

Measuring Transport Resilience

A Manawatu-Wanganui Region Case Study



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Executive summary

The resilience of transport networks is attracting greater scrutiny at the international, national and sub-national levels. This research report explores the current state of knowledge about measuring transport resilience and presents a case study to address the question is: How resilient is the road and rail infrastructure in the Manawatu-Wanganui Region? This region in New Zealand's lower North Island provides an interesting case study due to its strategic location in the North Island's and indeed New Zealand's transport network. In addition, it has experienced significant disruptions in the recent past, most notably widespread failures caused by flooding in 2004, and the lengthy closure of a significant inter-regional road connection, the Manawatu Gorge State Highway 3 road, due to a landslide in 2011-2012. It also provides an opportunity to explore this topic outside of a major metropolitan region. The region's transport networks and infrastructure also have important social and economic functions.

This research report is structured around a proposed Transport Resilience Indicator Framework (RIF) which explores six key dimensions of transport infrastructure resilience: engineering, services, ecological, social, economic and institutional. This holistic approach to measuring transport resilience and is envisaged to accommodate both qualitative and quantitative indicators. Within this framework, data were gathered via analysis of secondary sources and nine key informant interviews. The interview participants were from public sector agencies responsible for managing aspects of the region's transport network, the private sector and one social service provider. The participants had considerable knowledge relating to the planning of the road network and/or its economic and social significance. They also had knowledge of the impacts and/or management of recent disruptions.

The institutions responsible for managing the region's transport network can identify vulnerabilities in the network, but can also collaborate and learn from past disruptions. Concerns were expressed about the level of funding for maintaining and upgrading the region's transport networks, particularly for territorial authorities with large networks and small rates bases. The region is strongly dependent on the roading network, with limited alternatives during roading network disruptions. It proved difficult to quantify the environmental impacts of transport disruptions. A case study of the response of a local

health shuttle service provided an example of how a community, by drawing on social capital, was able to adapt and respond appropriately to a transport disruption.

One key area identified for further research is assessing the capacity of private contractors to respond to natural hazard events of varying magnitudes. The RIF could also be strengthened by the use of indicators based on quantitative data, in addition to qualitative data. It is suggested that one method of achieving this could be to adopt a multi-disciplinary approach, drawing on expertise, methods and perspectives from related professions, such as engineering and economics.

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Cover photo: Manawatu Gorge Slip in 2011. Photo taken by Muhammad Imran

List of Figures

Figure No.	Title	Page Nos.
1.1	The Manawatu Gorge landslip photographed during remediation works	1
1.2	Map showing the State Highway 3 route east from Palmerston North through the Manawatu Gorge	2
1.3	Map showing the location of key state highways and the Manawatu Gorge in the lower North Island	3
1.4	Map showing Kiwirail's North Island network	4
1.5	The composition of the roading network in the Manawatu-Wanganui Region	5
1.6	Classification of the State Highway network	6
1.7	Proposed road hierarchy in the Palmerston North-Manawatu Strategic Transport Study	7
2.1	Overall effective FAR rate for Horizons Regional Council and constituent territorial authorities 2012-2013	13
2.2	Local road network length and population size for the main territorial authorities in the Manawatu-Wanganui Region	16
2.3	Number of road bridges and population size for the main territorial authorities in the Manawatu-Wanganui Region	17
2.4	Proportions of the local road network of each major category for the main territorial authorities in the Manawatu-Wanganui Region	17
2.5	Change in total employment in the distribution and transport sectors in Manawatu and New Zealand, 2000 to 2009	21
2.6	Transportation Network Resiliency Cycle	27
2.7	Dimensions of resilience and impacts of ex ante and ex post measures	30
3.1	Proposed Transport Resilience Indicator Framework (RIF)	32
4.1	Quarterly change in domestic visitor spending March 2009 to June 2013 in selected areas of New Zealand	50
4.2	The 2006 to 2010 average traffic flow (both directions) at selected monitoring sites around Palmerston North	51

