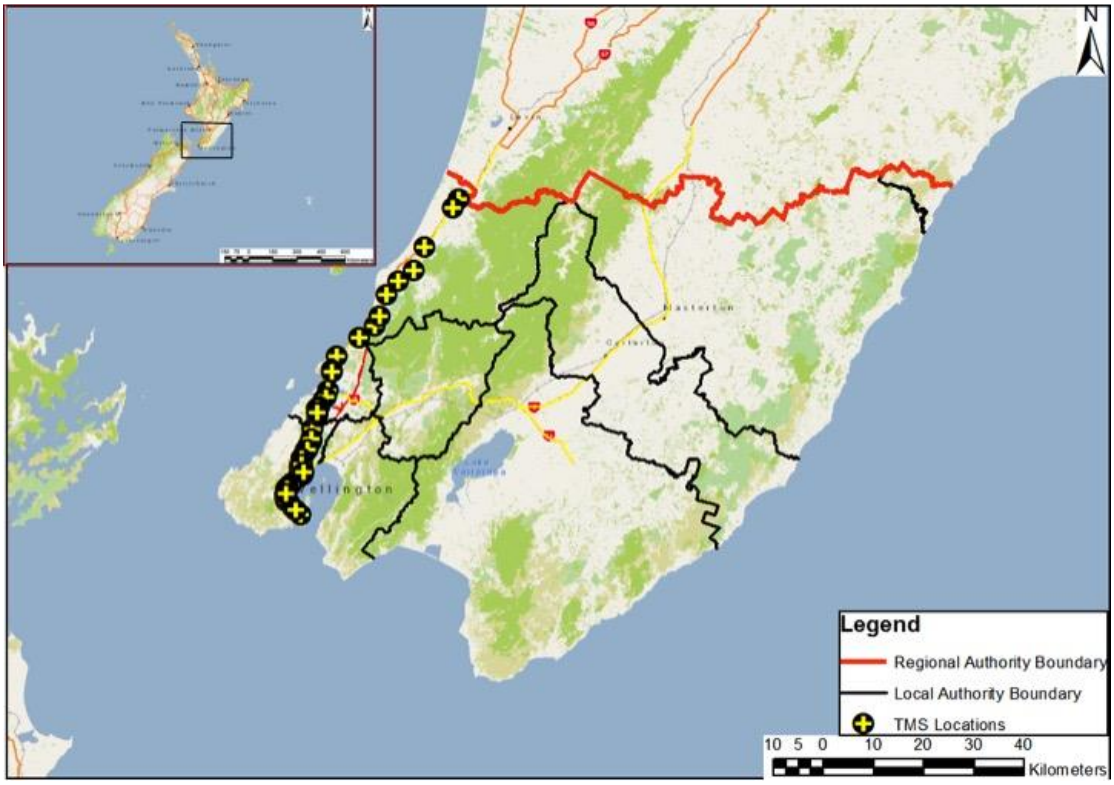


**Figure 9: Map of the Wellington Region case study area.**

Population growth and land use intensification are projected to occur in the Wellington Region in the future. By 2041, the population of the Wellington Region is set to increase by 55,000, from 471,000 to 526,000 people (Foy, 2014). This increase in population growth is set to increase demand on the existing motorway network. Further, the Kapiti Coast is expected to receive 22% of this predicted growth (Foy, 2014). Growth demonstrates the need that exists for an

improved motorway link between the Kapiti Coast and Wellington City. In the case study of Wellington, the provision of new motorways and transportation options could dictate where development can occur through the provision of infrastructure alongside motorway development (Early, Howden-Chapman & Russell, 2015). The provision of infrastructure then enables intensification along these motorway developments.

Wellington as a city also possesses the highest per capita public transportation usage in New Zealand (Early, Howden-Chapman & Russell, 2015). Through providing a high-quality public transportation network, the demand on some of the region's roads and motorways is minimised by citizens using public transportation for their commuting needs (Greater Wellington Regional Council, 2015). The public transportation network's high patronage numbers reflect this (Dodson & Mees, 2003). However, private motor vehicle ownership and access is still high in the region. In the 2013 census, 88.3% of people had access to a private motor vehicle (Statistics New Zealand, 2013a). As a result, demand is set to increase drastically, especially from the northern ends of the Wellington Region as displayed in Figure 10.

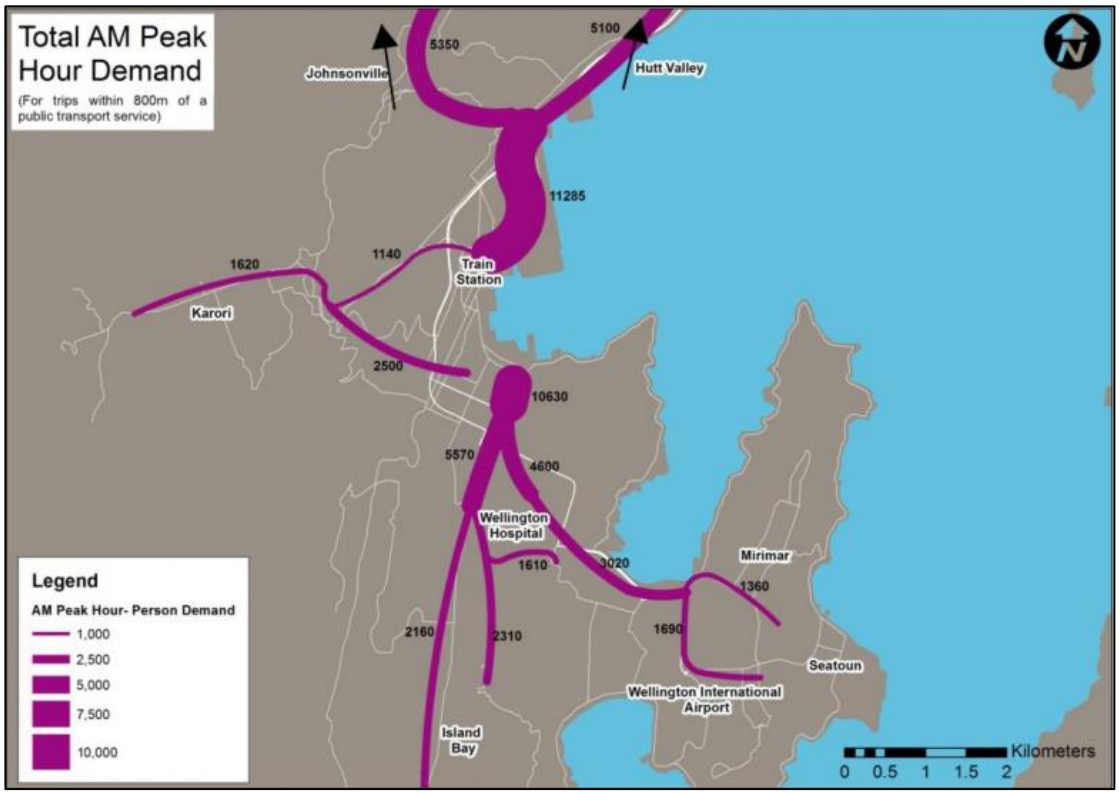


**Figure 10: Potential future travel demand by 2031 (Foy, 2014).**

In this figure, it is clear to see the increase in demand, which is likely to occur to the north and north-east of Wellington City. Increased demand justifies motorway development in these directions. Consequently, motorways are an important feature, and future feature, of the Wellington Region's landscape. The next section of this chapter discusses motorway development that has occurred in the Wellington Region.

## *4.3 Motorway Development in Wellington*

Rail and tram lines influenced transportation development in Wellington before World War Two (Dodson & Mees, 2003). Rail was the primary form of long-range transportation and also influenced the development of surrounding suburbs. With suburban development came the development of roads, particularly in the 1960s with the proposed Foothills Motorway and government encouragement for citizens to shift their modal choice to private motor vehicles (Lets Get Wellington Moving, 2016).

Motorway options for the Wellington Region were discussed in the De Leuw Cather report of 1963. The report presented a range of options including trenching sections, constructing bypasses, and motorway connections to the surrounding suburbs. The De Leuw Cather Report was meant to be the comprehensive transport plan for the Wellington Region progressing into the future (Dodson & Mees, 2003). Due to this vision not being fully realised, motorways in the Wellington region are often suffering from congestion and unreliable trip times. A section of the originally envisioned motorway development from 1963, trenching through Wellington city, is displayed below in Figure 11. Trenching the motorway would have resulted in smoothly flowing traffic due to uninterrupted flow.

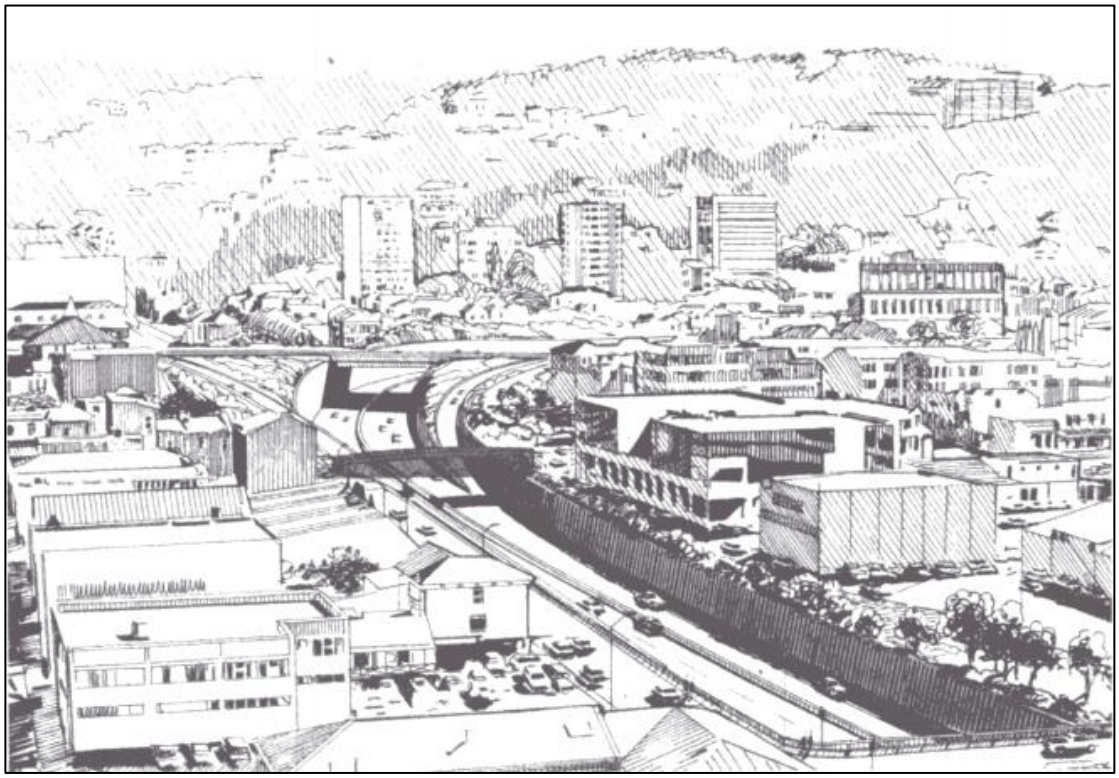

**Figure 11: Trenching of the Wellington motorway through the Wellington CBD (Dodson & Mees, 2003).**

The motorway network in the Wellington region serves an important purpose in providing a connection between suburbs and cities whilst also facilitating economic growth. However, the network is substandard and requiring investment to address significant issues (Greater Wellington Regional Council, 2015). In response, there was the development of the Smart Motorway,

the Kapiti Expressway and construction is currently underway to build Transmission Gully (New Zealand Transport Agency, 2017; SAHA, 2010). The realisation of the importance of Wellington's motorway network occurs through substantial investment. Existing network issues will be mitigated, and the resilience of the wider transportation network should be improved (Greater Wellington Regional Council, 2015). Through this thesis it is possible to assess the efficacy of large-scale motorway development in the case study of Wellington.

## *4.4 Study Area*

The research focused on three motorway developments. They are the Wellington Smart Motorway, Transmission Gully and the Kapiti Expressway. As a result, three territorial authorities are impacted by this thesis research. They are the Wellington City Council, the Porirua City Council, and the Kapiti Coast District Council. The boundary of the Wellington Regional Council encompasses all three territorial authorities. These developments impact the suburbs and towns surrounding them due to their scale.

Displayed in Figure 12 is the location of the Wellington Smart Motorway. The Smart Motorway goes from the centre of Wellington City to the Ngauranga interchange, from where it travels for a short distance up State Highway One and State Highway Two.

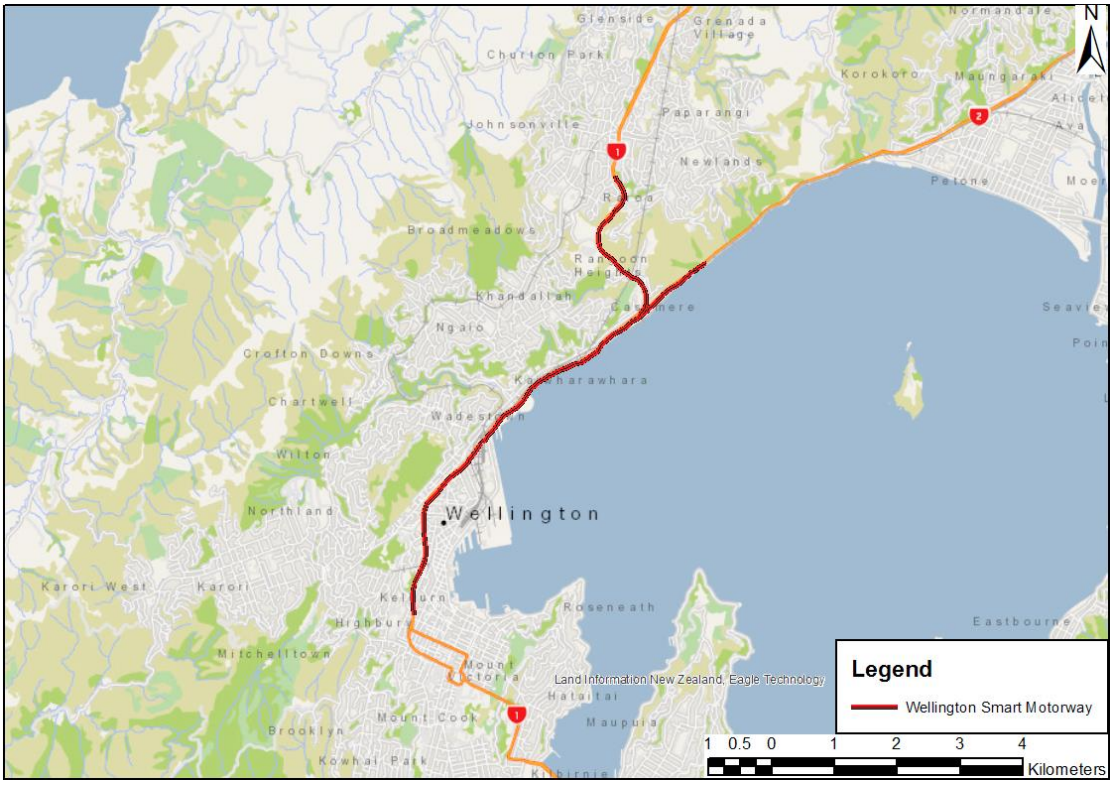


**Figure 12: Location of the Wellington Smart Motorway.**

Figure 13 displays the route for Transmission Gully. Transmission Gully is currently under construction, but upon its completion, it will travel from Tawa to MacKays Crossing, bypassing Porirua and Plimerton.

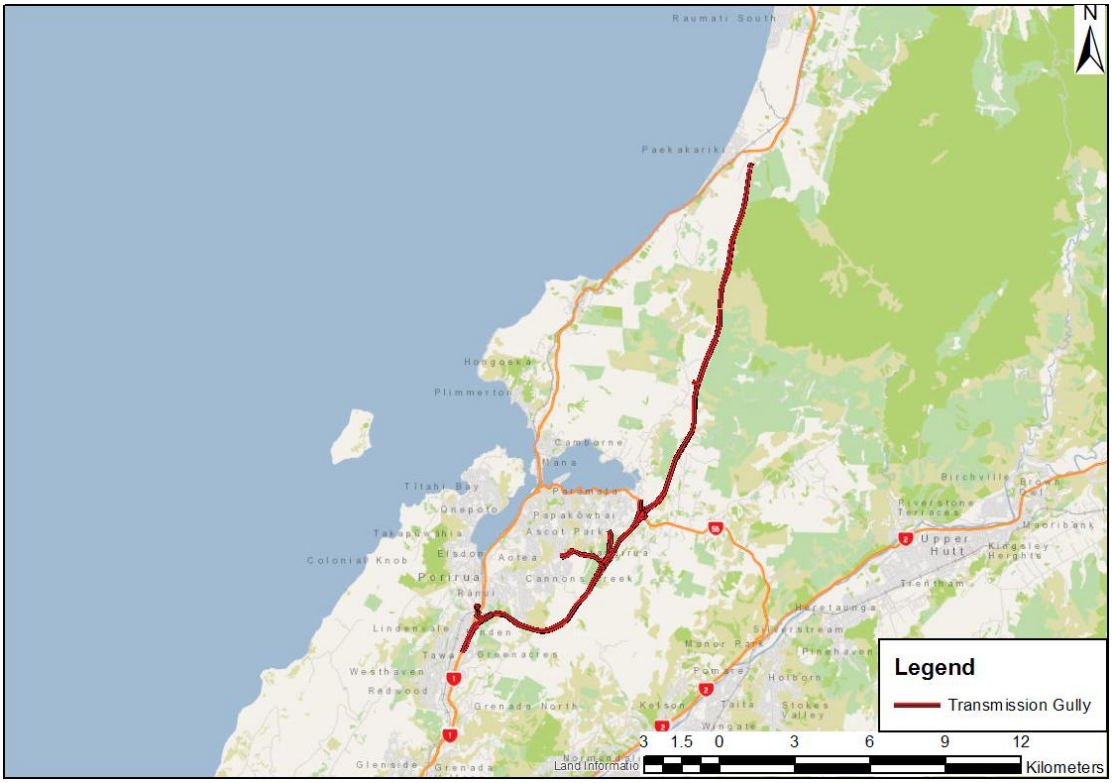


**Figure 13: Location of the Transmission Gully motorway development.**

Displayed In Figure 14 is the location of the Kapiti Expressway. The Kapiti Expressway begins in MacKays Crossing, travels through Paraparaumu, and terminates north of Waikanae. This is the northernmost point of research that this thesis undertook in the Wellington Region.

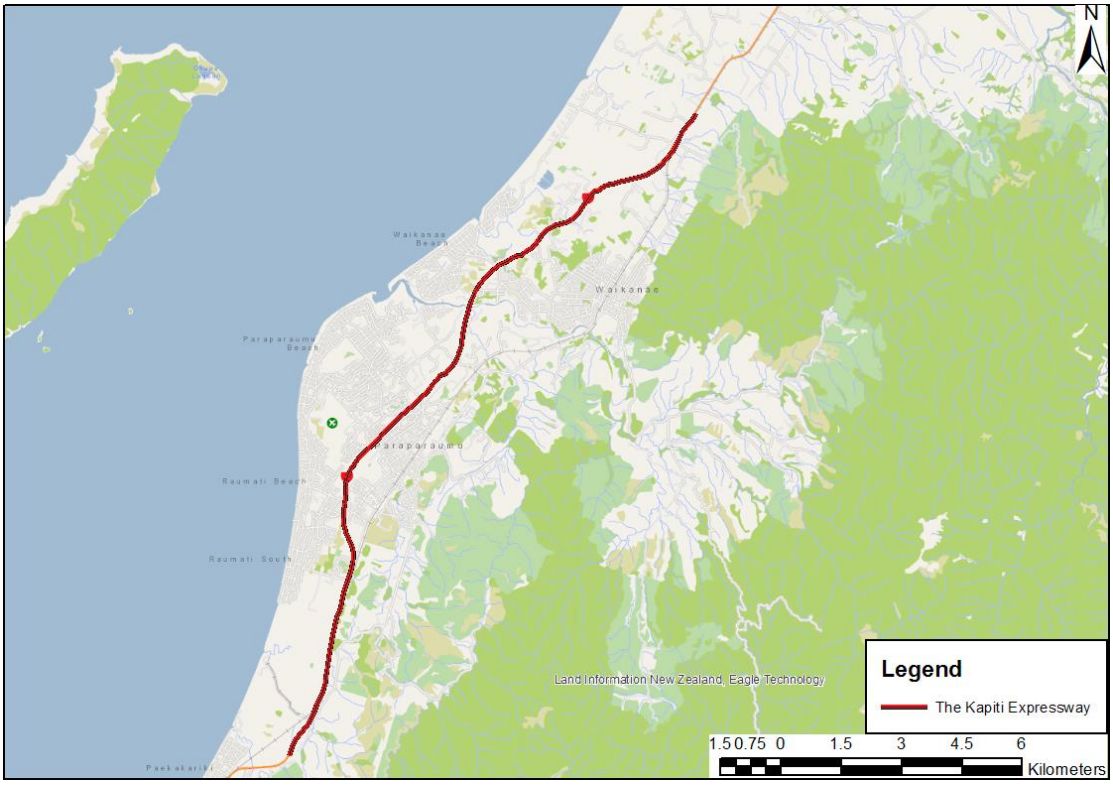


**Figure 14: Location of the Kapiti Expressway.**

The three motorway developments combine to provide a route direct from Wellington to the north of Waikanae. The NZTA envisions that this connected network should improve the efficacy of motorways in the area, and will improve the road user experience. These are the three developments analysed in this thesis.

## *4.5 Conclusion*

As discussed in the previous chapter, the use of Wellington as a case study enables the testing of theories within the context of a case study. Further, Wellington offers an excellent case study in that large-scale motorway development has, and is currently occurring. By analysing the Wellington Smart Motorway, the Kapiti Expressway and Transmission Gully, an insight is offered into the efficacy of large-scale motorway development and what positive and negative effects occur. It is also possible to assess how similar the reality of motorway development is in Wellington compared to international examples, by analysing links from the results to the literature review. The next chapter, Chapter Five, discusses the main effects of large-scale motorway development.

# 5 - The Effects of Large-Scale Motorway Development

## 5.1 Introduction

Large-scale motorway development occurs for a number of reasons. These reasons include issues with existing roads and their layout, changes to urban form, improving technology, and as a response to regionally specific issues. Motorways are constructed to address these issues. This chapter addresses Research Objective Two, which seeks to establish and identify the main effects of large-scale motorway development in New Zealand. This chapter identifies the effects of large-scale motorway development on urban growth and development, and it discusses the economic effects. The chapter also identifies how large-scale motorway development can impact on the delivery and creation of plans and policies, discusses how it improves resilience to natural hazards, and how motorway development can adversely affect communities. The following chapter, Chapter Six, addresses the efficacy of large-scale motorway development.

The researcher utilised a mixed methodology to address this research objective. This included Key Informant interviews and quantitative data extracted from the NZTA's TMS database. Additionally, the literature review informs the discussion and conclusions reached in this chapter.

## 5.2 Effects on Urban Growth and Development

Motorway developments are used as a tool for encouraging urban growth, targeting specific geographical areas for development and as a method for improving accessibility. The impact that motorway development may have on urban form has been widely acknowledged, with most literature focusing on this

as an adverse effect (Brueckner, 2000; Carey & Semmens, 2003; Handy, 2005). Literature also noted that motorway development improved accessibility and increased economic activity in the surrounding areas (Grimes & Liang, 2010). Only one Key Informant opposed the idea that motorway development is a tool for growth, stating:

> *"I mean I will say that I kind of philosophically have an opposition to the idea that building roads creates growth. Building roads creates congestion, it doesn't create growth. It might unlock some areas, but it certainly doesn't need to be achieved via motorway development", KI5.*

The other Key Informants discussed a multitude of ways in which changing urban form can be a driver of large-scale motorway development, and the use of motorways as a tool to create growth. This section discusses how urban growth could drive large-scale motorway development by identifying the types of growth that may occur, areas in the Wellington Region identified for future growth, and the effects of motorway development on growth.

### *5.2.1 Types of Growth*

Urban growth can come in many forms, with district councils attempting to implement their ideal growth through their district plans. Key Informants from the affected councils had a view on what type of growth they would like to see in the region, and what has currently occurred. Figure 15 displays these views.