List of Tables

Table No.	Title	Page Nos.
2.1	Overall emergency works funding assistance rates 2009/10 to 2013/14	15
2.2	Selected approaches to measuring the resilience of transport infrastructure or networks	24
2.3	Variables and corresponding metrics used to measure transport resilience	25
2.4	Table of variables used to measure transport resilience	26
3.1	Potential indicators of and data sources for the transport resilience indicator framework	32

Contents

Executive summary	i
Acknowledgements	iii
List of figures	iv
List of tables	v
1. Introduction and background.....	1
2. Transport resilience - Literature review	9
2.1 Challenges facing transport networks	9
2.1.1 Ageing transport infrastructure and funding shortfalls.....	110
2.1.2 Demographic and geographic factors	18
2.2 Defining resilience in the context of transport	20
2.3 Current projects in New Zealand	21
2.4 Research in the Manawatu-Wanganui Region	22
2.5 Measuring resilience	25
2.6 Planning relevance	32
2.7 Summary	33
3. Methodology	34
3.1 Proposed Transport Resilience Indicator Framework (RIF)	34
3.2 Data sources	36
3.3 Limitations	38
3.4 Summary	38
4. Results	39
4.1 Institutional factors	39

4.1.1	Identifying vulnerabilities.....	39
4.1.2	Collaboration and learning	42
4.1.3	Allocation of resources	45
4.2	Services	51
4.3	Economic impacts	52
4.4	Engineering	57
4.5	Ecological	60
4.6	Social.....	60
4.7	Summary	61
5.	Discussion	63
5.1	Institutional indicators.....	63
5.2	Services indicators.....	64
5.3	Economic indicators	64
5.4	Engineering indicators.....	65
5.5	Ecological indicators.....	65
5.6	Social indicators	66
5.7	Summary	66
6.	Conclusion	67
7.	References.....	73

1. Introduction and background

Resilience is becoming a significant consideration when planning New Zealand's transport networks and infrastructure. Currently, the government's major land transport goal is to create "...an effective, efficient, safe, secure, accessible and resilient transport system that supports the growth of our country's economy..." (Ministry of Transport, 2011b, p. 6). The Manawatu-Wanganui Regional Land Transport Strategy 2010 to 2040 also affords resilience a high priority (Horizons Regional Council, 2010). The strategy envisions the region's transport network in 2040 as being: "[a] safe, sustainable and resilient transport system that supports economic development and lifestyle choices, with strong connections to national corridors" (Horizons Regional Council, 2010, p. 35). This emphasis on resilience in the Manawatu-Wanganui region is, in part, driven by concerns about predicted shocks to the region's transport networks due to the effects of climate change and increases in the price of oil (Horizons Regional Council, 2010). The former is expected to lead to more intense and frequent heavy rainfall events causing more frequent floods, landslips, and other disruption to the transport network, while the latter could increase demand for other modes of transport (Horizons Regional Council, 2010).



Figure 1.1 The Manawatu Gorge landslide photographed during remediation works.
(Photo: Muhammad Imran, March 2012)

Perhaps one of the main drivers for this emphasis is that the Manawatu-Wanganui region has also had its share of recent disruptions. This includes a significant flood in 2004, in which bridges were destroyed and State Highways 1, 2 and 3 were blocked (Lloyd, 2009). In total, about 9300 kilometres, or half of the region's road network, was closed (Kumaran, 2004). In July 2013, a 30-metre landslip occurred 15 kilometres north of Dannevirke and undermined the rail line between Manawatu-Wanganui and Hawke's Bay (Ellingham, 2013). The line was closed for more than a month (Ellingham, 2013). Additionally, the 2011 to 2012 State Highway 3 Manawatu Gorge closure was one of the most significant and lengthy disruptions to New Zealand's state highway network in recent times.

The Manawatu Gorge road was closed after it was blocked by a large landslip (Figure 1.1) on August 18, 2011 (Forbes, 2011). Several smaller slips and concerns over the stability of the hillside exacerbated the situation (Forbes, 2011). The road was not fully re-opened for more than 12 months (Radio New Zealand, 2012). Two alternate routes, the Pahiatua Track and Saddle Road (Figure 1.2), were used while the gorge was closed. These routes are winding, longer and less direct and the latter route crosses very steep terrain. These routes were not designed for high volumes of traffic (MacIntyre, 2012) and there were significant delays (Forbes, 2011; MacIntyre, 2012). The closure severed the main road link for the movement of freight between the Port of Napier and the Hawke's Bay region to the east and the Manawatu-Wanganui region to the west (MacIntyre, 2012) (Figure 1.3).

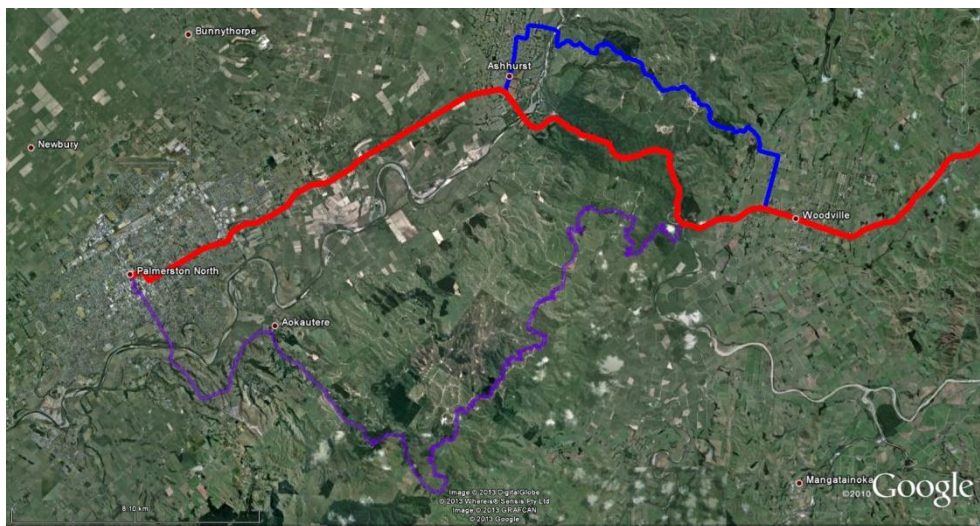


Figure 1.2 Map showing the State Highway 3 route east from Palmerston North through the Manawatu Gorge in red, the Saddle Road route in blue, and the Pahiatua Track route in purple. (Image: Google Earth (n.d.))



Figure 1.3 Map showing the location of key state highways and the Manawatu Gorge in the lower North Island. (Image: Google Earth (n.d.))

This was particularly problematic for the logistics and supply chain sector, and is a serious concern for the regional economy (Palmerston North City Council, 2010). As of 2011, in the Manawatu-Wanganui region, the logistic and supply chain sector generated an income of \$294 million and provided over 6,000 jobs, accounting for nearly 11% of total regional employment. In fact, the sector has been one of the fastest-growing sectors in the region, with a 54% increase in employment between 2000 and 2011 compared to a regional average of 18% (Palmerston North City Council, 2011). As Palmerston North City Council (2011) points out, the strong performance of the logistics and supply chain sector relies heavily on the central location of Manawatu-Wanganui and the ease of access to neighbouring regions (Wellington, Taranaki, Wairarapa and Hawkes Bay) afforded by the road, rail and air transport infrastructure (Palmerston North City Council, 2011). Therefore, ensuring the hazard resilience of the key freight routes such as State Highways 1, 2 and 3 is of paramount importance to the continued growth of the sector.

The Manawatu Gorge also provides a key rail link between the east and west of the lower North Island (Figure 1.4) but this is vulnerable to landslips. In September 2010, a landslip caused a train carrying milk from Hawke's Bay to Taranaki to derail (Duff, 2010). Freight trains had to take a much longer route between Napier and Wellington, or alternately freight had to be transferred onto trucks for part of the journey until the line was cleared (Duff, 2010).



Figure 1.4 Map showing Kiwirail's North Island network. (Image: Kiwirail (2013)).

Apart from the transport corridor in the Manawatu Gorge, some other important routes are also susceptible to hazards. For example, Fitzherbert Bridge is currently the only road link across the Manawatu River in Palmerston North. Moreover, the Bridge also includes infrastructure for other essential services such as sewerage, water, electricity and telecommunications. Although the Bridge is structurally resilient to hazards, with the ability to withstand a one-in-500-year flood and one-in-2500-year earthquake, it is estimated that the destruction of or severe damage to the Bridge by an adverse event could lead to a social-economic loss of \$430,000 per day (Rankin, 2012).