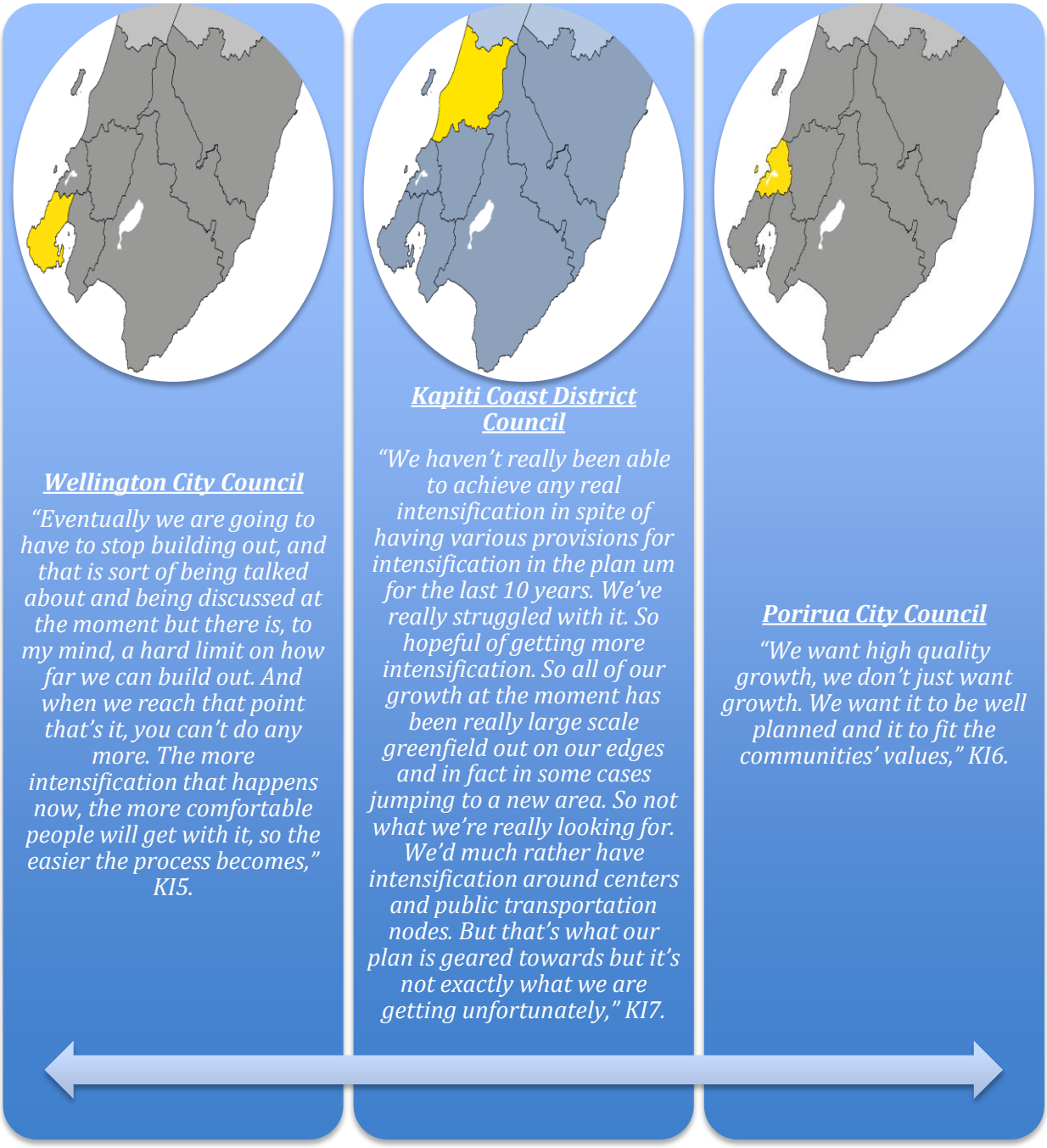


**Figure 15: Types of growth desired by the three territorial authorities interviewed.**

As displayed in Figure 15, Key Informant Five identified the need for Wellington City to encourage urban infill over urban sprawl. Infill could come in the form of apartment buildings that were already commonplace within the CBD (KI5). A higher quality urban form is a result of encouraging residential infill (Litman, 1995). However, by applying this reasoning by Key Informant Five, the Wellington City Council's vision for growth would not be a driver of large-scale motorway development.

The Wellington City Council was not the only territorial authority expressing an interest in encouraging intensification and residential infill. Key Informant Seven noted that their attempts at achieving intensification have been unsuccessful. With many residents of the Kapiti Coast moving for a lifestyle decision, sprawl is a more common feature (KI7). Due to sprawl, motorway development can facilitate the transportation of the more spread-out population, as is present in Kapiti (Handy, 2005). The urban form of Kapiti is a driver of large-scale motorway development.

The only territorial authority that is not actively trying to pursue urban infill is the Porirua City Council. The desire for infill was shown in the statement by Key Informant Six in Figure 15. Yet, they also want high-quality growth. With growth occurring within the region, sprawl can drive the need for motorway development (Brueckner, 2000). However, from the Key Informant interviews with the three different territorial authorities, it was not apparent if the changes to urban form were a driver to the specific Wellington motorway development. What these Key Informants did express was that urban development and regional growth would occur as a result of the analysed large-scale motorway developments.

### *5.2.2 Areas Identified for Growth*

As a result of large-scale motorway development, territorial authorities in the Wellington Region have identified specific areas for urban growth to occur. Growth desires can be a reason for territorial authority support of large-scale motorway development as it can help them achieve their development and growth aspirations. While not a driver of large-scale motorway development, it is a response. This reflects the findings by Gunder (2002), who found that motorway development in Auckland resulted in growth and development along the motorway corridor. However, in this study, it was also credited with causing Auckland's sprawling urban form (Gunder, 2002). Pre-planning for this growth could, in this case study, result in a higher quality of urban form.

When interviewed, the Key Informants identified areas that they expected to experience future growth due to the large-scale motorway development that is

currently occurring in Wellington. Across the three affected territorial authorities, this varied greatly, with the areas being influenced primarily on accessibility to transportation routes and land availability (KI5, KI6, KI7). The Wellington City Council has identified the area of Linden as a possible development area due to the Petone Grenada Link Road, as shown in Figure 41. However, the Wellington City Council did not believe any of these motorway developments would result in growth in Wellington City (KI5). The reasoning for this is primarily due to the location of their territorial boundaries and reflects the findings of Munoz (2003). If the Wellington City Council's boundary extended further out from the CBD, then the city may experience more diffuse urban sprawl as a result of these motorway developments (Munoz, 2003). However, due to the territorial boundary, the Wellington City Council is appropriately placed to pursue a dense infill approach as their primary urban form.

The Porirua City Council has actively planned for significant development to occur as a result of these motorway projects, specifically Transmission Gully. The current plan reform of their district plan has further assisted this (KI6). Key Informant One discussed how the development of Transmission Gully was creating a hard edge for the Porirua City Council's urban boundary. The NZTA expects that the Porirua City Council would like to see development up to Transmission Gully but not beyond it (KI1). However, Key Informant Three identified that Transmission Gully was opening up vast areas of land for development that had previously been inaccessible. As a result, it was assisting the Porirua City Council in meeting the requirements of the new NPS on Urban Development Capacity (KI3). Key Informant Six elaborated on which specific areas the city council would like to see development and growth as a result of these developments, as shown in Figure 16.

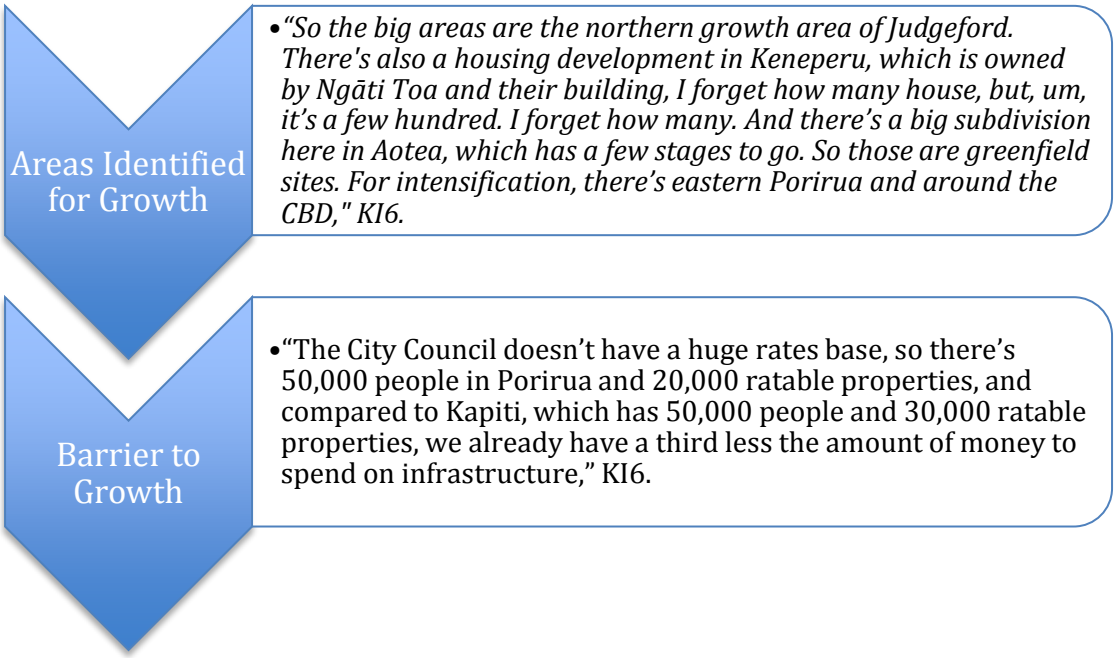


**Figure 16: Areas identified for growth by the Porirua City Council and the barriers to development experienced.**

Figure 16 demonstrates that the Porirua City Council is expecting significant growth within its area of authority as a result of these motorway developments. It can also have a positive impact on the road network in the area, through dispersing congestion over a larger area (Ewing, Pendall & Chen, 2003). However, the increase in vehicle miles that some residents have to travel could negate this benefit. To ensure that new development areas are accessible to Transmission Gully, the NZTA has established a series of Link Roads as shown in Figure 40.

The last territorial authority that this research analysed was the Kapiti Coast District Council. The Kapiti Coast is set to significantly benefit from the development of these motorway projects in the Wellington Region. Key Informant Three identified that by combining these motorway developments with the double tracking of the railway network as far as Waikanae would mean that the Kapiti Coast would experience significant growth. As a result, the Kapiti Coast District Council has been encouraging the development of these motorway projects (KI7). The Kapiti Coast District Council has identified areas where they would like to see growth, yet did not specify what type of growth they would like

to occur in these areas (KI7). Key Informant Seven identified these areas in the below statement:

> *"We have a large growth area at Waikanae North, um, just adjacent to the existing Waikanae urban area. And we have another area to the North edge of Ōtaki, which is our next big leap of growth. We've also recognised that the expressway has left a lot of land that was originally designated for a previous road at Raumati South. So there's an opportunity as a result of the expressway there. So those are our three main areas at the moment, but there is some push for Paekakariki to consider some growth there as a result of Transmission Gully, again freeing up some land adjacent to the town," KI7.*

It is vital to identify areas for growth before the completion of the project. Identification ensures the council retains a degree of control over where growth and development can occur. This is similar to the approach being employed by the Porirua City Council. Further, due to identifying these areas in advance, the council is not reacting to an unprecedented volume of growth. This was an issue Gunder (2002) identified with the Auckland example, as sprawling growth had occurred due to the impact the motorway could have on growth not being considered. By pre-planning for this development, the Porirua City Council and Kapiti Coast District Council should avoid similar undesirable growth occurring (Zhao, 2010). However, whilst a substantial volume of planning has gone into identifying where growth could occur, the growth aspirations of the territorial authorities are not a driver of large-scale motorway development in this case study. The following section discusses the specific effects of these motorway developments.

### *5.2.3 The Influence of Topography*

The topography of the Wellington Region has significantly influenced where motorway developments can occur. Key Informant Five spoke about the traditional suburban form present in many areas of Wellington. Further Key Informants Three, Five and Eight all stated that the topography of Wellington has influenced where infrastructure can go. This demonstrates how restricted planners are on where infrastructure, such as motorways, can go in Wellington due to the topographical constraints. Displayed in Figure 17 are three of these arguments.


**Figure 17: Key Informants' observations on the influence topography has on infrastructure in Wellington.**

The Key Informants differed, however, on the degree to which topography could hinder infrastructure projects. In the study by Frank et al., (2008), topography was found to impact the receiving environment significantly. In Wellington, the receiving environment is similarly topographically constrained, which can result in impacts to the motorway's desired efficacy. This is discussed further in Chapter Six.

Key Informant Five viewed topography as a feature requiring consideration as having influenced Wellington's urban form. Key Informant Three noted that topography had caused difficulties for infrastructure development (KI3, KI5). Key Informant Eight did observe that topography had been a barrier to infrastructure development, and that it had severely influenced the cost and options for some infrastructure projects within the Wellington region (KI8). This

thesis discusses the influence that topography has had on urban form and motorway development in the Wellington Region.

### *5.2.4 The Effect of Motorway Development on Growth*

Although Key Informant Five had a philosophical opposition to the impact that motorway development may have on growth, it cannot be discounted based on one Key Informant's opinion (KI5). In Kapiti, Key Informant Seven identified the impact that the opening of the Kapiti Expressway, and soon Transmission Gully, has had on property prices (KI7). Studies have previously identified the positive impact that motorway development can have on land values due to increased accessibility, and how development can occur as a result of these motorway projects (Carey & Semmens, 2003; Gunder, 2002; Müller, Steinmeier & Küchler, 2010). Motorway development is thus a tool that enables urban growth.

Interviews with the NZTA occurred as part of this thesis research, with two experts participating. When discussing the drivers of the motorway projects, Key Informant One discussed how the NZTA did not intend to create growth through these developments. Key Informant One stated:

> *"So, um, the projects haven't specifically tried to drive urban growth or anything like that. I guess they tried to respond to the actual local council or regions or whatever, more than aspirations … their expectations around urban growth," KI1.*

The above quote does, however, identify that the NZTA did consider the growth aspirations of the relevant territorial authorities as a driver to these motorway developments. This has resulted in urban growth for both Porirua and Kapiti. This is primarily due to these outlying districts becoming more desirable due to improved accessibility caused by these motorway developments (KI1). Key Informant Three discussed Transit Oriented Development around on- and off-ramps of motorways, identifying that:

> *"Well, I guess with, I mean, what you've seen overseas with big developments is that wherever the on and off points are for motorways it tends to result in quite a bit of growth around those on and off points," KI3.*

The Kapiti Coast District Council has attempted to control this by limiting the number and location of interchanges along the Kapiti Expressway (KI7). By doing this, accessibility to specific areas is controlled by the council, and the resulting urban form can be of a higher density instead of sprawling (Carey & Semmens, 2003). What has been consistent throughout all of the Key Informant interviews, apart from one, was that motorway development and urban development are linked. A multitude of studies have also previously reached this conclusion. They identified how motorways could change urban form but also how motorways are a tool used to respond to changing urban form (Carey & Semmens, 2003; Catalán, Saurí & Serra, 2008; Gunder, 2002; Handy, 2005; Munoz, 2003). This was summed up by Key Informant Three, who discussed this link, stating:

> *"Having said that, when a motorway development does go through, it absolutely does create new opportunities for development and any planner worth their salt should say that land use and transportation planning really needs to go hand in hand. Because it creates new opportunities to develop land. Ideally, you know what you're doing in a very strategic way and, um, it can be lined up with what councils' plans are for opening up new bits of land, and how is a council going to fund infrastructure being stretched to a new part of the city and all that kind of thing. You'd kind of hope it was done strategically," KI3.*

As previously identified, increased accessibility due to motorway developments can result in increased land prices and desirability (Munoz, 2003). This means motorway developments are a tool that enables urban growth and a feature that can be driven by urban growth. It also demonstrates the impact that building motorways can have on an area from a broader perspective. While one Key Informant registered opposition to the fact that motorway developments create growth, the above quote demonstrates how motorway development and growth can coincide because of each other (KI3, KI5). The next section of this chapter discusses the regional effects that motorway development in the Wellington Region could have on the surrounding environment.

## *5.3 Commercial Effects*

Large-scale motorway development can also have some economic effects associated with it. This is not limited to increasing land prices, but can

encompass businesses relocating to a different area due to improved accessibility, or the effect new roads may have on commercial road users. Discussion about this occurred in the Key Informant interviews. The impact of the RONS projects on wider economic growth was initially not considered in the planning stage. The results demonstrate this wider economic impact.

### *5.3.1 Business Relocation*

Two Key Informants noted the potential for businesses to relocate due to the new accessibility created by these roads. Key Informant Six identified that Porirua could benefit from these roads, in that some businesses may feel that they can easily relocate into the Porirua CBD and still be accessible to Wellington (KI6). Professions identified in the Key Informant interview that could relocate some of their staff included banks and government ministries. Key Informant Six identified that this would also be in the interest of staff, as for some it would make their commute much shorter (KI6). Key Informant Seven discussed the hope that Kapiti would experience some business diversification, stating:

> *"We've seen a lot of hope for a lot of business diversification. So we've got a big problem in that a lot of businesses here are either construction or retail. So we are not a very diversified economy, and so there's a lot of hope that we will move out of that a bit with it becoming more accessible for Wellington and like a good place for people to have a satellite office with more reliable road networks in the future," KI7.*

This shows the hope that these road developments have brought to some of the surrounding districts of Wellington City, and the potential that increased accessibility due to motorway development has on these communities. Zhao (2010) argued that the development of an area is reliant on transportation routes, such as motorways, because of how this can improve accessibility. Handy (2005) also made this point, linking transportation and transportation projects to economic development and growth of an area (Handy, 2005). By applying this reasoning to the case study, Porirua and Kapiti are set to benefit economically from the development of motorways in the Wellington region.

Within the context of the case study, Wellington City does not lose out economically to Porirua or Kapiti as a result of these motorway developments. This is because Wellington City is perceived to be the economic heart of the

region (KI3). Noting that, both the Porirua City Council and Kapiti Coast District Council are optimistic about the business opportunities these motorway developments present them.

### *5.3.2 Commercial Road Users*

Motorway developments can also affect commercial road users. Commercial road users here are any road user who utilises the discussed motorways for economic gain. These may include heavy haulage, taxis, couriers, and freight trucks. Key Informant Two had a wider viewpoint on the impact that these developments may have for commercial road users. Key Informant Two argued that productivity was a key deliverable of these road developments, saying:

> *"The second thing is, transport, in my opinion, is all about ease of movement about a city about an area. And why is that important? Because productivity is dependent on it. There's nothing affecting productivity more than congestion, ok?" KI2.*

The quote demonstrates how commercial road users benefit from a decrease in congestion which in turn can boost their productivity due to ease of movement. Key Informant Five agreed with this, discussing how congestion was bad for commercial road users as it created inconsistencies in trip times through congestion. With motorway development improving the free-flow speed of vehicles, commercial road users benefit from motorway development (Deardoff, Wiesner & Fazio, 2011). Key Informant Five elaborated, noting that at this time, there is no alternative to commercial road use. This makes it a necessity for these businesses (KI5). Through motorway development, productivity should be improved by a reduction in congestion that will benefit commercial road users.

Key Informants Four and Eight then discussed the impact that these new roads may have on heavy haulage and freight users. This is shown below in Figure 18, where the impact that Transmission Gully may have on freight companies is identified, and the NZTA outlines the goal of these developments for commercial users.

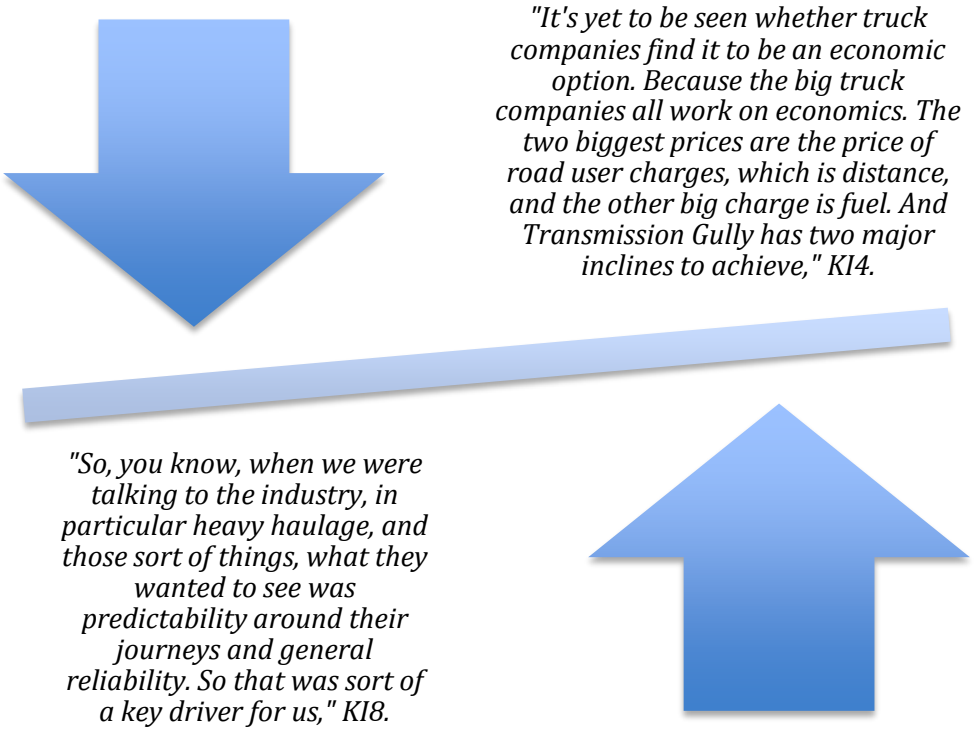


**Figure 18: Manners in which motorway developments may impact on freight companies.**

Key Informant Eight demonstrated that during the development stage of these motorway developments, the NZTA was actively engaging with commercial road users, such as freight companies, to ensure a more reliable road network. However, while routes such as Transmission Gully may be shorter than the existing route, Key Informant Four highlighted the fact that it may not be economically viable for these road users. If that is the case, commercial users may keep using the existing coastal route.

## *5.4 The Effects of Policy, Plans and Reports*

Motorway developments are affected by or can affect policy and plans. This is because policies and plans have to respond according to the effects of large-scale motorway development, which can be far-ranging. In New Zealand, plans and policies influence where motorways can be developed and what effects they may have (Lee & Rivasplata, 2001). Further, policy, plans, and reports have influenced the development of roads in New Zealand. The Wellington foothills motorway demonstrates this. It was planned in a report carried out by an engineering firm named De Leuw Cather in 1963 (KI2). This report was to

inform the route that the motorway would take from Ngauranga, skirting the city of Wellington and ending at the Mt Victoria tunnel. Reports from external agencies such as De Luew Cather influenced motorway development in New Zealand (Dodson & Mees, 2003). With these engineering companies being based out of the United States, motorway development was thus influenced by the American approach to motorway development. Consequently, being located in New Zealand instead of the United States may have exacerbated the effects of existing motorways.

In the context of Wellington, the De Leuw Cather report suggested trenching the motorway upon entering Wellington to ensure a smooth and consistent flow through to the Mt Victoria tunnel. However, trenching did not occur (KI2). If this had been carried out in the 1960s, then the receiving environment issues currently experienced in Wellington City may not have been an issue (KI3). Discussion of this occurs in more detail in the following chapter, which discusses the efficacy of large-scale motorway development.

Some Key Informants identified policy issues when it came to understanding the form that urban development may take due to increased road capacity caused by these motorway developments. Discussion of this occurs next.

### *5.4.1 District Plans and the RMA*

Motorway development encourages the development of previously undesirable areas due to increased accessibility, so it is important to understand in what ways policy may be influencing where this development occurs. In this context, plans can be affected by motorway development. Three different territorial authorities are impacted by the motorway developments in this research, meaning that three different district plans are affected. The Porirua City Council is currently reviewing their district plan. With this, they are considering creating new zones for development. As Key Informant Six noted, this was due to the pressure put on the council by developers wanting to attain this land due to its increased desirability arising from the Transmission Gully development:

*"We've got lots of developers quite keen to go. And they want to build homes and we've got with the urban development NPS and the new section 31 functions, we have to think about providing this capacity. So, we would rather do it in a strategic way rather than just have random private plan changes," KI6.*

This demonstrates the desire for development due to an increase in accessibility arising from motorway development (Gunder, 2002). By changing the plan to respond to motorway development, the Porirua City Council can maintain a degree of control over what type of growth occurs within its district. Further, this offers them the opportunity to control the effects (Lee & Rivasplata, 2001). This is because they can implement their vision for future growth in the district plan. In the Wellington City Council District Plan, there are provisions to encourage urban infill. However, the City Council is not expecting to experience growth from these motorways (KI5). Key Informant Five did note that policy, such as district plans, can be incredibly important for influencing the direction that growth takes in an area, stating that:

*"I mean, yeah, policy is incredibly important otherwise you don't have anything to give you any direction. And then you can't argue one way or the other. If you set the policy to be containment, or set the policy to be urban sprawl, if you do that in a really sustainable way then you could probably argue that might even be a good thing to do," KI5.*

This again alludes to how a territorial authority can control the effects of motorway development on their territory through the implementation of their district plan. Key Informant Six was the only Key Informant to elaborate on what role the RMA could have on restricting urban growth. However, they noted that the RMA is relatively restricted and that other tools and techniques need to be utilised to control where growth may occur in a district, saying:

*"The RMA, in my opinion, probably might restrict development a little bit. But not nearly as much as other things, such as other government policy, such as capital gains taxes, you know, construction labour costs, the ability of developers to put private covenants on land. Yeah, I suppose just the general market, what sort of houses people want. And, ya know, and what investors and developers are building. There's a whole bunch of policy that affects urban form and sprawl. And the RMA is a part of it. But I suspect probably a small part. Yeah, obviously under the RMA we've got our district and/or regional policy. So, regional policy in terms of the natural stuff, such as the harbour and biodiversity. And the regional policy statement. And then our district plan that does zoning, development and environmental considerations when you develop," KI6.*

Key Informant Six thus demonstrates the interconnected nature of a variety of tools that can be utilised to control where urban development occurs. The literature acknowledged that planning in New Zealand is interconnected, with the RMA having to work with a variety of plans and policies that it provides for (Lee & Rivasplata, 2001). This is a view shared by Key Informant Seven, who emphasised the importance of utilising non-regulatory measures to control where development occurs (KI7). This again provides territorial authorities with the ability to manage the effects of development. Under the RMA they cannot, however, consider effects such as increased vehicle emissions due to motorway development (Lee & Rivasplata, 2001). Key Informant Seven also noted that within the Kapiti Coast District Plan there is an extensive use of transport thresholds, which dictates the density of development allowed to occur. This accounts for the pressure that new development may put on existing roads and public transportation services (KI7). Tools such as this are available to authorities to mitigate the effects that new motorways may have on a territorial authority (McDermott, Toleman & Lee, 1997). These are also available to territorial authorities to help them with implementing their growth vision for an area as a result of these motorway developments.

One Key Informant identified that the Wellington region was in need of a high quality, collaborative spatial plan that it currently does not have. This would enable a collaborative vision for the future of the Wellington Region to be established and realised. Key Informant Three discussed this, saying:

> *"It would be great to have a really high quality spatial plan for the Wellington region, where not only did councils talk to each other and agreed on future land use, um, but we're working with the NZTA and in fact all of other major infrastructure providers and all of them to get on the same page as to how and when and where and the phasing of development. And that's land use and transport development. For me, that's the role of, um, a really good policy, a spatial plan process," KI3.*

The implementation of a spatial plan would communicate the growth and transportation needs for the Wellington Region. This, in turn, could result in a more efficient transportation network by taking a region-wide approach to the congestion issue. However, implementing a strategic transportation vision in the Wellington Region has been critiqued before. Criticism focussed on how councils

were acting in their own self-interest instead of implementing the joint vision (Early, Howden-Chapman & Russell, 2015).

Further, motorway development may assist in achieving the purpose of promoting sustainable management for the RMA. This is because a high-quality transportation network would ensure that this purpose is met (Lee & Rivasplata, 2001). This, combined with a collaborative high-quality spatial plan, as envisioned by Key Informant Three, would minimise the effects of motorway development.

### *5.4.2 National Policy Statements*

Only one Key Informant noted the impact that the RONS developments could have on assisting authorities in meeting their obligations of the new National Policy Statement (NPS) for Urban Development Capacity. The NPS has the primary purpose of ensuring that both regional and district plans are providing for the development needs of their businesses, whilst also providing adequate housing. Through this, communities are more resilient to growth and change because of development (MBIE, 2017). This National Policy Statement affects all the territorial authorities of New Zealand, but the three authorities affected by these RONS projects will be assisted in meeting their obligations. Key Informant Three identified how the RONS were going to assist with this, observing:

> *"And it's the sort of thing that councils that are affected by the National Policy Statement for Urban Development Capacity, they will be looking for where these new bits of land are that we need to provide capacity to enable development. So any motorway development that opens up land is kind of the first obvious place that you'd look, assuming that you'd already looked at all of your other bits of land and they had been accounted for," KI3.*

The quote demonstrates how the RONS projects, specifically the Wellington Northern Corridor, could be utilised to meet the requirements set forward by the NPS. This is a positive effect of both this NPS and motorway development. With the Porirua City Council and Kapiti Coast District Council expecting growth to occur as a result of these motorway developments, creating areas in their plan for this growth now ensures that they meet this requirement (KI6, KI7). Further, by planning these new areas in advance, one Key Informant noted that they

could ensure that infrastructure is efficiently installed and distributed, such as roading, gas pipes and water pipes (KI7). This again assists in meeting the purpose of promoting sustainable management through sustainable transportation (Lee & Rivasplata, 2001). By managing the provision of this infrastructure together and in advance of development, the authority is likely to ensure that the development that occurs within the district is the type of development that they want (KI5).

## *5.5 Other Effects*

The development of Motorways in the Wellington region could have other effects, both positive and negative. This section discusses the effect that motorway development could have on responding to natural hazards and improving resilience. This section then discusses the effect that motorway development can have on existing communities. Whilst these carried less importance in the Key Informant interviews, they are still important effects.

### *5.5.1 Natural Hazards and Improved Resilience*

With Wellington being situated along active earthquake faults and facing topographical restrictions, with the presence of the harbour and steep hills, resilience is at the forefront of many future developments for the region (Early, Howden-Chapman & Russell, 2015). The resilience that Transmission Gully should offer to the city of Wellington has not been missed by most Key Informants, as it offers an alternative route in and out of Wellington City should a disaster occur (KI1, KI3, KI4). Key Informant One even noted that due to the route chosen for Transmission Gully, the design has ended up being very resilient and that resilience of the network was a key goal of this development for the NZTA (KI1). When asked about the resilience improvements needed in Wellington City, Key Informant Three noted that:

> *"But increasingly it's really important for Wellington City to have a more resilient network. So, to have some multiple options in and around the region in the event of landslips and earthquakes. Any other major disasters, we kind of need that resilience," KI3.*

This was further elaborated on by Key Informant Three, who identified a resilient transportation network as one of the goals for the Wellington City Council (KI3). The improved resilience of the transportation network was also widely acknowledged in plans and policies from the regional council (Greater Wellington Regional Council, 2015). The continued discussion around improving resilience demonstrates the current degree of vulnerability the transportation network in Wellington has for natural disasters. Key Informant Three identified the issue with the current network by discussing the impact that the 2016 November Kaikoura Earthquake had on Wellington. With a storm occurring the day after with extensive flooding, Wellington became separated by road to the rest of the North Island (KI3, KI4). Key Informant Seven discussed how Wellington's reputation for being hazard-prone is likely to put people off from moving there due to the perceived risk (KI7). However, Key Informant Seven did then go on to elaborate as to how the motorway developments could help with the region's resilience, stating that:

> *"So they will improve our resilience, we will have at least two roads to choose from. And, hopefully, parts of the expressway will be easier to fix if there are liquefaction and/or other seismic issues," KI7.*

The quote demonstrates that while individuals may identify the Wellington region as particularly hazard-prone, these motorway developments ease some of these tensions. The NZTA also designs their road developments with resilience in mind. With such large-scale engineering and development, there is a need for built infrastructure to withstand the stresses caused by significant disaster events (New Zealand Transport Agency, 2017). Key Informant One discussed the level of resilience that the NZTA designs for, identifying that the design standards take into account a one-in-2,500-year earthquake event or a one-in-100-year storm event for all of their bridges and other forms of built infrastructure (KI1). Further, these projections take into account the effects that climate change may have on the network. Two Key Informants identified issues for resilience linked to the impacts of climate change. Figure 19 depicts these issues.

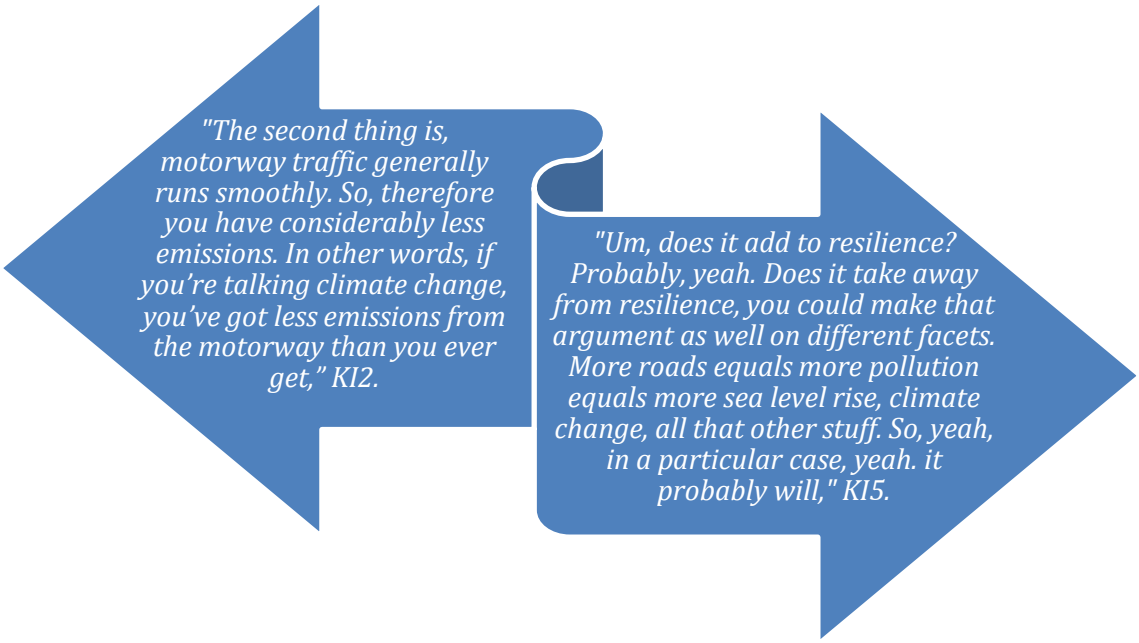


**Figure 19: Key points on the link between motorway developments, climate change and resilience.**

Both of the points displayed in Figure 19 discuss climate change and link it to resilience. However, Key Informant Two argues that by improving motorway networks the impacts of climate change may be reduced, whereas Key Informant Five links roads to increasing climate change (KI2, KI5). Whilst smart technologies may reduce greenhouse gas emissions, it remains unclear from the international literature the effect that large-scale motorway development would have on climate change (Nissan & Koutsopoulosb, 2011). The effects that motorway development may have on climate change were considered to be outside of the scope of this thesis.

### *5.5.2 Existing Communities*

Motorway developments also possess the potential to impose adverse effects on existing communities. As Key Informant One identified, the development of the alternative route along the Coastal highway instead of developing Transmission Gully would have adversely affected existing communities. Key Informant One identified this, saying:

> *"… but then also there's a number of sort of urban, well, semi-urban communities along the existing coastal route which will sort of suffer from severance, if you'd like, due to it being difficult to get on and off the existing highway 'cause of the traffic volume and long delays. So, there should be a marked improvement in terms of*

*access along there and easier for people who live on the landward side to actually access the stuff on the other side of the road and the foreshore and all of those sorts of things. So there's some quite nice, um, community benefits from relocating the traffic away from those coastal communities," KI1.*

Along with severance, motorway development along this route had the potential to affect resident's health adversely. Through an increase in vehicles, this area would have suffered from an increase in emissions of respirable particulates (Dunt, Abramson & Andreassen, 1995). Improved community wellbeing occurs because the NZTA chose to go with the Transmission Gully Development, due to a decrease in motor vehicles (KI1). Further, their health should improve due to a reduction in motor vehicle-related emissions (Grumert, Ma & Tapani, 2015).

The NZTA has a goal of minimising the impact that these developments could have on existing residential properties and to also minimise the amount of community dislocation felt by property owners in these communities (KI1). Key Informant Six discussed the impact that Transmission Gully could have on existing communities and the impact that motorway development may have on a broader scale, saying:

*"Um, I suppose socially there's already existing communities, Pauatahnui, there's eastern Porirua, it's, um, a large area of state housing. And there's a risk that having a motorway, an on and off ramp, might perhaps displace that community. It could maybe get too expensive for people to live there. Houses may get sold off one day, where do those people go. So, social threat to that community. Um, I suppose it impacts the whole district plan, really. We see it open space, infrastructure, transport, wastewater, development contributions," KI6.*

The quote demonstrates a substantial degree of consideration into how these developments could impact on existing communities. The consideration of effects is because motorway development does affect existing communities (Dunt, Abramson & Andreassen, 1995). Key Informant Six also demonstrated a more comprehensive understanding of the potential impacts that could occur because of these motorway developments by alluding to the potential for gentrification (KI6). Gentrification has been discussed previously in the context of the effect motorway development could have on increasing land values.

## *5.6 Conclusion*

This chapter has discussed both the positive and negative effects associated with large-scale motorway development in the case study context of the Wellington Region. Understanding the effects occurred through the analysis of Key Informant interviews and a literature review. The research concluded that large scale motorway development could have effects on: urban growth and development; economics; the delivery and creation of plans and policies; improved resilience to natural hazards; and can adversely affect communities. By acknowledging the effects that motorway development may have on the surrounding environment, future motorway development should be planned in a manner that mitigates any adverse effects that may have arisen previously. This chapter has found that whilst motorway development may have some adverse effects, the associated beneficial effects outweigh the negative effects. The beneficial effects partially justify the implementation of large-scale motorway development to address increasing roading pressures and as a tool for managing congestion. The following chapter, Chapter Six, addresses the efficacy of large-scale motorway development in Wellington.

# 6 - The Drivers and Efficacy of Large-Scale Motorway Development

## 6.1 Introduction

Large-scale motorway development attempts to improve traffic efficacy. For this thesis, efficacy is focussed on achieving an intended result. Products of enhanced efficacy for motorway development include reduced bottlenecks, improved trip time reliability, reduced congestion, improved safety, and improved road design. Chapter Six addresses Research Objective Three, which sought to evaluate and assess the efficacy of large-scale motorway development within the case study of Wellington, New Zealand.

This chapter identifies the traffic characteristics of Wellington's existing motorway network, discusses the efficacy of current motorways, identifies approaches mentioned by Key Informants for improving motorway efficacy, and then discusses future motorway development that are set to occur in Wellington, before concluding remarks. The analysis of data, provided by the NZTA TMS database, enabled a full understanding of the efficacy of large-scale motorway development in the Wellington Region. Quantitative data was combined with Key Informant interviews to address the scale of this research objective and to answer it appropriately. By doing this, the mixed methodology discussed in Chapter Four was carried out. Chapter Seven, which summarises and concludes the findings of this thesis, follows this chapter.

## 6.2 Wellington's Existing Motorways

To understand how large-scale motorway development may contribute to an improvement in efficacy for the road user, the original motorway network must be understood and analysed. This understanding establishes the benchmark to

compare the new motorway development with. This section of Chapter Six seeks to identify the goals of motorway development in Wellington, discuss what motorway development in Wellington has currently achieved, identify the alternatives that were considered, and then discuss the importance of the Roads of National Significance for Wellington.

### *6.2.1 Goals of Motorway Development in Wellington*

A number of Key Informants discussed the goals of Wellington's new motorway developments. Primarily, these were identified by those involved with the NZTA or transportation engineering, with other Key Informants being less informed. Figure 20 below identifies what Key Informants thought the goals were of the Wellington motorway developments. Improving trip time reliability was consistently mentioned in Figure 20, meaning that reliability of trip times is critical for ensuring that the motorways are achieving their goals (KI1, KI4, KI7 and KI8).

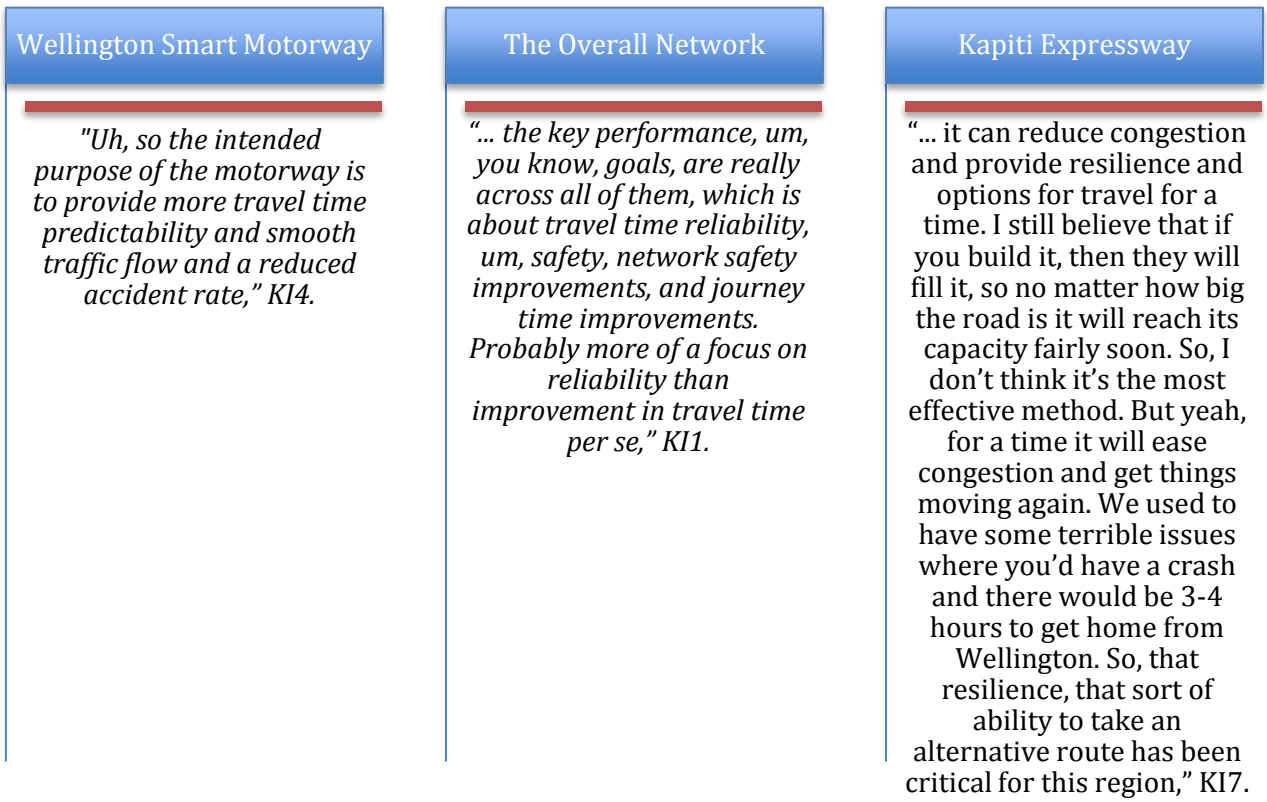


**Figure 20: Key performance goals of the motorway developments according to Key Informants.**

Whilst improving trip time reliability appears to be a cornerstone of these motorway developments, it is essential that other performance goals are also acknowledged. Key Informants noted that they thought goals of these motorway developments included reducing congestion, decreasing trip times, improvements for commercial truck companies, and reducing fuel consumption (KI1, KI3, KI4, KI8). Key Informant Eight made a crucial observation about the difference between improving travel time and travel time reliability, stating:

> *"I mean, essentially, there were a number of key objectives but probably the important ones at the time were around reducing congestion. Um, improving travel time reliability, now, it's probably worth distinguishing between improving travel time versus reliability," KI8.*

Although motorway development could result in a shorter trip time, as has been observed with the Kapiti Expressway, the motorways are more focussed on ensuring travel time reliability (KI7). Improved trip time reliability is attainable by increasing the capacity of the motorway, guaranteeing that free-flow speed occurs for the duration of a vehicle's journey (Deardoff, Wiesner & Fazio, 2011). Improved reliability could also ensure that the point of critical accumulation for congestion is harder to reach, resulting in longer periods of free-flow conditions (Xu *et al.*, 2013). Key Informant Eight noted that a number of objectives need to be addressed to reduce congestion (KI8). However, Key Informant Eight did not elaborate on what all of those objectives could be.

### *6.2.2 What has Motorway Development in Wellington Achieved*

The Key Informants spent less time discussing what had been achieved by the Wellington motorway developments. Instead, Key Informants fixated on the issues that they perceived to have arisen because of these motorway developments, or faults they had identified with the existing network. Key Informant Eight did identify some benefits of the Wellington Smart Motorway, primarily regarding easing congestion. Key Informant Eight claimed:

> *"Yeah, well, I think given the downstream constraints, yes. I think we certainly have observed reduced congestion and while we are trying to sort of work through the actual metrics around it, we have seen reduced congestion, but also a reduced duration of congestion. So, certainly, in terms of the Managed Motorway or the Smart Motorway, we actually have a fairly small window each day which we can*

> *derive that benefit. And really where we apply the variable speed limits is on those shoulder peaks. So as congestion is building that's when we try to control the speed of the vehicles to try and reduce queuing and that sort of thing. But once you're into the peak of the peak you really, flow is broken down, and really there is nothing you can do. So what we have observed is certainly a reduced length of the overall peak," KI8.*

When Key Informant Eight identified downstream constraints, they were acknowledging the impact that the receiving environment of a motorway can have on congestion. The limited capacity of the Wellington CBD, train lines, and the Terrace Tunnel all act as constraints and result in limited road capacity. The acknowledgement of geographically specific constraints mirrors the findings by Frank et al., (2008), who identified similar issues in Puget Sound as contributing to congestion. Applying these findings to the Wellington Smart Motorway means that the capacity of the receiving environment contributes to the congestion experienced on the Smart Motorway.

Key Informant Eight also alluded that the maintenance of free-flow speed on the Smart Motorway is not possible upon breaching the motorway's vehicle capacity. The addition of a lane heading north will have improved the capacity and alleviated congestion during the evening commute (Dumbaugh & Rae, 2009). However, with the Wellington Smart Motorway development, it was not possible for an additional lane to be added heading south. As a result, increased capacity for the morning commuter period did not occur. Deardoff, Wiesner and Fazio (2011) have acknowledged how maintenance of free-flow speed becomes more difficult during peak traffic periods. Since increased capacity heading south did not transpire, the breakdown of free-flow speed that results in congestion is more likely (Xu *et al.*, 2013). Key Informant Eight acknowledged this by identifying issues with the Smart Motorway attempting to recover from periods of peak traffic.

This particular answer, while insightful, is only applicable to the Wellington Smart Motorway. However, Key Informant One also discussed the rapid nature in which vehicles now travel along the Kapiti Expressway until they reach MacKays crossing (KI1). This road has increased vehicle capacity for the area whilst also improving the free-flow speed attainable through Kapiti. Primarily, this is

because of the design of the new expressway, which is uninterrupted by traffic lights and has limited on- and off-ramps. Daniel and Maina (2011) also found that wide lanes and motorway shoulders, as are present on the Kapiti Expressway, can increase the capacity, free-flow speed, and safety of a new motorway development.

Key Informant Seven, who claimed that that Kapiti Expressway had resulted in reduced trip times, mirrored this opinion (KI7). This has then resulted in a bottleneck at MacKays Crossing, which will persist until Transmission Gully opens in 2020. Bottlenecks are discussed later in this chapter.

When attempting to understand what the Kapiti Expressway has achieved in regards to flow characteristics, data is limited. The NZTA TMS has not yet collected enough viable information on the flow characteristics of the Kapiti Expressway to construct graphs for analysis. However, the difference in vehicle numbers travelling along the old State Highway One before and after the Kapiti Expressway opened is visible below in Figure 21.

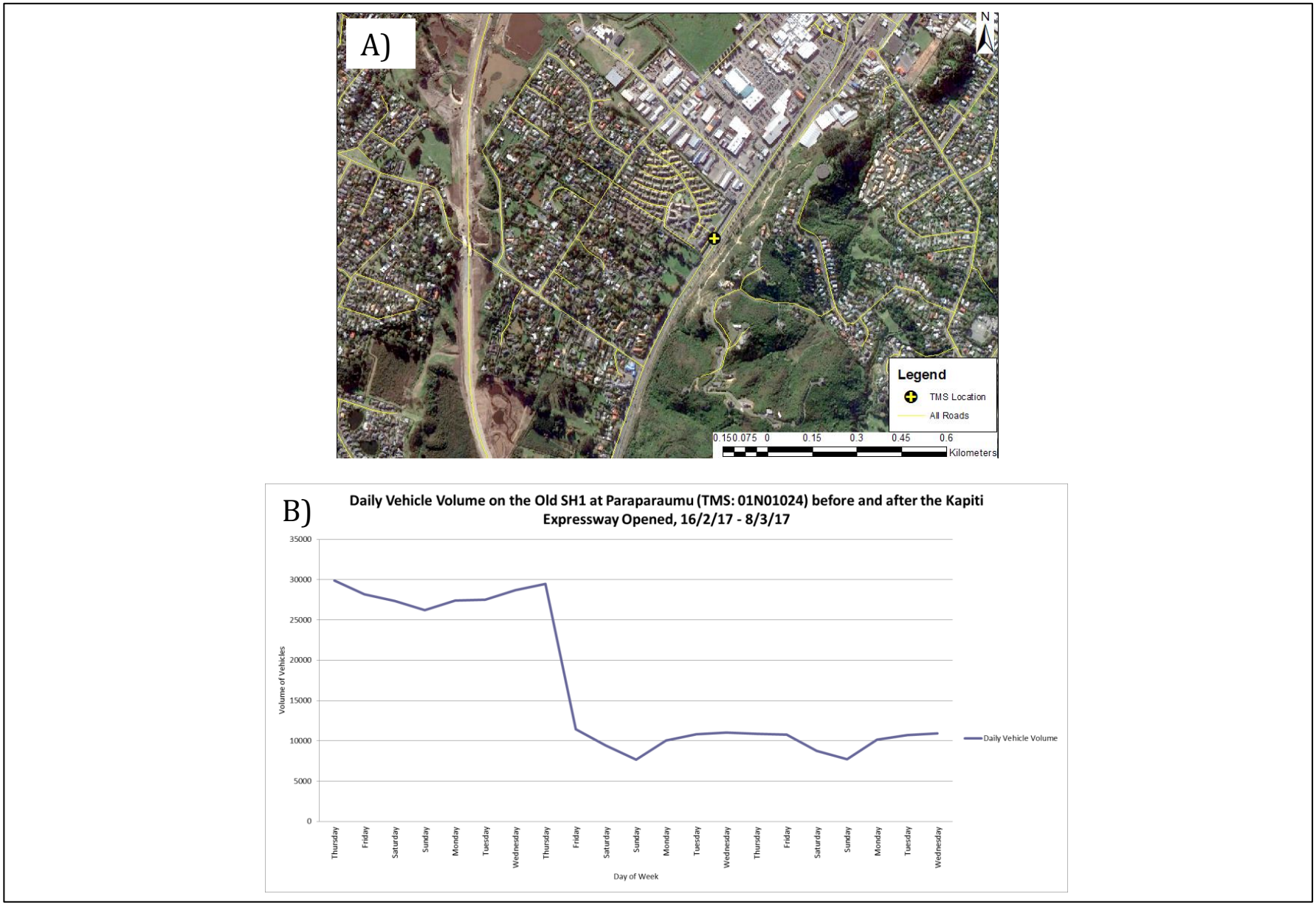


**Figure 21: Volume of daily vehicles on the old State Highway One at Paraparaumu.**

In Figure 21 (A) the NZTA TMS site is displayed on the old State Highway One, with the Kapiti Expressway located to its east. Figure 21 (B) then displays the vehicle count at this TMS location before and after the Kapiti Expressway opened on 24 February 2017. When the Kapiti Expressway opened, there was a drastic reduction in vehicles along the old State Highway One. This reduction in vehicle numbers mirrors the findings in the study by Carey and Semmens (2003), who attributed new motorway development to a reduction in traffic on existing motorways and roads. The research concludes that the development of new motorways can result in a reduction in vehicle numbers on existing motorways that reduces congestion. This reduction in vehicles is because the existing volume of vehicles is spread out over a far more substantial geographical area. The vehicles are then more easily accommodated on these new roads due to an increase in capacity (Carey & Semmens, 2003; Handy, 2005). As a result, existing motorway development in Wellington has alleviated some of the congestion experienced in the region. Further, this has improved free-flow speed and trip time reliability.

### *6.2.3 Alternatives Considered*

The thesis research focussed on motorways that were developed or were currently under construction. This research also identified the alternatives to these motorway developments. The Wellington Smart Motorway utilised the already built infrastructure that was in place and had to fit in with the topographical constraints (KI1, KI4, KI8). Key Informant Eight went into significant detail explaining some of the alternatives considered for the Wellington Smart Motorway. Key Informant One then gave highly detailed responses about the alternatives for the Kapiti Expressway and Transmission Gully. Figure 22 displays these alternatives.

| | |
|---|---|
| Wellington Smart Motorway | • *"We did look at increased capacity through road widening. I mean, that's often the most ... generally the first solution that comes to hand. It's going right, let's add more lanes. We then said, there's a huge amount of cost involved in that ... what can we do with the existing assets. And that was the idea that we then started saying, you know, if we start looking at the road shoulder what would that mean improving capacity, reducing congestion while trying to manage safety. So, the option that we've got out there now is what [we] call all lanes running. So essentially you've got ... all of your lanes are live all the time; one of the other options that was considered was essentially peak hour shoulder running. Which is used in the UK, used similar to the bus lanes in Auckland. So basically during the peak hours the road shoulder is utilised as a running lane. So that was another option, but the conclusion we came to was that the best option was all lanes running," KI8.* |
| Kapiti Expressway | • *"One was, um, was sort of upgrading the exisiting State Highway or the old State Highway corridor from two lanes to four lanes. Um, there'd been, as I said, that corridor of the expressway, it had been sitting there sort of vacant for 50 years or more, waiting for a road. And there had been discussion over time about whether it would be a motorway or whether it would be a State Highway or whether it would be a local road. So, um, the latest sort of incarnation before the expressway was that it would be a local connector road between Paraparaumu and Waikanae. So there was a project called the Kapiti Western Link Road, which was being developed by the council up there to use that corridor. So one of the options was to build, or upgrade, the existing State Highway to an expressway and still retain that other corridor as a local connecter road. Between Paraparaumu and Waikanae, obviously what did get built was to flip those two around so that that new corridor became the highway and the existing corridor is being modified so that it can be revoked so it wont be a state highway anymore and it will better serve the local travel needs," KI1.* |
| Transmission Gully | • *"Uh, yeah, so there's been a very long term traffic gestation period for the Transmission Gully project and I guess the biggest, um, sort of large scale alternative was looking at upgrading the coastal route rather than Transmission Gully, and so not to build Transmission Gully at all. And upgrading the existing State Highway One to four lanes, and so that was sort of being developed or progressively in a number of shorter projects, um, for quite a long period of time. But it left all of the hard ones till last. Or the ones that were either expensive or more contentious around this ... sort of impacts it had on, through Mana/Pukerua Bay, there's quite a lot of Iwi cultural impacts, um, which would be really hard to mitigate, and there's quite a lot of community in that area as well, which are quite hard to mitigate, so part of that Western Corridor study in 2004 was one of the major questions that grappled with was whether it was better to build Transmission Gully or continue to just progressively build that coastal route," KI1.* |

**Figure 22: Alternatives considered to the respective motorway developments in Wellington.**

The topographical constraint and geographic location of the Smart Motorway limited viable options. Alternatives considered included adding an extra lane and peak hour shoulder running (KI8). By going with the Smart Motorway option, it was possible to improve the free-flow speed and capacity at a fraction of the cost utilising tools such as VSL (Grumert & Tapani, 2012). The addition of extra lanes would have increased the capacity of the motorway. This increase in capacity would have then increased the volume of vehicles that could have utilised the motorway within a set period due to an improvement in the consistency of the motorway's free-flow speed (Daniel & Maina, 2011). However, due to the topographical constraints, the Smart Motorway option was the only viable option for addressing congestion issues.

The Transmission Gully development is the most expensive of the three developments analysed by this thesis. The route that Transmission Gully is taking bypasses Porirua, Pauatahnui and Pukerua Bay. It avoids the single lane coastal route and disjointed traffic light controlled stretches of road. Attempts were made to upgrade this route, but the impacts were eventually decided to be too costly and would cause too many adverse effects (KI1, KI6). Dunt, Abramson and Andreassen (1995) acknowledged the impact that motorway development can have on existing communities. Attempting to increase the capacity of the existing coastal route would have resulted in community disruption along its length (Dunt, Abramson & Andreassen, 1995). As a result of this, the NZTA selected Transmission Gully due to the reduced impact that it would have on the surrounding environment.

Finally, the Kapiti Expressway development considered whether it was feasible to widen the existing State Highway One to four lanes along the existing road corridor. Additional lanes would have resulted in a significant increase in the capacity of the road. Through increasing this capacity, the volume of vehicles that would have been able to travel along the motorway smoothly would increase (Frank *et al.*, 2008). In turn, the free-flow speed for this stretch of State Highway would have been easier to maintain, resulting in improved trip time reliability (Xu *et al.*, 2013). However, it was decided to use the existing road designation to create the Kapiti Expressway and revoke the State Highway One

status of the old route and return it to being a local road (KI1, KI7). This decision was because the impacts were seen to be too drastic and the costs of improving the old State Highway outweighed the benefits. The cost outweighing the benefits is a common reason for new motorway development to occur (Mackie, 1996). The benefits of building the Expressway outweighed the benefits of improving the existing State Highway.

### *6.2.4 The Importance of the Roads of National Significance*

The majority of Key Informants mentioned the Roads of National Significance (RONS) developments in New Zealand, with a primary focus on the Wellington Northern Corridor RONS project. The RONS developments did not use a traditional cost-benefit analysis. Instead, there was an assessment considering the wider economic good the projects would bring to the region (SAHA, 2010). This assessment is one of the primary reasons for the large expenditure for both the Kapiti Expressway and Transmission Gully developments, which would have potentially not been feasible using a traditional cost-benefit analysis. It was also possible to consider other factors, such as job creation, arising from the projects (SAHA, 2010). This finding mirrors the finding by Grimes and Liang (2010), who found that motorway development could result in net economic benefits.

With the RONS projects, specifically the Wellington Northern Corridor, a number of developments have been planned that are part of the RONS project. These include: Ōtaki to North of Levin; Peka Peka to Ōtaki Expressway; MacKays to Peka Peka; Transmission Gully motorway; the Wellington Smart Motorway; Terrace Tunnel duplication; the Tunnel to Tunnel Inner-city transport improvements; and the Mt Victoria Tunnel duplication (New Zealand Transport Agency, 2017). Key Informant One liked that the RONS project was composed of multiple projects that occur within a set window of time, stating:

> *"I mean, I think there's a real benefit in getting your whole network in place rather than sort of just doing it on a bit of a piecemeal basis," KI1.*

This quote demonstrates that by doing all of the projects in a quick time period, the overall vision for the network can transpire. This approach is instead

of waiting for individual projects to be completed over a long time period. Further, with the NZTA establishing the scope and number of projects that are required to achieve the network vision this early on, the residents of the Wellington Region can fully understand what disruption is likely to occur to them until the projects' completion. While some Key Informants stated issues with the concept of building more roads, Key Informant Two had a different perspective when viewing the RONS projects (KI5, KI7). Key Informant Two observed that:

> *"… basically, the RONS for Wellington, through Wellington, was an improvement of existing roads. It wasn't new motorways, it was widening existing roads," KI2.*

This is true when considering the developments likely to occur within the Wellington CBD. With a focus on increasing the capacity of these roads, it is hoped that the effects of congestion would be mitigated (Dumbaugh & Rae, 2009). However, projects such as the Kapiti Expressway heading north as far as Levin and Transmission Gully were new greenfield motorway developments. As a result, this may influence the public's perception on some of the RONS projects implemented as part of the Wellington Northern Corridor. As upgrades, the developments also presented some difficulties when it came to constructing the Wellington Smart Motorway, as it was an upgrade of an existing road. Key Informant One identified this, saying:

> *"Um, we've got sort of 100,000 vehicles a day travelling through that part of the corridor. And unlike some of our other big RONS projects, particularly the likes of Transmission Gully, MacKays to Peka Peka, in fact, all of our big RONS projects to the north, a lot of those are being built offline. Which makes it a lot like a greenfields construction. Where we are trying to build a motorway or trying to remove the central medium barrier, which allowed us to crib a bit more space from the central medium, we were trying to do all that sort of complex building while trying to keep traffic moving," KI8.*

The research found that the different aspects of the Wellington Northern Corridor RONS project each faced unique development issues. However, the remaining construction of the RONS developments to be implemented through Wellington City occurs online. This is whilst road users are still using those roads, meaning that residents of the Wellington Region should expect

disruptions to their travel during the development of these projects. Ultimately, all of these projects increase the capacity of motorways in the Wellington Region. Through increasing capacity, congestion is reduced and free-flow speed is more readily maintained (Carey & Semmens, 2003; Handy, 2005).

## *6.3 The Efficacy of the Current Motorway Network*

For this research, the current motorway network is considered to be all current motorways that are open to the public. Within the research scope, this is the Wellington Smart Motorway and the Kapiti Expressway. This section discusses the efficacy and issues that the current motorway network is experiencing. Currently, some of the issues identified with the network include bottlenecks, trip time, technology, safety, compliance, and road layout.

### *6.3.1 Flow Characteristics*

The Key Informants identified the flow of traffic as an issue with the current network. They identified existing bottlenecks being any areas that experience a break down in free-flow speeds. A bottleneck occurs because a "bottleneck has fixed capacity, and if the number of drivers arriving at the bottleneck exceeds this capacity a queue forms" (Arnott, De Palma & Lindsey, 1993, p. 161). Consequently, bottlenecks frequently occur in the same location and at similar times of the day. Two Key Informants discussed the bottleneck that has developed at the southern end of the Kapiti Expressway. In both interviews, the conclusion reached was that the bottleneck would cease with the completion of Transmission Gully. Figure 23 displays these two quotes.

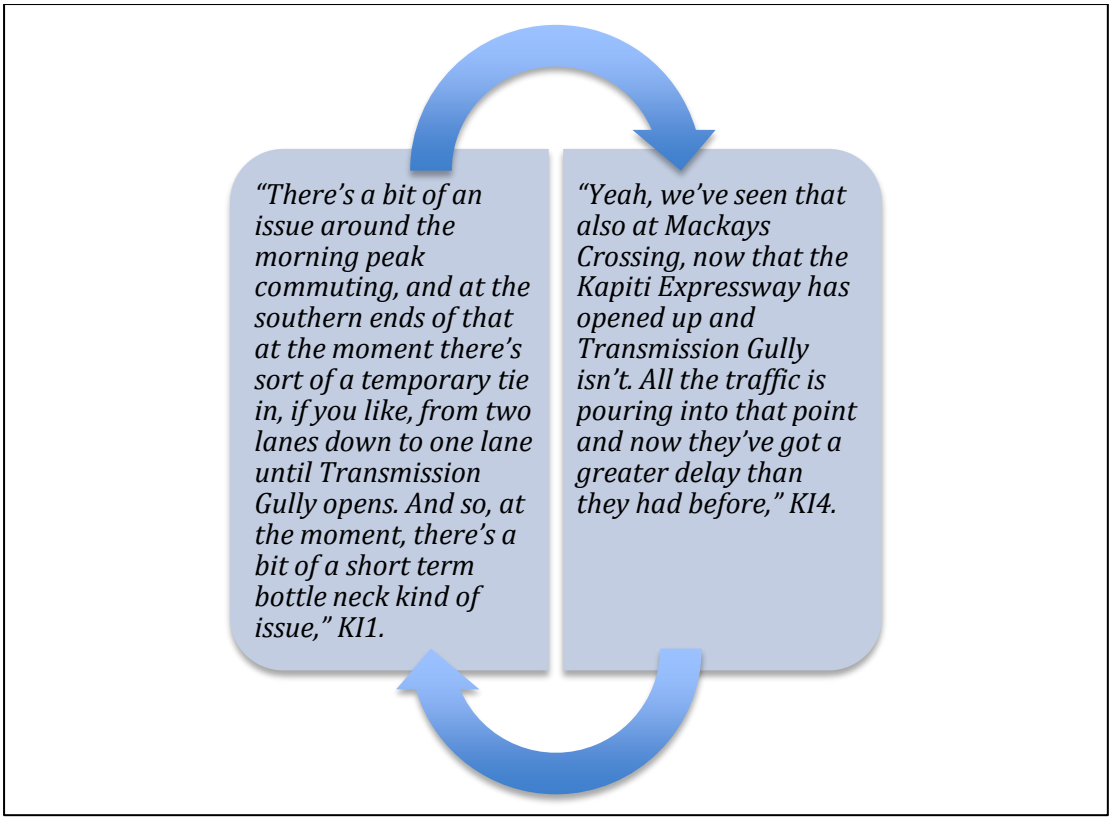


**Figure 23: Discussion around regionally specific bottlenecks.**

Both Key Informants One and Four identified the impact a location-specific bottleneck was having on the wider roading network. The completion of the Kapiti Expressway exacerbated this bottleneck (KI1, KI3, KI4). However, as discussed in Figure 23, the completion of Transmission Gully is set to alleviate/remove this bottleneck from the roading network. This emphasises the impact that the receiving environment of a motorway can have on traffic flow, specifically the impact it can have on the formation of bottlenecks (Frank *et al.*, 2008).

Currently, the limited capacity of the existing coastal route is unable to appropriately receive and manage an increase in vehicle volume from the Kapiti Expressway. This mirrors the findings by Handy (2005), who noted the limited capacity of receiving roads as a primary reason why bottlenecks form. Upon the completion of Transmission Gully, the capacity of the receiving environment is increased, resulting in the removal of this specific bottleneck. Figure 24 displays the geographic location of this bottleneck. Further, in Figure 24 the daily vehicle

counts, yearly growth, and hourly average are also displayed, utilising data from the NZTA TMS.

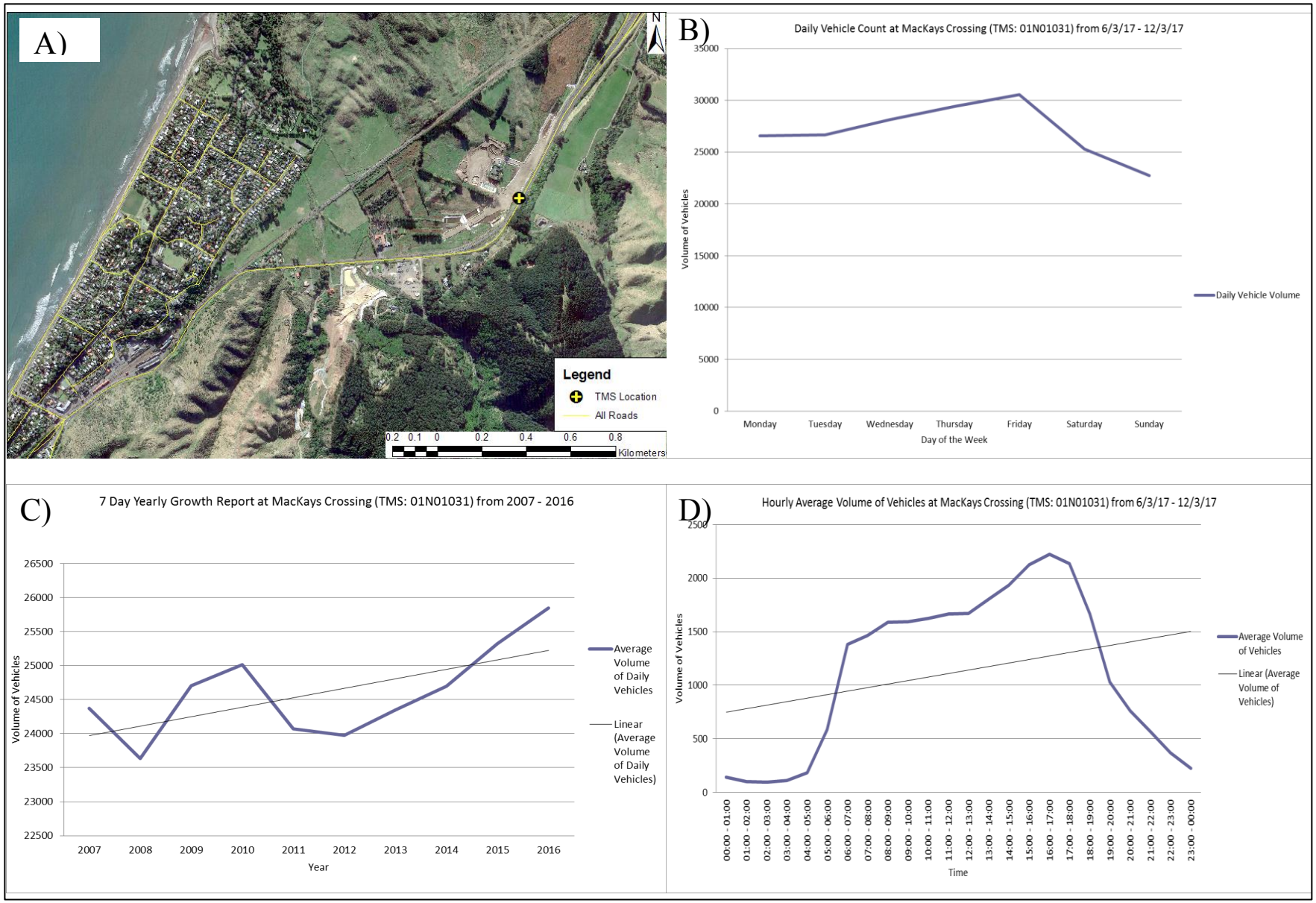


**Figure 24: Hourly, daily and yearly vehicle counts at MacKays Crossing.**

Figure 24 (A) displays the location of the measurement site. To the north of this measurement site is the Kapiti Expressway and directly to the south is the northern end of Transmission Gully. Figure 24 (B) displays the seven-day volume of vehicles through that measurement site. There are on average 25,000 to 30,000 vehicles per day through this measurement site during the working week, which then declines significantly on Saturdays and Sundays. As a result of this, the current route is at its highest vehicle density during the week. Exceeding the road's vehicle carrying capacity results in the formation of bottlenecks (Deardoff, Wiesner & Fazio, 2011). Further, in Figure 24 (D) the flow characteristics are shown in more detail over the course of a single day. With the main volume of vehicles flowing through this area between 1600-1800, this is the period when congestion is at its worst heading north. This is also when free-flow conditions of the motorway are likely to be exceeded and, as a result, congestion occurs (Xu *et al.*, 2013). Finally, Figure 24 (C) shows the increasing trend of vehicles at this measurement site over a seven-year period. This is important, as it shows the need for investment in the development of motorways to meet this increasing demand (Mackie, 1996). Demonstrating the increase in vehicle volumes along a particular stretch of road justifies the need for investment into motorway development.

Key Informant interviews established the location of other bottlenecks. One bottleneck that received mentions from several of the Key Informants was the bottleneck located before the Terrace Tunnel. With the Smart Motorway heading south ending in one lane here, bottlenecks occur here during peak periods. Tunnels are often features that can cause congestion and bottlenecks due to their limited vehicle capacity as discussed by Handy (2005), and are a critical limitation of a receiving environment. Key Informant Three noted the impact that the Terrace Tunnel has on congestion, saying:

> *"I think that there's already major bottlenecks at the terrace tunnel anyway. So, the fact that you might save a few minutes somewhere else on the motorway only to get bottlenecked at the terrace tunnel is an issue," KI3.*

Key Informant Three identified the impact of the receiving environment as identified as an issue that can negate the effects or benefits of undertaking large-

scale motorway development. This was also identified by Mackie (1996) when he attempted to establish the worth of large-scale motorway development work. If the receiving environment is unable to accommodate an increase in vehicle volumes due to motorway development, then the benefits that may result from this investment can be negated. Through the NZTA TMS, it was then possible to visually display the volume of vehicles that are arriving at the terrace tunnel and having to merge into one lane heading south. Figure 25 displays the vehicle characteristics of this section of motorway below.


**Figure 25: Hourly, daily and yearly vehicle counts at the Terrace Tunnel.**

The location of the NZTA TMS measurement site for the terrace tunnel is displayed in Figure 25 (A). This measurement site is only measuring vehicles travelling south along the motorway. Displayed in Figure 25 (B) is the daily vehicle count for a week. Like Figure 24, the main volume of traffic occurs during the period from Monday to Friday, with a reduction in vehicle volumes on Saturdays and Sundays. As a result of this, the motorway is flowing at its highest capacity during the working week, which means that during this period is when a bottleneck is most likely to occur (Lighthill & Whitham, 1955). However, as displayed in Figure 25 (D), the volume of vehicles along this section of the motorway remains consistent between 0600-1800. This means that the capacity of the road needs to be high for vehicles to maintain their free-flow speed (Cheu & Ritchie, 1995). Upon exceeding the road's capacity, free-flow speed is no longer possible, and a bottleneck forms at the Terrace Tunnel (Handy, 2005). Unlike Figure 24 (C), the average volume of vehicles using the motorway is displaying a decreasing trend since 2007 in Figure 25 (C). However, in 2016 the volume of vehicles using this section of the smart motorway was increasing.

Key Informant Eight discussed that by improving traffic heading along the corridor in the southerly direction, the road was delivering more vehicles in a shorter period to the terrace tunnel bottleneck (KI8). Xu et al., (2013) acknowledged this as a condition that breaches the road's carrying capacity. This results in flow breakdown and congestion due to an increase in the volume of vehicles (Xu *et al.*, 2013). Key Informant Eight further elaborated on this, saying that the issue with the southern end of the smart motorway was that there was not the capacity in the receiving environment to get this volume of traffic off the motorway quickly (KI8).

However, at the southern end of the Smart Motorway, it is not just the Terrace Tunnel that is causing bottleneck issues. With exits heading south along the Smart Motorway at Aotea Quay, Murphy Street, Hawkestone Street, and the Terrace before reaching the Terrace Tunnel, the receiving environment for large volumes of traffic becomes increasingly important. With a large number of motorway exits all leading into the Wellington urban core, widespread congestion has been found to be an unintended consequence of motorway

development (Frank *et al.*, 2008). Key Informant Four noted a unique issue with the Aotea Quay exit that leads onto Waterloo Quay, stating:

> *"… in some mornings the traffic is bumper to bumper from Wellington central, particularly when they're shunting trains across Waterloo Quay, just out there. And the railway by law has right of way," KI4.*

Figure 26 shows this traffic as it leaves the motorway at the Aotea Quay exit. It is not possible to establish when the railway is in use to demonstrate the effects of railway-specific congestion. Yet, it is possible to identify periods of peak traffic flow.

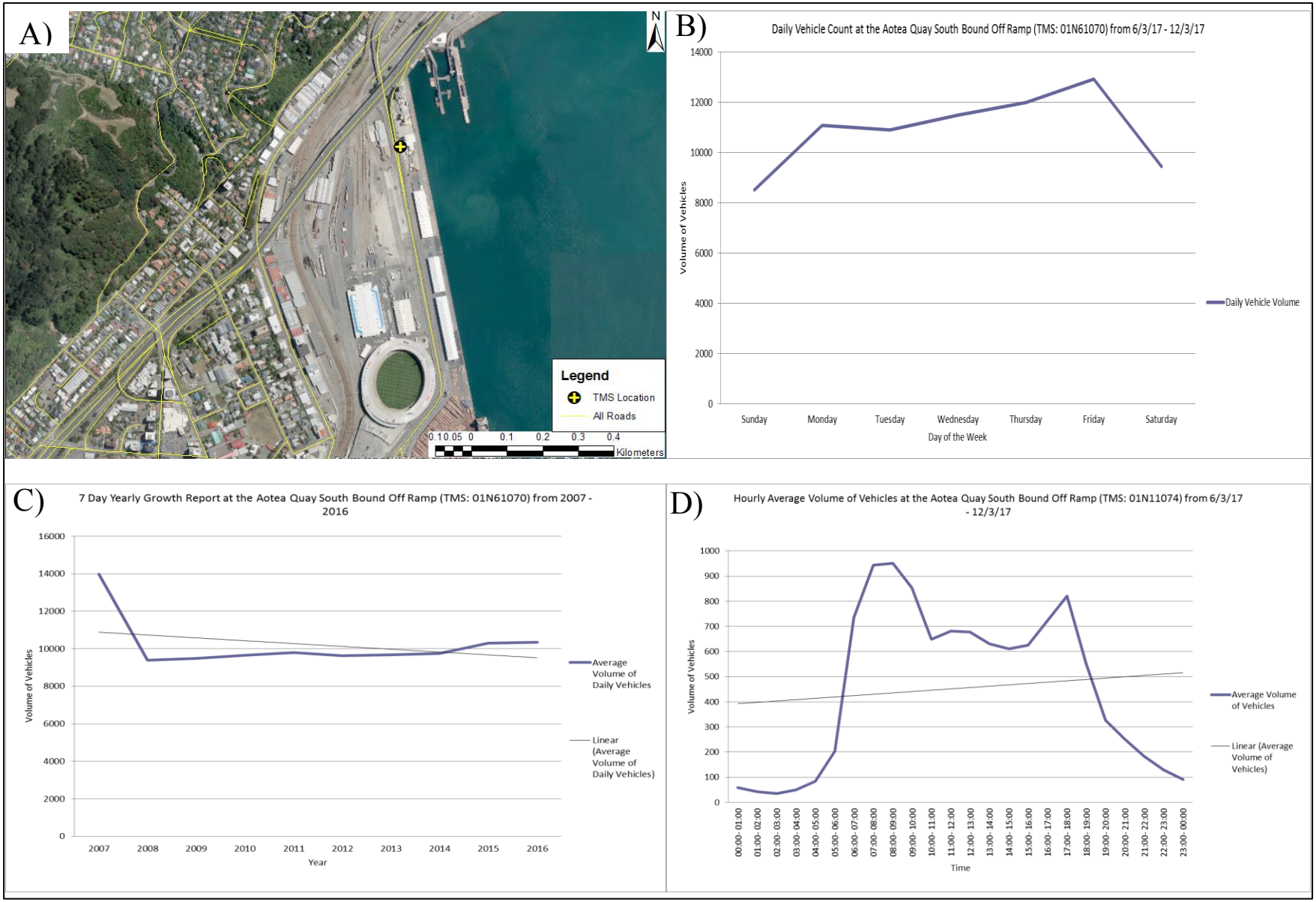


**Figure 26: Hourly, daily and yearly vehicle counts at Aotea Quay.**

In Figure 26 (A), the location of the TMS measurement site is displayed, just off the motorway heading south. This measurement site is only measuring traffic heading south of the Smart Motorway. Figure 26 (B) displays the daily vehicle counts for a week, and like the previous figures, this also displays higher numbers of vehicles during the working week and then a reduction on the weekends. With motorway developments, it is possible that commuter costs can fall due to an improvement in efficacy, resulting in an increase in vehicles on the road (Brueckner, 2000). However, the yearly growth graph displayed in Figure 26 (C) displays a trend that has only slightly increased after a peak period in 2007. Finally, in Figure 26 (D), the hourly average volume of traffic is displayed. Heading south into the Wellington CBD means that the peak flow observed on this off-ramp is between 0600-0900, with a smaller peak in the evening occurring between 1700-1900. This smaller peak is because of people commuting back into Wellington from work in the surrounding cities and suburbs, which are all connected by these roads (Early, Howden-Chapman & Russell, 2015).

By entering a receiving environment that is frequently disrupted or brought to a complete standstill due to the railway line, Aotea Quay is susceptible to periods of congestion. However, it is worth noting that the reduction of vehicle lanes does not cause this bottleneck like the MacKays Crossing bottleneck. A combination of the railway crossing and the limited capacity of the roads heading into the Wellington CBD means that during peak periods these vehicles exceed the road's capacity, resulting in the free-flow speed for the road no longer being attainable (Deardoff, Wiesner & Fazio, 2011). This is partially limited by the design of the receiving environment, with the local roads being unable to handle this increase of vehicles during peak periods (Strömgren, 2011).

Figure 27 displays the volume of traffic heading into the Wellington CBD along the Smart Motorway. At this point, every vehicle that enters the city has to travel through this monitoring station, offering a complete picture of the traffic volumes entering Wellington city during a typical day.

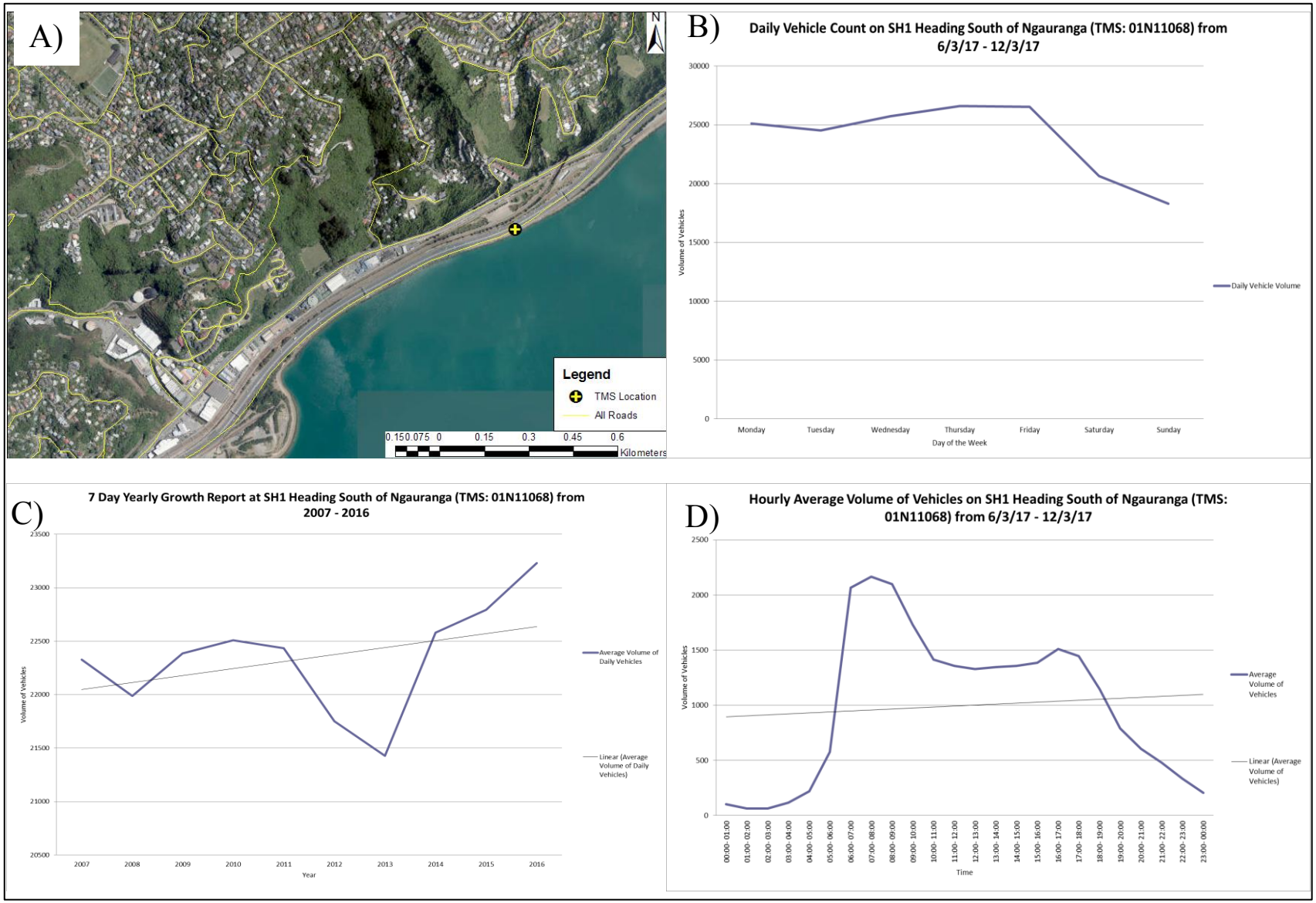


**Figure 27: Hourly, daily and yearly vehicle counts on SH1 heading south of Ngauranga.**

The TMS site displayed in Figure 27 (A) captures all of the vehicles heading south into Wellington City before they become dispersed amongst the various exits. In a trend similar to the previous figures, Figure 27 (B) displays the daily vehicle counts for a typical week, with the peak periods being from Monday to Friday and a reduction in vehicle volumes on the weekend. This demonstrates that the motorways experience the largest volumes of vehicles during the week. In Figure 27 (C), the seven-day yearly growth is displayed for the Wellington Smart Motorway. Apart from a substantial reduction of vehicle numbers in 2013, this section of the Wellington Smart Motorway has experienced consistent growth. An increase in the volume of vehicles using a section of motorway exceeds both the motorway's design and its capacity, resulting in increased congestion (Carey & Semmens, 2003; Strömgren, 2011). Figure 27 (D) then displays the hourly average vehicle volumes heading into Wellington City. The main peak occurs between 0600-0900, demonstrating the demand that exists along this section of the Wellington Smart Motorway during the morning commuter period. As a result, this volume of vehicles is the volume that the motorway should be designed to provide capacity for (Strömgren, 2011). However, to provide this type of capacity, there would be a need for an increase in the number of lanes, which, given the topographical constraints, is not possible.

The issues with the existing motorway network in Wellington are not limited to traffic heading south into Wellington in the morning. Key Informant Eight identified issues heading north out of Wellington during the evening peak commuter period. Key Informant Eight identified this issue by stating:

> *"So, at the moment we've got congestion in the northbound traffic, where the congestion point is at the northbound State Highway 2 on-ramp. Um, and we are getting queuing back from that location in the evenings. And what that is creating for us northbound is that you [are] actually getting a speed difference between the four lanes. We've sort of got a bit, State Highway One northbound we've got the four lanes from Aotea Quay through to Ngauranga, um, the two left-hand lanes travelling into the Ngauranga Gorge, and the two right-hand lanes travelling to Petone. Because we are sort of getting queuing back from the on-ramp, the State Highway 2 on-ramp. We are having to artificially lower the speed limit to manage the queue on state highway 2," KI8.*

Here, a convergence of roads that then head in different directions is causing issues for other connecting roads. Deardoff, Wiesner and Fazio (2011), found that a breakdown in free-flow speed occurs when a car's speed becomes influenced by the vehicle in front. This was expanded to include the influence that vehicles in other lanes may have on maintaining free-flow speed (Deardoff, Wiesner & Fazio, 2011). By applying these findings to the situation identified by Key Informant Eight, there will be a better understanding of the specific congestion issues. While Key Informant Eight identified this to be an issue, the other Key Informants briefly mentioned that they viewed traffic leaving Wellington City to be smooth flowing. This suggests that the Key Informants interviewed viewed traffic entering Wellington City to be more of an issue.

To attain a full understanding of the complex traffic interaction that is occurring at this motorway junction, three figures were constructed and analysed. Figure 28, Figure 29, and Figure 30 show the key locations on both State Highway One and Two where this vehicle interaction and separation in free-flow speeds is occurring. Displayed in Figure 28 is the volume of vehicles travelling north along State Highway One after clearing the Ngauranga interchange. Figure 29 shows the total volume of vehicles before they split into State Highway One and Two, offering an overall picture of the volume of vehicles. And Figure 30 shows the vehicles travelling north along State Highway Two, after they have passed the Ngauranga interchange.

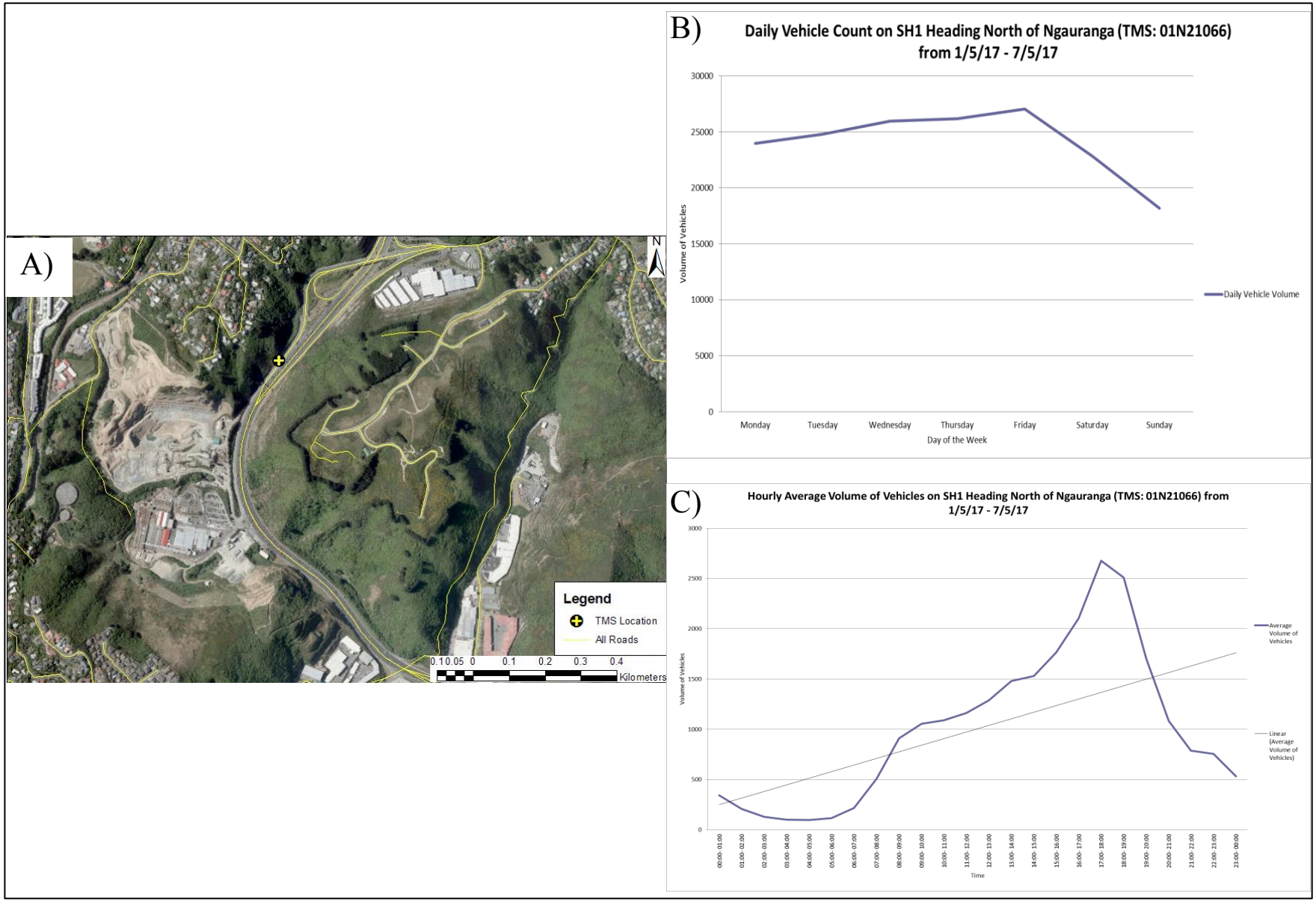


**Figure 28: Hourly and daily vehicle counts on SH1 heading north of Ngauranga.**

In Figure 28 (A) the TMS location is displayed. This measurement site is located north of the Ngauranga interchange on State Highway One. Whilst Figure 28 (B) displays a weekly vehicle volume trend that mirrors the previous findings, Figure 28 (C) displays a significant increase in vehicle volumes from 1600-1900. This demonstrates that there is a substantial volume of traffic commuting north along this motorway in the evening, away from Wellington. This peak in the volume of vehicles during this period can result in the breakdown of free-flow conditions, which can then result in congestion (Xu *et al.*, 2013). However, with the receiving environment here being a two-lane motorway, congestion is dispersed at a rapid rate (Lighthill & Whitham, 1955).

This is only one aspect of the issue as identified by Key Informant Eight. Figure 29 displays the junction between State Highway One and State Highway Two. This provides a picture of the traffic situation as it occurs for some of these affected lanes.

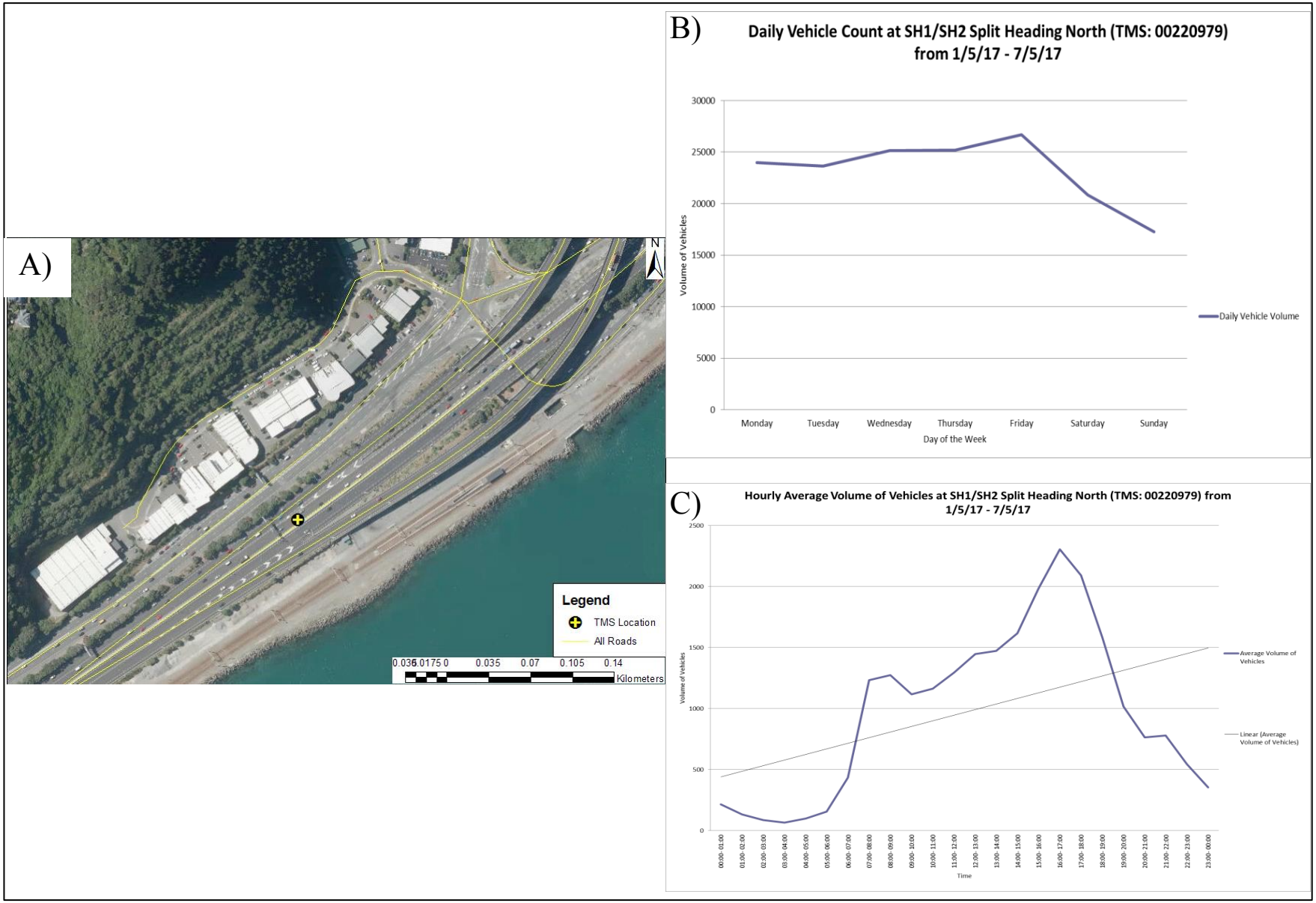


**Figure 29: Hourly and daily vehicle counts on SH1/SH2 split at Ngauranga.**

The TMS information presented in Figure 29 offers an insight into the traffic characteristics heading into the State Highway One/State Highway Two interchange. The location of the TMS site is displayed in Figure 29 (A). Figure 29 (B) displays the weekly vehicle volumes experienced through this monitoring site, and mirrors the previous figures by showing that the volume of vehicles is at its highest during the work week. This confirms the impact that commuting has on the capacity and flow of these motorway developments (Brueckner, 2000).

Figure 29 (C) is important for providing insight into where peak periods of traffic flow occur at this interchange. While a morning peak occurs between 0600-0800, the main peak of relevance to the claim by Key Informant Eight occurs between 1500-1800. This period is when the interchange experiences the largest volume of vehicles and is when the interchange's capacity is likely to be breached, resulting in congestion (Handy, 2005). What is apparent from Figure 29 is that congestion is always going to occur, unless there is an increase in motorway capacity. Figure 30 below offers an insight into the receiving environment of State Highway Two.

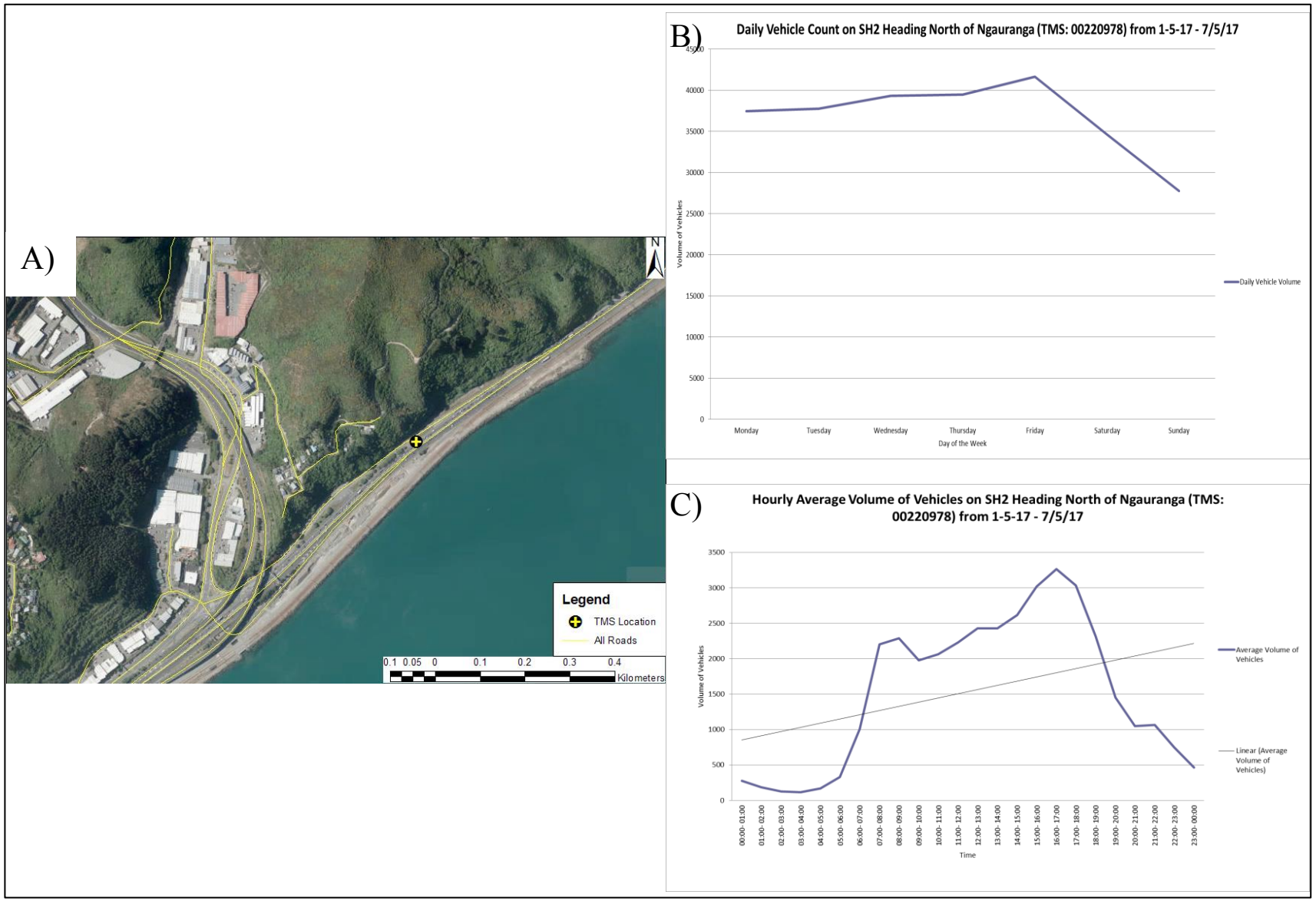


**Figure 30: Hourly and daily vehicle counts on SH2 north of Ngauranga.**

In Figure 30 (A) the TMS location is displayed north of the interchange on State Highway Two. Whilst Figure 30 (B) reflects the previous findings, Figure 30 (C) displays the impact that the evening commute has on the capacity of this section of the motorway. With none of the future motorway developments increasing the capacity north of this point on State Highway Two, this could continue to be an issue into the future. However, the creation of the Grenada to Petone Link Road could result in a decrease in the volume of traffic through this section of the motorway due to an increase in capacity elsewhere. This is similar to what Handy (2005) found, in that improvements to motorways elsewhere can result in a decrease in demand due to an increase in supply. The Petone to Grenada Link Road is discussed in more detail later in this chapter.

### *6.3.2 Technology and Compliance*

The development of the Wellington Smart Motorway has also caused an issue to arise regarding motorist compliance with the new technology. The benefits of smart technology, such as VSL, is only attainable if the motorists change their behaviour to comply with posted speed limits (Grumert, Ma & Tapani, 2015). Through the Key Informant interviews, it became apparent that compliance with these VSL was an issue experienced on the Smart Motorway. Key Informant Four questioned the manner in which the technology had been introduced to the motorway network, saying:

> *"Two things. First thing is, if you open up more capacity, you get more traffic. Second thing is, if you put in technology without accounting for human behaviour, you're never going to achieve the outcome," KI4.*

This demonstrates the impact that human behaviour can have on the efficacy of the motorway network. If the road user does not understand how the Smart Motorway works, then they are less likely to understand what impacts their actions may have on the wider network. Key Informant Four discussed this issue further, claiming:

> *"… And you can tell with a system like this that you're never going to get credibility. 'Cause what they are timing it for is a sudden stop at the end of the motorway, 2-3km on. That doesn't stack up in people's minds. They're not thinking about 3km on, no amount of education will change that," KI4.*

If the road user is not complying with the VSL, the real benefits of a reduction in congestion and reduced emissions are not attainable (Grumert & Tapani, 2012). As a result, the road user's understanding of the technology employed on the Smart Motorway is an issue with the existing motorway system.

Key Informant Eight elaborated on the compliance issues previously discussed. Overall, Key Informant Eight was happy with the level of compliance being observed on the Smart Motorway, saying that:

> *"Yeah, we're doing a bit of work on that at the moment to look at it. We are getting reasonable compliance within that sort of 10km/h threshold which is sort of what the police use for enforcement," KI8.*

What is unclear from the research and the literature is the impact that 10km/h could have on the overall effectiveness of the smart technologies employed. Whilst acknowledged as a limitation of the research here, the author of this thesis is of the opinion that 100% compliance is required to ensure a harmonised traffic flow and a reduction in congestion. This is because previous research into the effectiveness of tools, such as VSL, have all been carried out under the assumption that the simulated vehicles comply with the posted speed limit (Grumert & Tapani, 2012; Sun *et al.*, 2014). As a result, non-compliance with the VSL signs is adversely affecting the efficacy of the Wellington Smart Motorway.

Figure 31 displays the average speeds for the monitoring site on State Highway Two, north of the Ngauranga interchange (previously displayed in Figure 30). The NZTA TMS system is limited in the provision of average vehicle speeds data, meaning that this was the only graph constructed that was of relevance to this thesis research.

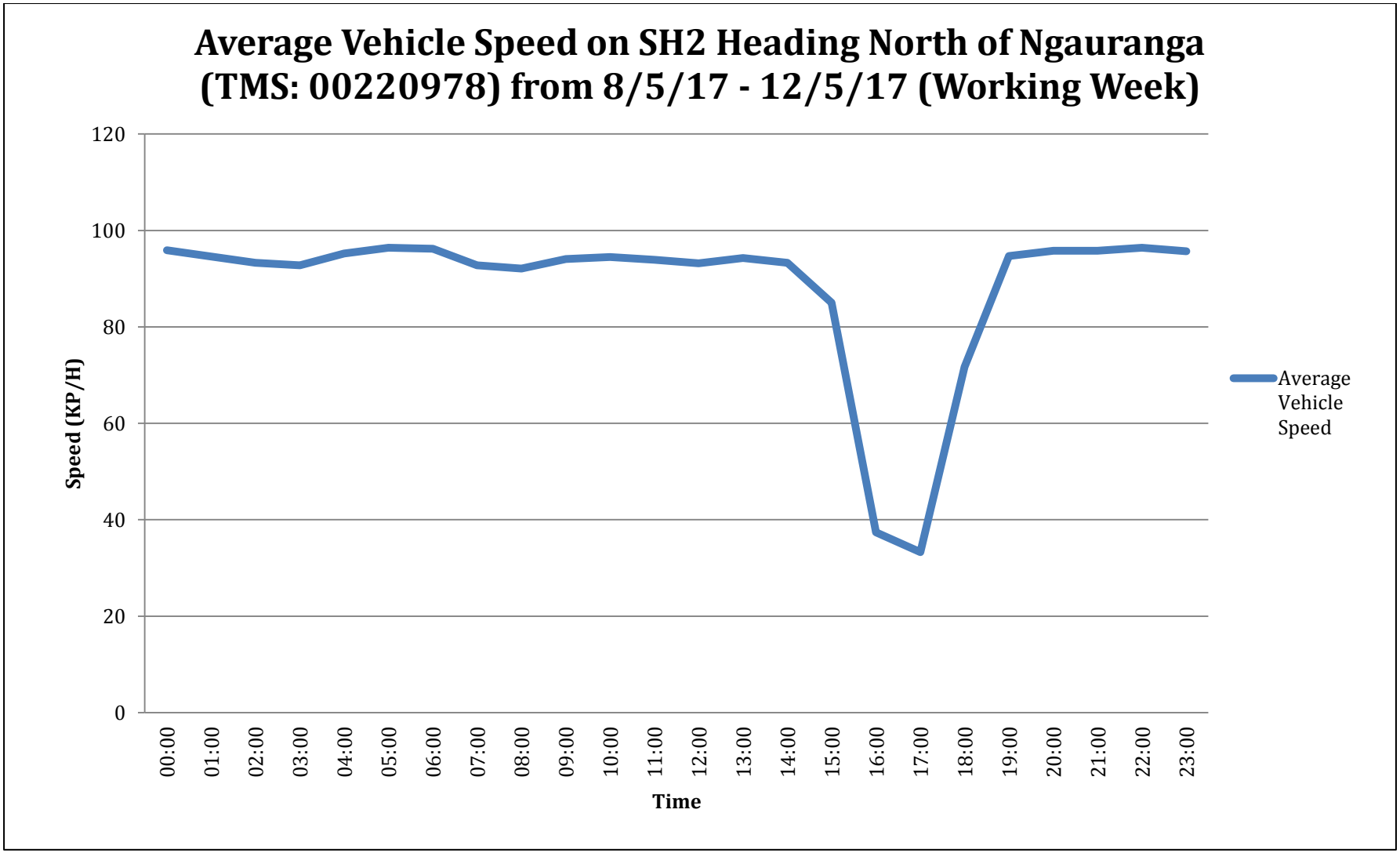


**Figure 31: Average vehicle speed on SH2 heading north of Ngauranga.**

Displayed in Figure 31 is the average vehicle speed heading north of the Ngauranga interchange on State Highway Two. In normal flow conditions, the average speed stays just below 100km/h, yet during the evening peak commuter period, this speed drops to below 40km/h. This demonstrates a breach of the motorway's capacity during this time period, and a breakdown in free-flow occurs (Xu *et al.*, 2013). The importance of this figure for technology, however, is that it demonstrates that the VSL is not capable of stopping a complete breakdown in free-flow once the capacity of the motorway is breached (Chiou, Huang & Lin, 2012). The literature on how VSL may be used to aide flow recovery is also limited.

However, outside of this peak period, the Smart Motorway is resulting in improved flow harmony through the utilisation of VSL, as shown in Figure 31. Until the volume of vehicles surpasses the capacity of the road, the average speed remains high, ensuring that more vehicles are travelling through a set point than if they were not informed by VSL (Morris *et al.*, 2011). Increasing the motorway's capacity at this point would ensure that a higher average speed is attainable during these peak periods, combined with VSL.

### *6.3.3 Safety*

Safety is an important aspect of any motorway development. The NZTA identified a series of safety goals for these motorway developments (KI8). In contrast to this, Key Informant Four raised some safety concerns with these motorway developments. Displayed in Figure 32 are the safety issues discussed by one of the Key Informants. The removal of the safety margin is also an issue identified by Key Informant Four, with the Wellington Smart Motorway lacking the traditional shoulder found on normal motorways.

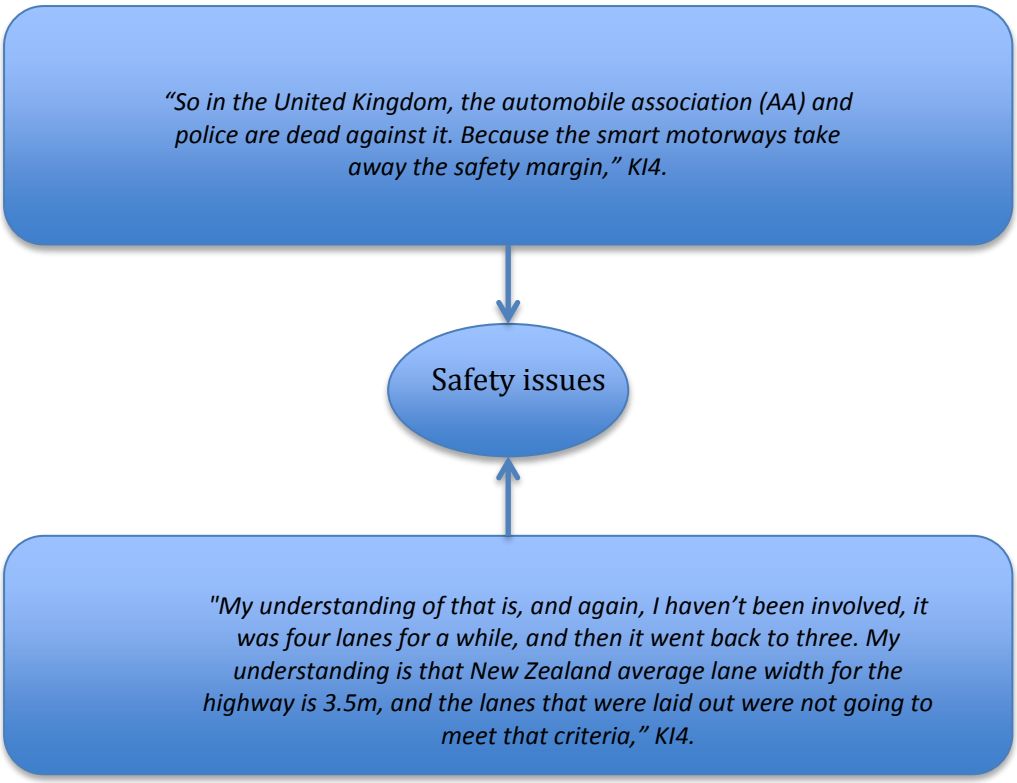


**Figure 32: Safety Issues identified by Key Informant Four.**

These issues identified by Key Informant Four are all concerned with the introduction and development of the Wellington Smart Motorway. However, Daniel and Maina (2011) found that new motorway developments result in a decrease in the probability of vehicle incidents. This means new motorway developments are less likely to be congested due to vehicle incident-related traffic (Dia & Rose, 1997). This results in improved efficacy.

Key Informant Eight identified where the NZTA had attempted to ensure the maintenance of safety levels while adding an additional lane and removing the motorway shoulder for the Wellington Smart Motorway. Safety was one of the main goals of the development, which was demonstrated by Key Informant Eight when he stated:

> *"Um, the other one was around, ultimately it was a sort of congestion management project, but we wanted to ensure that we were maintaining safety through the process. We certainly didn't want to see degradation in safety. Um, because there were some changes, some fairly significant changes being made particularly around the removal of the northbound shoulder to allow us to, um, implement the fourth northbound lane," KI8.*

This demonstrates that the NZTA had safety as a priority during the development of the Smart Motorway. Another way to assess the impact these motorway developments may have on safety is to analyse historical vehicle incident information. The number of vehicle incidents on the roads contained in the Wellington region has been decreasing, as shown in Figure 33.

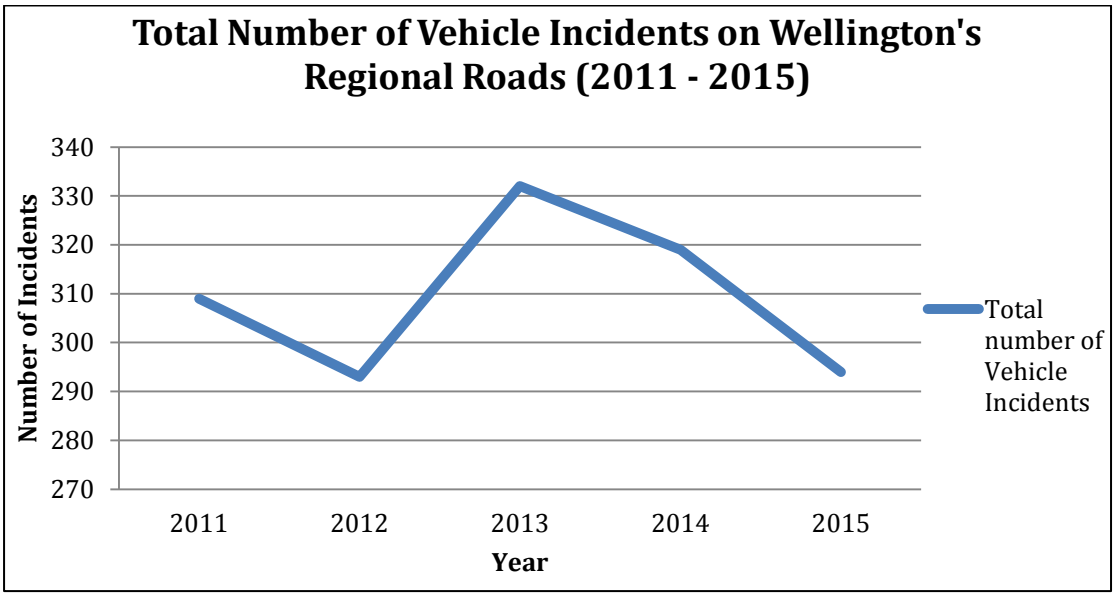


**Figure 33: Total number of vehicle incidents on Wellington's regional roads from 2011 to 2015.**

The decrease in vehicle incidents highlights the potential that motorway development in Wellington has to improve safety. Since 2013, the number of vehicle incidents has been steadily decreasing. This trend is also reflected in the volume of fatal crashes as shown in Figure 34. This graph is of a more extended time period, spanning from 1996 to 2015, providing a greater insight into the incident characteristics of the Wellington Region.

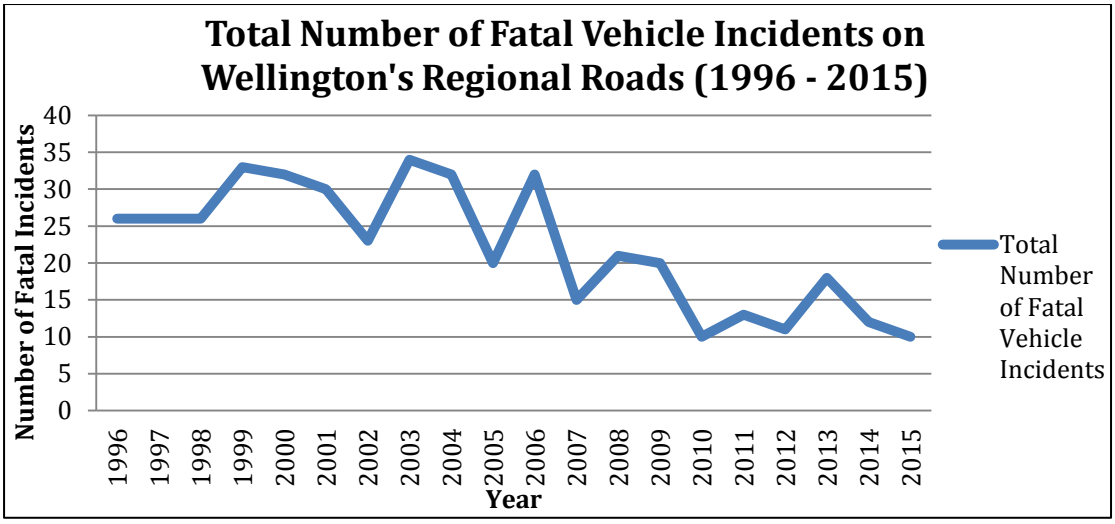


**Figure 34: Total number of fatal vehicle incidents on Wellington's regional roads from 1996 to 2015.**

The reduction of fatal accidents could be a result of motorway development. This relationship has previously been acknowledged and identified by international literature (Daniel & Maina, 2011). A comparison of crash statistics shows that of all fatal vehicle incidents in the Wellington Region, motorways are not responsible for a high volume. Figure 35 displays the road typology where fatal incidents have occurred. However, it is not possible with the information available to this thesis to accurately locate where these motorway incidents have occurred. This could have been utilised to identify areas of Wellington's motorways that were particularly vulnerable to vehicle incidents.

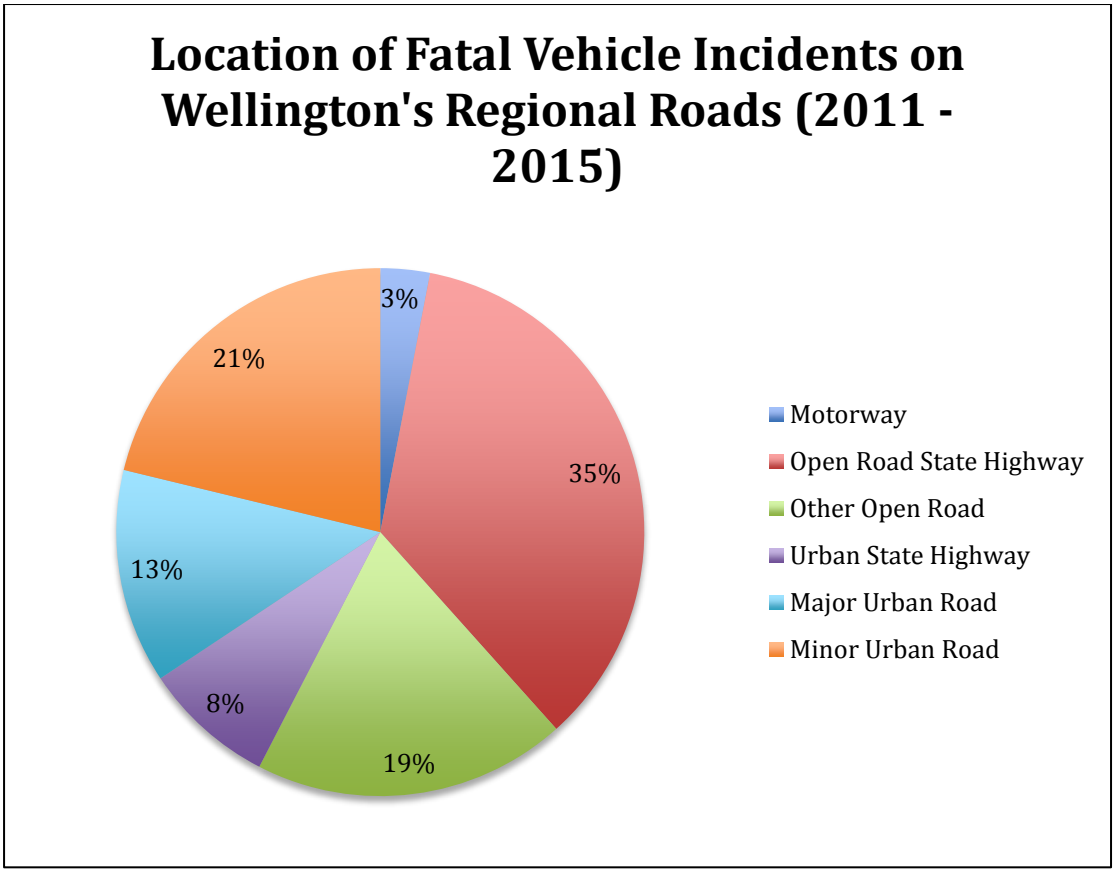


**Figure 35: Percentage of fatal accidents and their locations on Wellington's regional roads between 2011 and 2015.**

As displayed in Figure 35, motorways were only responsible for 3% of fatal accidents in the Wellington Region. However, this does not take into account the volume of non-fatal accidents that may have occurred on Wellington's motorways. What is apparent, however, is that motorway development does result in safer roads through decreasing the probability of vehicle incidents (Daniel & Maina, 2011). This then results in a decrease in vehicle incident related delays, resulting in an improvement to motorway efficacy (Cheu & Ritchie, 1995; Dia & Rose, 1997). Through these findings, then, the development of motorways in the Wellington Region has, and should, result in further safety improvements.

### *6.3.4 Road Layout*

With the current motorway network, Key Informants were quick to identify areas where the road layout was not adequate, or needed to be improved. Key Informant Seven discussed how the community of Kapiti was not happy with the manner in which the northern end of the new expressway terminated, saying:

*"There's a complaint in the community that it's a half interchange at the northern end, and they're looking at making it a full interchange probably with the next section, which wasn't on the plans until just recently," KI7.*

Figure 36 below displays where the termination of the expressway can be seen feeding into the original one-lane State Highway One. This is a receiving environment issue.

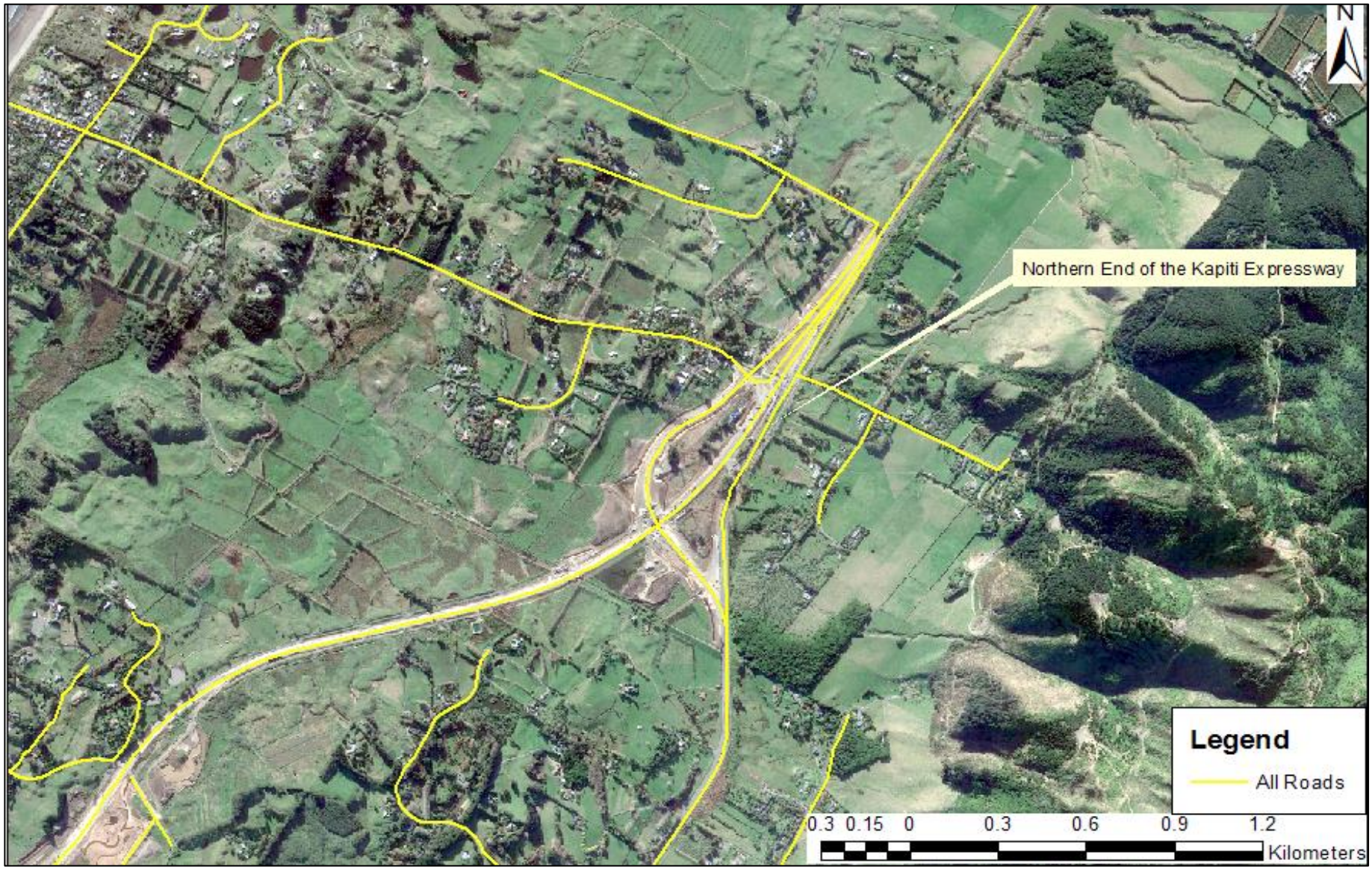


**Figure 36: Aerial image of the northern end of the Kapiti Expressway.**

Figure 36 displays how the Kapiti Expressway terminates into the existing single-lane State Highway. It was previously identified that the receiving environment could cause traffic issues and the manner in which the Expressway terminates is not going to result in a smooth vehicle transition (Frank *et al.*, 2008). Further, Key Informant One identified regionally specific issues in the Porirua area that, in their opinion, hindered the regular flow of traffic, stating:

*"There are no convenient connections from Eastern Porirua sort of to the South from Whitby, and to the East to the Hutt Valley from Waitangirua and Cannons Creek and stuff," KI1.*

Key Informant One also raised an issue with the form of motorways in general. They argued that consistency of roading quality is vital for enhancing user experience and that it is something that in New Zealand is not currently carried out to a high standard. They stated that:

*"I personally think it's quite hard for drivers if they don't really understand what to expect next and, you know, you're going through varying standards of roads and going from dual carriageways to separated carriageways to the two-way roads. You've got a whole lot of potential safety issues with people not realising that they've transferred from one type of road to another," KI1.*

As a result of this, the quality of New Zealand's existing roading network is an issue that needs attention in order to provide efficient and enjoyable roads. The motorways that this thesis is analysing contribute to a greater consistency of motorway development in the Wellington Region. They should also result in an increased capacity, which in turn results in improved free-flow speed, a reduction in congestion, and an improvement in safety (Daniel & Maina, 2011; Frank *et al.*, 2008). By then implementing these motorway developments, efficacy is improved.

## *6.4 Approaches to Further Improve Motorway Efficacy*

Key Informants discussed a number of potential solutions relating to Wellington's transport and congestion issues. These solutions ranged from alternative modes of transportation, to applying tolls and congestion charges, and completing some of the future RONS developments. Discussed next are the possible solutions to Wellington's road pressure issues.

### *6.4.1 Tolls and Congestion Charges*

One of the methods for minimising congestion and incentivising commuters to utilise public transportation or carpooling was to introduce a congestion charge. The discussion also addressed if Transmission Gully should be a Toll Road. Key informants had mixed opinions about whether this was a good option to help solve Wellington's motorway issues. Figure 37 below identifies some of the arguments about congestion charges in Wellington.


**Figure 37: Opposing views as to the validity of implementing a congestion charge in Wellington City.**

By implementing a congestion charge, it is possible that commuters would be incentivised to use public transportation. However, the Wellington City Council has previously looked at decreasing this private road user demand by creating a policy to limit the availability of commuter parks in Wellington City (KI3). While this policy was rolled out, it had limited success according to the Key Informant. This was due to a proliferation of private commuter car parks being available in the city (KI3).

One Key Informant also discussed the introduction of road tolling on Transmission Gully. At this stage, the NZTA is uncertain whether Transmission Gully will be a toll road in an attempt to retain some of the development costs or to assist with ongoing maintenance. The benefit of toll roads is the principle of a user-pay system, where fewer people may utilise the road because of the cost (Federal Highway Administration, 2017). While this would result in fewer vehicles on Transmission Gully, it would not reduce the volume of vehicles

arriving into the Wellington CBD, as alternative routes could be utilised by those not willing to pay.

However, under New Zealand law, a road cannot be turned into a toll road; it must be made a toll road before it opens (KI1). The potential to toll Transmission Gully was discussed by Key Informant One, who stated:

> *"But there's quite a process around public consultation and willingness to pay, you know, a toll. Um, so that's still being considered, um, and I … there needs to be a decision made relatively soon in terms of getting all of the infrastructure in place by the time the road opens, because the way the legislation currently is, you can't toll existing roads, you can only toll new roads. This means you'd have the tolls in place before the road opens," KI1.*

The above quote highlights some of the difficulties of implementing Transmission Gully as a toll road. Further, there was no discussion from Key Informants around how making Transmission Gully as a toll road could assist with controlling demand and congestion. The determination of this is difficult due to the literature limitations on the subject.

### *6.4.2 Future Road Developments*

Another solution to Wellington's traffic issues identified by a number of Key Informants was around future road developments. Whilst this has previously been discussed, it is worth a mention again here. Key Informant One did discuss that while future motorway developments may be part of the solution, they are not the solution by themselves. This was noted when Key Informant One said:

> *"My personal view is I don't think you can just build your way out of congestion, you can't just build more motorways forever 'cause you end up being LA, which is still congested but it's got 15 lane motorways. And I think having said that, I don't think, my personal view is, I don't think you can get away without having decent roading infrastructure as part of the solution. I don't think you can go directly to 'we will just have a good Public Transport network and not have decent, you know, roads' because clearly there's always going to be a high demand for people, both individual families or whatever, but also for freight movements to use the road network as well as rail. Trying to get an integrated solution really between modes is the key," KI1.*

Key Informant One identifies the need for an integrated transportation solution to Wellington's congestion. However, planners have previously focused on the provision of public transportation, which alone is not enough due to the

popularity of private motor vehicles (Gunder, 2002). Gunder (2002) goes as far as claiming that this bias of planners to favour public transportation has resulted in motorway developments playing catch-up to meet the demand of private vehicle use. An integrated approach may ensure that private vehicle numbers do not exceed the new motorway development's capacity.

The RONS developments are a potential solution for improving motorway capacity, easing congestion and improving trip time reliability in the Wellington Region (KI1, KI8). It is also worth noting that the RONS developments were always going to be packages, which according to Key Informant One means that people should not assume that they have not solved the Wellington Region's traffic issues until all of the programs have been delivered (KI8). These RONS projects, specifically the ones in Wellington City, are likely to significantly alter the receiving environment for the flows of traffic and could result in reduced congestion (KI4). So it is important to acknowledge these future road developments as a possible solution to the Wellington Region's traffic issues.

### *6.4.3 Alternative modes of transportation*

The majority of Key Informants were of the opinion that part of the solution to the Wellington Region's traffic issues involved the exploration of other modes of transportation. In doing this, the dependence that Wellington's regional residents have on private motor vehicles may be thus minimised (KI3). Already, significant investment has been made into the existing rail network in order to make this a more attractive and reliable option. This has taken the form of double-tracking as far as Waikanae, new railway stations, and new rail cars (KI1). However, one Key Informant argued that the solution does not lie with one mode, but a multimodal approach is needed. Key Informant Two emphasised this point, noting:

> *"Now, basically we want all those four modes to interact together, so we want them to be able to coexist. But we mustn't forget that underpinning every society is a sound economy, and that's all about productivity, and productivity recognising population growth, etc.," KI2.*

By achieving a multimodal system, the productivity of the Wellington CBD would be improved (KI2). Wellington currently has the highest per capita public transportation usage rate of any city in New Zealand (Early, Howden-Chapman & Russell, 2015). Key Informant Five argued that the public transportation network in Wellington was efficient, saying:

> *"Wellington itself is incredibly well serviced by bus. We have fairly good patronage of our train line, even though it only services parts of the north. But our buses are quite good. And we have a lot of people that walk, and there is an increasing amount of people who are cycling and that sort of stuff. So absolutely, you can't build a transport network that is focused on one mode. My personal preference would be to always prioritise other modes. So whether that's bus priority or rapid transit or whatever else gives the advantage to those mass transit or alternative transport, so cycling or walking. That's where we should prioritise the benefits of the transport network. And the cars really just fill in the gaps," KI5.*

This quote demonstrated the bias Key Informant Five had towards public and active transportation. Whilst many of the Key Informants would like to see an increase in public and active transport, the majority acknowledged that motorways are a necessary aspect of urban infrastructure (KI1, KI2, KI3, KI6, KI7, KI8). This acceptance of motorways as an aspect of urban infrastructure was captured by Key Informant Seven, who noted:

> *"Yeah, well, that's the provide and then they fill it out kind of thing. I suspect that there will never be enough if we just keep doing roading. But I hope that when they have completed these that they really take a serious look at an improvement to the public transport system," KI7.*

Key Informants noted the necessity of improving public transportation in the Wellington Region in order to make it a viable alternative. However, the quality of the public transportation system is already high, meaning that there is a good base to make improvements from (Early, Howden-Chapman & Russell, 2015). Only Key Informant Two elaborated on what the public transportation network should be providing to commuters. Key Informant Two claimed:

> *"Public transportation, in my opinion, is incredibly important, and I'm much more supportive of Public Transport in Wellington. My fundamental thing is that I want daily commuters to use Public transport if at all possible. In other words, if they're just coming to the city and going home again. This means we've got to make public transport absolutely attractive. Now, what does that mean? We've got to make it*

> *accessible, we've got to make it, um, reliable, we've got to make it, you know, attainable or cost-effective for the person, it can't be too expensive, etc.," KI2.*

This vision for a more efficient public transportation network in Wellington could result in a reduction of roading pressure due to individuals not driving into the Wellington CBD. Key Informants also identified frequency, dedicated lanes, and park and ride facilities as being a response that could ease roading pressure. The integration of park and ride facilities with public transportation is already occurring in Europe (Dijk & Montalvo, 2011). This approach is being used at some train stations in the Wellington region already (Greater Wellington Regional Council, 2011).

Whilst Key Informant Five went into detail about the need for an increase in the frequency of trains and buses, Key Informant Three discussed the advantages of having dedicated public transportation lanes on the motorway (KI3, KI5). Key Informant Three discussed this, saying:

> *"Public Transportation with dedicated lanes on the motorway. That would be quite something, just thinking about, um, you know, even in the northern suburbs where you've got all of the bus networks that rely on the motorway to get people through, if they had a dedicated lane for, I don't know, between 7:30 and 9:00 in the morning and 4:30 and 6:00 in the afternoon. I mean, that in itself might be enough to get people out of their cars and on the PT network. And then make the whole network work better for everybody else," KI3.*

Through the implementation of some of these alternative solutions to motorway development, it is possible that Wellington's congestion issues could be mitigated. However, whilst the NZTA can be seen as only wanting to promote motorway development, Key Informant Eight highlighted the vision for road development in the Wellington Region by saying:

> *"It was never just about roading improvements, it was also about what we could do in a public transport space and the work that Greater Wellington have done around the double-tracking through to Kapiti. And also, I guess, what we could do around just, yeah, not just mode sharing but also park and ride opportunities, demand management, all those sorts of things. So there's a number of tools that are available to the agency, and the smart motorway was one of those. With a view to try and deliver an overall package," KI8.*

This highlights that Wellington may require a multimodal solution to its congestion issues. Motorway development, whilst a part of the answer, is not going to minimise Wellington's traffic issues by itself. The NZTA, as a government agency, is trying to implement and deliver this overall package for Wellington's roads.

## 6.5 Future Motorway Developments

As part of the RONS projects, there is an array of future road developments for the Wellington Region. These developments are set to improve the network's resilience, trip time reliability, and capacity. However, some of the Key Informants interviewed raised issues with these developments due to the volume of cars that they deliver to the Wellington CBD. This is shown below in Figure 38.

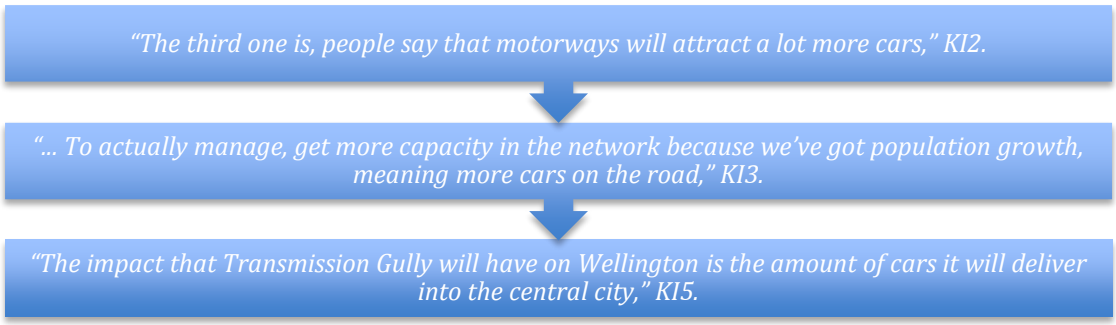


**Figure 38: Opinions about increasing volumes of cars due to future road developments.**

In fact, many motorway developments occur as a result of increasing volumes of private motor vehicles; they then aim to reduce the impacts of these vehicles (Featherstone, Thrift & Urry, 2005). Whilst the increasing volume of cars can be cast in a negative light, it is also worth considering how some of the future motorway developments could handle this increasing number of vehicles. This section discusses some of the future RONS developments and then connector roads that may be implemented to help improve the Wellington Region's motorway issues.

### *6.5.1 Roads of National Significance*

The RONS have been discussed previously in this chapter in the context of existing road developments. Yet they also need to be acknowledged in how they could impact on future road developments. With Transmission Gully currently under construction, this can be considered one of the significant future road developments currently being built. However, other developments currently under construction include the Peka Peka to Ōtaki leg of the Kapiti Expressway, and a number of other roads linked to these are in their planning stages. Key Informant One elaborated on some of these developments, identifying that:

> *"I mean, Transmission Gully picks up sort of at the southern end of MacKays to Peka Peka. And at the northern end of that, the next section is Peka Peka to Ōtaki, and that started construction in the last few months. And so that will take the sort of corridor all the way up to Ōtaki. And then there's another section beyond that which is still being investigated, which is sort of from north of Ōtaki to north of Levin," KI1.*

Upon completion of the Wellington Motorway as far as Levin, the network is closer to realising its original vision of the 1950s, which was the Wellington to Foxton motorway (KI4). With this having been the official title of the Wellington motorway, it emphasises the vision that the original planners had for this route (Dodson & Mees, 2003). Key Informant Seven elaborated on how some of the future RONS developments are going to fit together like a jigsaw, and upon completion ensure the realisation of the NZTA's network vision. Key Informant Seven discussed this by saying:

> *"We have a real problem with our one highway blocking up quite badly in various directions. And it won't be resolved by some of the projects they have done. So Transmission Gully and MacKays to Peka Peka don't resolve that. But when you add in the Petone to Grenada Link, Peka Peka to Ōtaki, and Ōtaki to Levin and then the Basin project where, not sure exactly what they are going to do with that. But then the city link across the Basin if they're going to do that. When you link all of those up, and you get the RONS project, then you start to see some resilience coming into the region. And we think that once there is that kind of … that reliability with the trains as a secondary reliability, then we should sort of remain competitive," KI7.*

Whilst some of the projects discussed above are in the construction stage, others still need to be planned and attain a resource consent through the board of enquiry process (KI2). It is also worth noting here that the Petone to Grenada

Link Road is not part of the RONS Wellington Northern Corridor Project, and is very much in the planning stage at this moment (KI8).

Key Informant One discussed the impact that completing these future RONS projects should have on road users during the development stage. In their discussion, Key Informant One highlighted both the positives and negatives of this development approach, as shown in Figure 39 below.

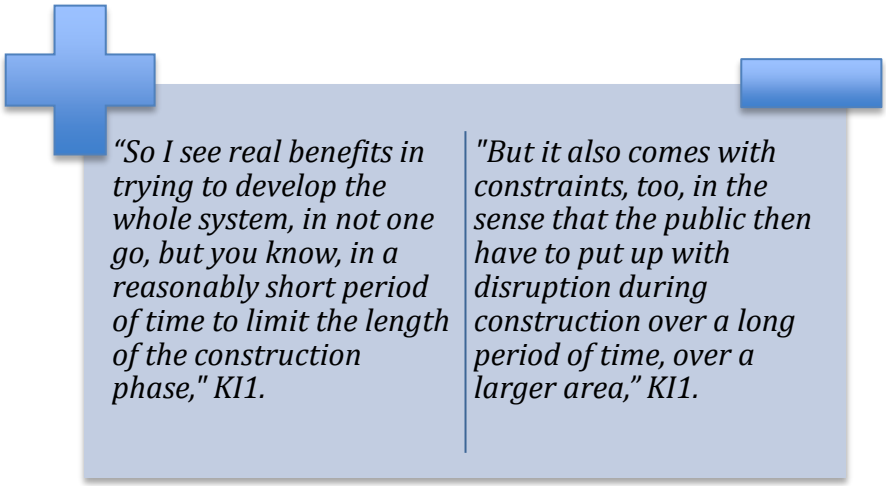


**Figure 39: Positives and negatives of undertaking multiple construction projects at the same time.**

Whilst Figure 39 highlights the potential disruption that road users could experience due to the RONS developments, it presents the point that in the long run, the road users of the Wellington Region should be better off enduring a shorter time period with more construction disruption. Key Informant Three highlighted the need for some of these future RONS developments, identifying the single lane Terrace Tunnel as posing issues. Key Informant Three noted:

> *"If you're already experiencing that, does that matter? Or, the question is, will that bottleneck actually stretch back further up the motorway? I don't know enough about how that will work. Um, which then suggests what are they doing and are they planning to do anything to increase capacity at the Terrace Tunnel? It then goes back to being two lanes through the middle of town again," KI3.*

With this issue being identified by Key Informant Three, one of the future RONS developments is looking into duplicating the Terrace Tunnel. The NZTA suspended this while they assessed what to do after the High Court decision ruling against consent for the Basin Reserve Flyover (New Zealand Transport

Agency, 2017). This ruling is ultimately working against implementing the vision and full benefits of the RONS Wellington Northern Corridor project. This is due to the limitations that currently exist with Wellington as a receiving environment.

### *6.5.2 Road Connections*

The RONS developments are not the only future road projects for the region. With the RONS developments, a new series of connector roads need to be constructed to link these new motorways to existing settlements, towns and cities. For the Kapiti Expressway, this was possible by establishing some interchanges in key communities. The number of interchanges was, however, limited in order to ensure that locals were not using the expressway like a local road, adding more vehicles to it, limiting capacity (KI1). For Transmission Gully, the remoteness of the route has created difficulties when attempting to create these routes. However, the NZTA was fortunate enough to have the opportunity with Transmission Gully to utilise some unfinished arterial routes. This was identified by Key Informant One, who explained:

> *"There are a couple of link roads into Whitby, and another one to Waitangirua, so that should help. There's always sort of been, if you like, um, an unfinished arterial road network in eastern Porirua, so those connector roads actually sort of help to provide connections that currently don't really exist," KI1.*

Upon the completion of Transmission Gully, these routes will link into existing communities, enabling people to use the new road network for their driving needs efficiently. Improved accessibility was a benefit of motorway development identified by Linneker and Spence (1996). Improved accessibility is another benefit of these motorway developments in the Wellington Region.

The road connections are shown in Figure 40, branching off the main Transmission Gully route and heading into some of Porirua's Suburbs. These roads result in an improvement of accessibility for those living in those areas and the surrounding areas.

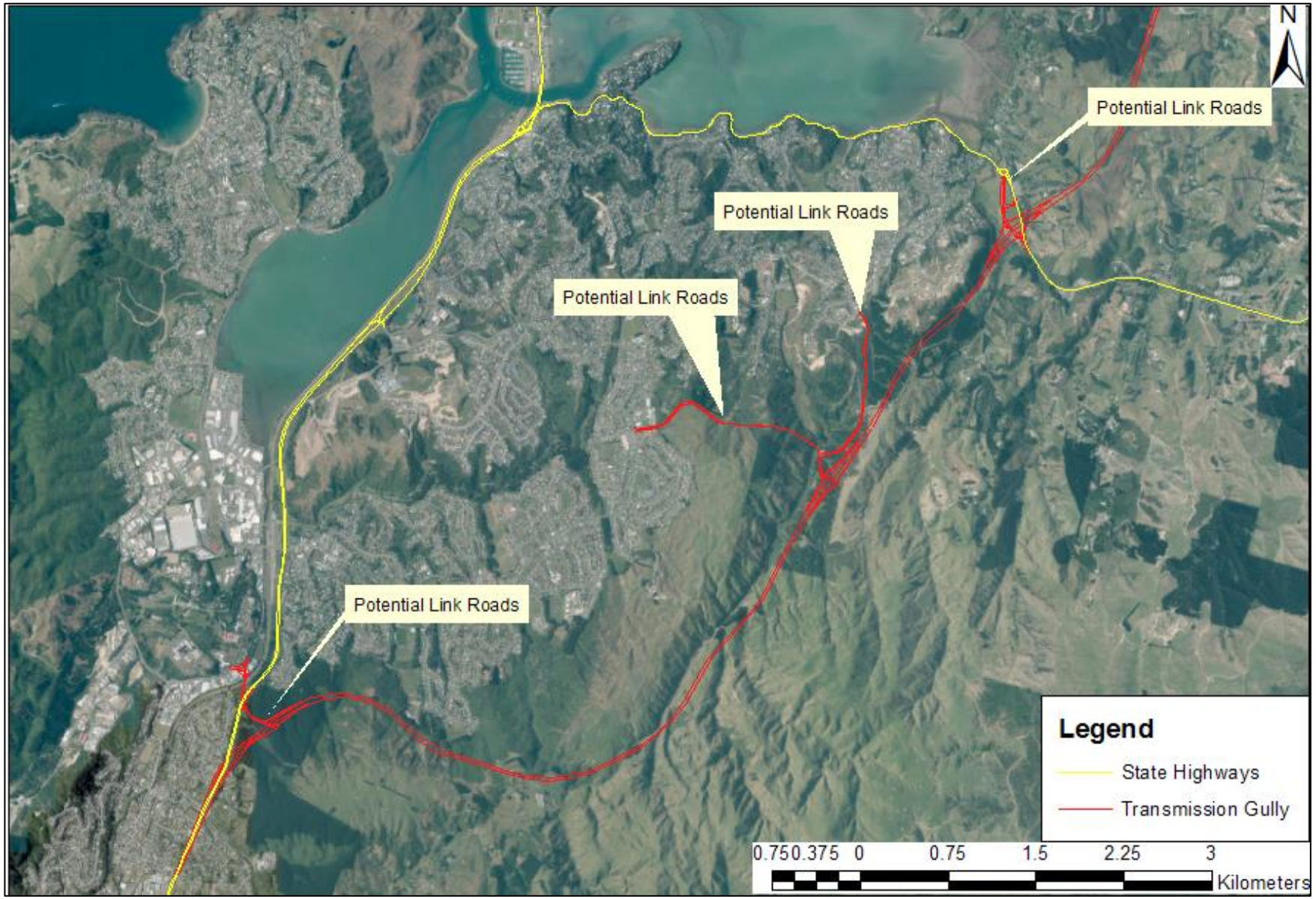


**Figure 40: Link Roads joining Transmission Gully and Porirua.**

The other main link road identified was the potential Grenada to Petone Link Road. In Figure 41 below, the potential route is shown. This route is a draft at this stage, with the NZTA not having confirmed the actual route for this road, nor whether it will go ahead.

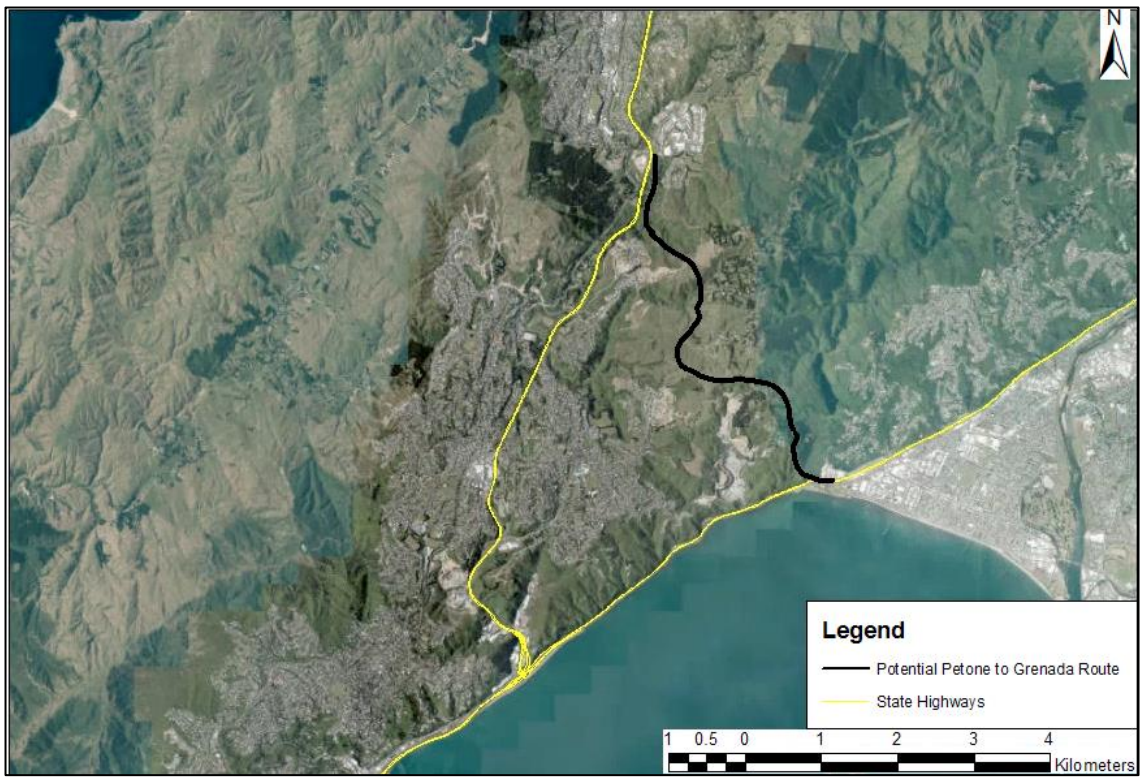


**Figure 41: The potential route of the Petone to Grenada Link Road.**

Key Informants One and Eight both identified the Petone to Grenada Link Road as having the potential to alleviate some roading pressure placed on the existing network at Ngauranga. This would be achieved by creating more capacity for vehicles on this road, meaning that free-flow speed would be more consistent on State Highway Two north of Ngauranga. Key Informant One went into some significant detail about the potential advantages of developing this link road, stating that:

> *"One of the other projects being considered is the Petone to Grenada link, but it doesn't necessarily finish at Grenada, it's still being planned and still being considered as to what exactly the route will be, and what exactly the configuration will be. But, fundamentally, what that will provide is another east-west connection between the Hutt Valley and the Porirua/Tawa basin. And by providing that link sort of near or beyond the southern end of Transmission Gully, uh, that will allow … is that you improve the connection to and from the north with Transmission Gully and the Kapiti Expressway, and then that east–west connection takes, should take, a lot*

> *of the demand that is actually currently going down State Highway One as far as Ngauranga Gorge and up State Highway Two from Ngauranga to Petone. And so, if you like, it sorts out the third side of that triangle. So it would take quite a lot of the demand off the section of state highway south of Transmission Gully, so that then provides additional, it doesn't provide additional capacity, but it takes away quite a bit of the existing demand, so it buys you more time if you like, or better future proofing," KI1.*

Key Informant Eight also agreed that the Petone to Grenada route has the potential to take away some of the road user demand currently being experienced in the Ngauranga Gorge. Whilst the route won't improve the capacity of the motorways running into Wellington City, it could remove cars that use the Ngauranga Gorge to then transfer onto State Highway Two in order to head north on that route. This route also has the potential to contribute to new development in currently inaccessible areas (KI5).

## *6.6 Conclusion*

In conclusion, it is clear that the development of Wellington's motorways through large-scale motorway development is improving the efficacy of the region's motorways. Improved efficacy occurs through increasing the capacity of these motorways, which ensures that it is easier for vehicles to maintain free-flow speeds. Whilst some areas are still facing traffic issues, these have been attributed to issues with the receiving environment or because they are awaiting the development of other road projects. Whilst motorway development may present a method to minimise the effects of congestion, the Key Informants emphasised an integrated transportation approach. However, as a method for addressing the impacts of congestion and increasing private vehicle use, this chapter has found that large-scale motorway development is an efficient way to address and manage these issues. The next chapter, Chapter Seven, summarises the findings of this thesis and presents concluding remarks.

# 7 - Conclusion

## *7.1 Introduction*

Internationally influenced by freeway development in the United States of America, large-scale motorway development has occurred in New Zealand without consideration afforded to the local environment (Gunder, 2002; Gunn, 2011). The historic driver of large-scale motorway development was focused on addressing rising private car usage that was resulting in widespread congestion. While literature exists on large-scale motorway development, it is important to accurately represent the efficacy of large-scale motorway development as a tool for addressing these impacts. The deployment of new tools, such as smart technologies, also improves efficacy.

This thesis addressed a gap in the literature regarding the use of large-scale motorway development as a tool to address the effects and impacts of increased private vehicle usage. Previous studies focused on individual aspects of large-scale motorway development, so the research addressed this by providing a comprehensive overview of a multitude of variables and elements of large-scale motorway development. The research aimed to determine the value of large-scale motorway development within our urban areas. In order to address this aim, the thesis research had three key research objectives. They were:

1. To investigate current international approaches for managing the effects and impacts of increased vehicle usage through large-scale motorway development.
2. To establish and identify the main effects of large-scale motorway development in New Zealand.
3. To evaluate and assess the efficacy of large-scale motorway development in the case study of Wellington, New Zealand.

To address Research Objective One, the researcher undertook an extensive literature review, and Chapter Two discussed these findings. To address

Research Objective Two, Key Informant interviews were conducted and analysed. The findings of this research were displayed and discussed in Chapter Five. Research Objective Three was the final objective addressed by this thesis. To assess the efficacy of large-scale motorway development, the research utilised a mixed methodology with both qualitative and quantitative data analysis. A discussion of this final research objective occurred in Chapter Six.

This concluding chapter discusses the findings of Chapter Five that addressed the effects of large-scale motorway development. Following this, there is an analysis of the efficacy of large-scale motorway development in Chapter Six. Next, some recommendations, which arose through the research process, are discussed. Finally, this chapter discusses the significance of the thesis research, how it contributes to international literature, and any opportunities for further research. The chapter concludes with final remarks.

## *7.2 The Effects of Large-Scale Motorway Development*

Research Objective Two was focused on the effects of large-scale motorway development. Large-scale motorway development can have a range of effects, both positive and negative. These effects could range from physical effects, such as the influence on the surrounding environment and urban form, through to effects on the formation and application of plans and policies. Motorway development was found to impact on urban growth and development through influencing settlement patterns and improving accessibility to previously inaccessible locations. The literature emphasised the improvement to accessibility due to motorway development (Grimes & Liang, 2010). Accessibility, in turn, was found to influence where growth would occur.

Large-scale motorway development was also found to have a range of economic impacts. Economic impacts were focussed on business relocation, commercial road users, and land values. As a result of large-scale motorway development, some Key Informants believed that businesses would relocate. The literature suggested businesses relocate due to transit-oriented development as was observed overseas because of motorway development (Catalán, Saurí & Serra, 2008). Further, through improving accessibility, it was found that large-

scale motorway development would affect land values. Often this is through an increase in land value as was observed in Auckland (Gunder, 2002).

This chapter then found that large-scale motorway development could affect the creation and implementation of plans and policies. The impact on plans and policies was due to how development could influence settlement patterns that plans had to address. This research also found that motorway development was positively affecting the implementation of the new NPS on Urban Development Capacity. This was because motorway development was making previously inaccessible areas accessible, assisting territorial authorities in providing new areas for future growth. Finally, this chapter acknowledged the positive effect motorway development could have on improving resilience and the negative effect it can have on existing communities. However, in the case study of Wellington, it was found that Transmission Gully would mitigate these adverse effects, and the proposed upgrade of the existing coastal motorway would have had significant adverse effects.

## *7.3 The Efficacy of Large-Scale Motorway Development*

Chapter Six of this thesis discussed the efficacy of large-scale motorway development. Understanding the efficacy of these developments was vital as it addressed Research Objective Three. The research analysed a variety of factors to understand the efficacy of large-scale motorway development within the Wellington Region case study. First, the research provided insight into the existing motorway network in Wellington. This found that the current motorway development in Wellington was meeting its goals of reducing congestion and improving trip time reliability. The research also found that there had been careful consideration afforded to a range of alternative options.

It was then possible to assess the efficacy of current large-scale motorway developments through analysing data provided by the NZTA. Data provided an accurate insight into the flow characteristics of these motorways in Wellington. The research found that improvements to both traffic flow and congestion occurred through increasing capacity. The findings were similar to the findings in international literature that acknowledged this link (Daniel & Maina, 2011;

Frank *et al.*, 2008). Large-scale motorway development in Wellington was also found to have improved road safety. Issues were identified with the Wellington motorway developments when it came to compliance with speed laws and road layout. However, these issues were already being addressed by the NZTA.

Discussion around how the efficacy of future motorway developments could be improved followed. Options discussed included a user-pay system focused on toll roads and congestion charges, alternative modes of transportation, and future motorway developments in the Wellington Region. The identification of a user-pay system occurred because of its ability to discourage private vehicle use. Consequently, fewer vehicles would be on the roads, increasing the ability for a motorway to maintain its free-flow speed through periods of peak congestion. This thesis did conclude that there needed to be future research into the role that alternative modes of transportation could play. This would again free up the motorway's capacity. Finally, this thesis discussed the impact that future motorways may have on improving the efficacy of Wellington's motorway network. Routes such as the Petone to Grenada Link Road were found to have the potential to have significant impacts on the motorway's efficacy.

## *7.4 Recommendations*

The research process revealed some clear areas of interest and room for recommendations. Two recommendations were developed through conducting Key Informant interviews. These recommendations are of special interest to key stakeholders such as the territorial authorities, NZTA, and MoT. Discussed below are the two recommendations.

1. The development of a high-quality Wellington Regional Spatial Plan.

One of the Key Informants suggested the development of a high-quality spatial plan. A spatial plan would ensure that the development of future roads and motorways within the Wellington Region would service areas that would benefit all of the impacted territorial authorities. Further, this would assist territorial authorities in identifying future areas for growth and development,

thus assisting them in meeting their responsibilities under the NPS for Urban Development Capacity.

2. Exploration of alternative modes of transportation for the Wellington Region.

The other recommendation is concerned with exploring the viability of alternative modes of transportation. This recommendation is encouraging more extensive public transportation usage, which would increase the capacity of the existing motorways in the Wellington Region. Public transportation improvements could involve bus-only lanes on the motorway, increased park and ride facilities, and increased train capacity. Wellington already has the highest per capita public transportation use in New Zealand, which means that its citizens are prepared to use alternative modes of transportation (Early, Howden-Chapman & Russell, 2015). Increased capacity on Wellington's motorways occurs due to less private car use, which improves the efficacy of the region's motorways.

The development of these recommendations occurred throughout the research process. The recommendations are not intended to be an exhaustive list; instead, they were developed from ideas suggested by the Key Informants. However, the exploration and implementation of these recommendations could result in a higher quality of motorway development and transportation planning occurring in the Wellington Region.

## *7.5 Significance of Research*

Criticism of large-scale motorway development arises from the perceived adverse effects. Yet, the recommendations discussed above are of special interest to the key stakeholders. This thesis has concluded that motorway development has the potential to minimise the effects of congestion and that it is an efficient tool for managing increasing private vehicle use. This research could be of use to all of the territorial authorities in the Wellington Region. The applicability to territorial authorities is because they are all affected by large-scale motorway development. Further, this research could be utilised by the NZTA to justify the

benefits of large-scale motorway development. In particular, this is relevant for the NZTA in the future application and development of large-scale motorways, particularly as part of future RONS developments in New Zealand around major urban centres.

The methodology employed by this thesis was a combination of methods utilised in previous research. Combined with data from the NZTA TMS, the methodology offered an insight into the complex research objectives addressed by this thesis. Further, by using Wellington as a case study, research now exists surrounding how the Wellington Region may be affected by future large-scale motorway development. This approach could be utilised in other urban centres and cities of New Zealand if a similar study was to be conducted.

## *7.6 Opportunities for Further Research*

This thesis identified gaps in the existing literature. In particular, studies focusing on the real-life application of smart technologies on motorways. Various studies have focused on the application of VSL and computer control systems such as METANET. However, these studies were often carried out through computer simulations, meaning that their validity to real-life situations is limited.

There was also a lack of recognition in previous studies regarding the impact that large-scale motorway development may have on motorway efficacy. Individual aspects, such as research on increasing flow capacity, have been widely studied. However, there is no comprehensive study on using large-scale motorway development to improve efficacy. This thesis offers the first comprehensive study of the effects and efficacy of large-scale motorway development.

This research recommends that future research looks further into the efficacy of large-scale motorway development for addressing increasing road user pressure and congestion. Future research could also validate or refute the case study of Wellington. By doing this, the case study will either be validated or disputed as specific features in Wellington, such as topographical constraints,

may impact on the efficacy of large-scale motorway development. This would develop further knowledge in transportation planning.

## *7.7 Final Remarks*

Wellington has provided a unique case study for analysing the value of large-scale motorway development in New Zealand. With an increasing population, especially in urban centres, New Zealand is experiencing significant population growth. Whilst this thesis acknowledged that there are adverse effects associated with large-scale motorway development, the positive effects of motorway development outweighed the negative effects. Further, large-scale motorway development was found to be an efficient tool for managing and mitigating the effects of increased road users and the associated effects, such as congestion. Often, this was achieved through an increase in the motorway's capacity, yet in this case study the introduction of smart technologies was also found to be beneficial. The research thus highlights and confirms the value of large-scale motorway development in New Zealand. This is because the research found that large-scale motorway development is an effective tool for improving motorway efficacy and for managing the effects and impacts of increased vehicle usage.

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# Appendices

## *Appendix A - Research Information Sheet*

Information Sheet for research participants.

***SMART MOTORWAY TECHNOLOGY AND LARGE-SCALE MOTORWAY DEVELOPMENT IN WELLINGTON.***
**INFORMATION SHEET FOR PARTICIPANTS**

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

**What is the Aim of the Project?**
The aim of this project is to explore how motorway development and advanced technology can assist with managing growing roading pressures as a by-product of urban infill and urban sprawl. Specifically this study is focussed on motorway development in Wellington focussing on the new Smart Motorway, the Transmission Gully development and the Kapiti Expressway.

This project is being undertaken as part of the requirements for the Master of Planning Postgraduate course at the University of Otago.

**What Types of Participants are being sought?**
Participants for this project will be older than 18 years of age. Participants will be sought from key groups. These groups will be:

- Key staff members at the Ministry of Transportation
- Key staff members at the NZTA associated with the specific roading projects
- Planning and Policy professionals working with the Wellington City Council and Greater Wellington Regional Council who are involved with transportation
- Professionals from consulting companies who have a background in roading in Wellington and potentially the development of these roads

**What will Participants be asked to do?**

Should you agree to take part in this project, you will be asked to consent to being involved in a semi-structured interview (ranging from 30-45 minutes). For the researcher's record these interviews will be digitally audio recorded and hand written notes will also be taken. The participants' responses will reflect their opinions on the current motorway developments in Wellington city, areas of policy and the wider issues being addressed by this thesis research. The precise nature of the questions that will be asked in these interviews has not been determined as it is hoped that they will be influenced by how the interview develops. These interviews will however be semi structured utilising an open ended questioning technique. Participants will receive a briefing in regards to their anonymity and their rights to withdraw from the research before the interview commences. On the Consent Form you will be given options regarding your anonymity. Please be aware that should you wish we will make every attempt to preserve your anonymity. However, with your consent, there are some cases where it would be preferable to attribute contributions made to individual participants. It is absolutely up to you which of these options you prefer.

**What Data or Information will be collected and what use will be made of it?**

Personal information such as name and occupation will be recorded. However it is important to note that the identity of participants will be kept anonymous within the report. The option to opt out of being audio recorded will also be presented. This choice is up to the participant.

The audio files along with any other recorded data will be securely stored and only the researcher and the supervisor to this thesis will be able to access this information. Upon completion of the project all personal information will be destroyed. The University of Otago's research policy dictates that raw data must be retained in secure storage for five years. After this period the data will be destroyed.

**Can Participants change their mind and withdraw from the project?**

You may withdraw from participation in the project at any time without any disadvantage to yourself.

**What if Participants have any Questions?**

If you have any questions about our project, either now or in the future, please feel free to contact either:-

| | |
|---|---|
| *Maxwell Pocock, Master of Planning Candidate* | *Rosalind Day-Cleavin, Supervisor* |
| Department of Geography, University of Otago, PO Box 56, Dunedin | Department of Geography, University of Otago, PO Box 56, Dunedin |
| Pocma671@student.otago.ac.nz | Rosalind.day-cleavin@otago.ac.nz |

This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph 03 479-8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

## *Appendix B - Consent Form*

Consent form for research participants.

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***SMART MOTORWAY TECHNOLOGY AND LARGE-SCALE MOTORWAY DEVELOPMENT IN WELLINGTON.***
***Consent Form for***
***PARTICIPANTS***

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;

2. I am free to withdraw from the project at any time without any disadvantage;

3. Personal identifying information such as audiotapes of recorded interviews or handwritten notes will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. This project involves an open-questioning technique. The general line of questioning includes opinions on the current motorway developments in Wellington city, areas of policy and the wider issues being addressed by this thesis research. The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops and that in the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable I may decline to answer any particular question(s) and/or may withdraw from the project without any disadvantage of any kind.

5. If at any time I the participant feel uncomfortable I acknowledge I can withdraw from being involved in the project.

6. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

..... .....
(Signature of participant) (Date)

.....
(Printed Name)

[*Options for Anonymity: in the case where your participants are public figures, artists, musicians, politicians or government officials, and it is anticipated that they will be identified/identifiable, you can offer the following options, which should match the paragraph in the Information Sheet which states "On the Consent Form you will be given options regarding your anonymity. Please be aware that should you wish we will make every attempt to preserve your anonymity. However, with your consent, there are some cases where it would be preferable to attribute contributions made to individual participants. It is absolutely up to you which of these options you prefer."]*

7. I, as the participant: a) agree to being named in the research, OR; ☐

b) would rather remain anonymous. ☐

## *Appendix C - Indicative Key Informant Questions*

**List of Indicative questions for the semi-structured interviews**

1. How long have you been involved in a planning role in Wellington?
2. Could you please explain your role at your organisation?
3. Have you got any experience in transportation planning?

4. Are motorways an important feature of urban infrastructure that needs to be appropriately managed to address changing populations?
5. What can effective motorway planning achieve?
6. How can policy address both changes to urban form, such as sprawl, whilst providing appropriate infrastructure to address this growing demand?
7. How can planning policy address increasing roading pressures and should this be considered as an effect for new developments?
8. In what ways could policy be created to alleviate roading pressures? Should it be more focussed towards controlling urban form?
9. With rising populations are changes to urban form a key issue for all authorities to be considering?

10. Have you been involved in the development of Wellingtons Smart Motorway, Transmission Gully or the Kapiti Expressway?
11. If you have, what was your involvement?
12. Have you been involved in the creation of any policy or plans for a territorial authority in the Wellington Region? If so, what was the document and did it address transportation or motorway development?
13. Have you been involved in the creation or development of policies or plan that address changes to urban form? If so, what was the document and what were some of the issues associated with changes to urban form and how were they addressed?
14. Have you used any of these new roading developments since they have been completed?

15. What do you perceive as an advantage of the development of Wellingtons motorway system?
16. How do you think these motorway developments alleviate roading pressure?
17. What could of these motorway developments done better? What are their shortcomings?
18. To what extent is the topography of Wellington an influencing factor for any future motorway development? Do you also think topography influences settlement patterns in Wellington?
19. What do you envision are some of the alternatives to large-scale motorway development?

20. Do you think that the current system is enough, or will future development of the motorway system be required?
21. Will Wellington's population keep on expanding to the point that territorial authorities should be placing more of an emphasis on public transportation networks instead of the motorway network? Should they be doing this already?
22. How do you think development of large-scale motorways could be applied to other centres experiencing similar pressures on their roading networks like in Wellington or are these developments only likely to work in the Wellington context?

23. Do you have any other comments/observations/concerns etc about this thesis research?
24. Can you envision any areas that would be suitable for future research?