The Manawatu-Wanganui region's transport network comprises just over 7800km of local roads administered by territorial local authorities and approximately 950km of state

highway administered by the New Zealand Transport Agency (New Zealand Transport Agency, n.d.-c). The majority of local roads traverse rural areas and a significant proportion of these are not sealed (Figure 1.5).

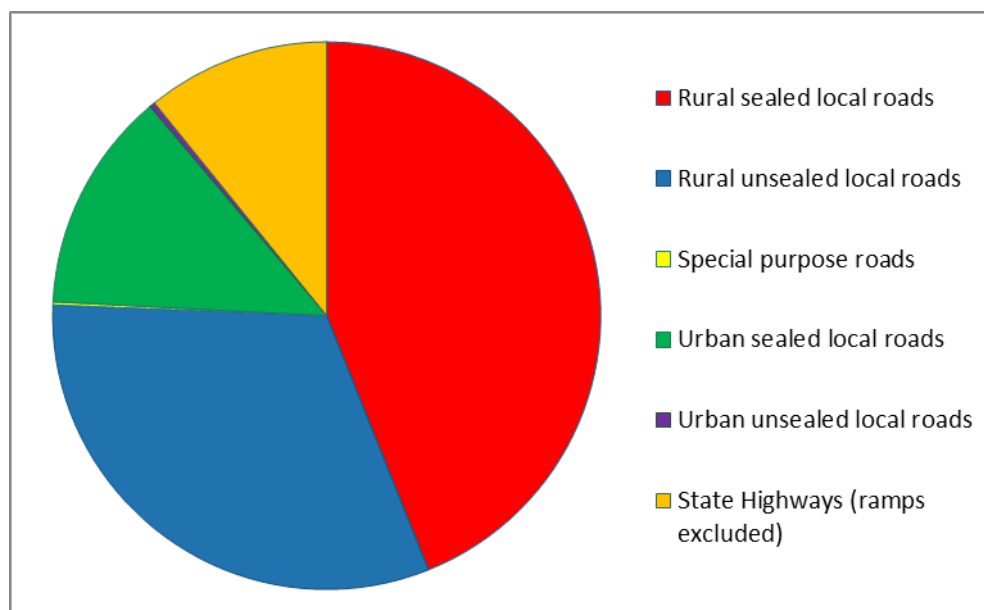


Figure 1.5 The composition of the roading network in the Manawatu-Wanganui Region. (Source: New Zealand Transport Agency (n.d.-c)).

The Manawatu-Wanganui Region also hosts some significant state highway routes, such as State Highway 1, connecting Wellington in the south to Auckland in the north, and part of State Highway 2, which connects the region with Napier and Hastings to the east (Figure 1.6). State Highways 3 and 4 provide vital links when State Highway 1 is closed. Other state highway routes in the region are deemed to be of less significance.

A joint transport study has been carried out by NZTA and relevant local authorities covering the Palmerston North and Manawatu areas. This study identified a need for a new bridge over the Manawatu River near Palmerston North (Figure 1.7) to enhance route security (Horizons Regional Council, 2010). The new bridge will be upstream of the existing Fitzherbert Bridge. It will not only help ensure the free flow of traffic within Palmerston North by sharing the traffic demand on Fitzherbert Bridge, but also improve the local road network's hazard resilience by providing an alternate route to road traffic and essential services (Rankin, 2012).



Figure 1.6 Classification of the State Highway network.
Source: New Zealand Transport Agency (n.d.-a)

The Manawatu-Wanganui Regional Land Transport Strategy (RLTS) also identifies the maintenance and improvement of the strategic transport network to “ensure safe,

efficient intra- and inter-regional accessibility and links with national roading corridors” as a key policy (Horizons Regional Council, 2010, (p. 56)). To achieve this, the RLTS not only proposes to implement the recommendations of the aforementioned joint transport study, but also to carry out safety realignments on strategic routes such as State Highway 1 Ohingaiti to Makohine and State Highway 2 at Manawatu Hill (Horizons Regional Council, 2010).

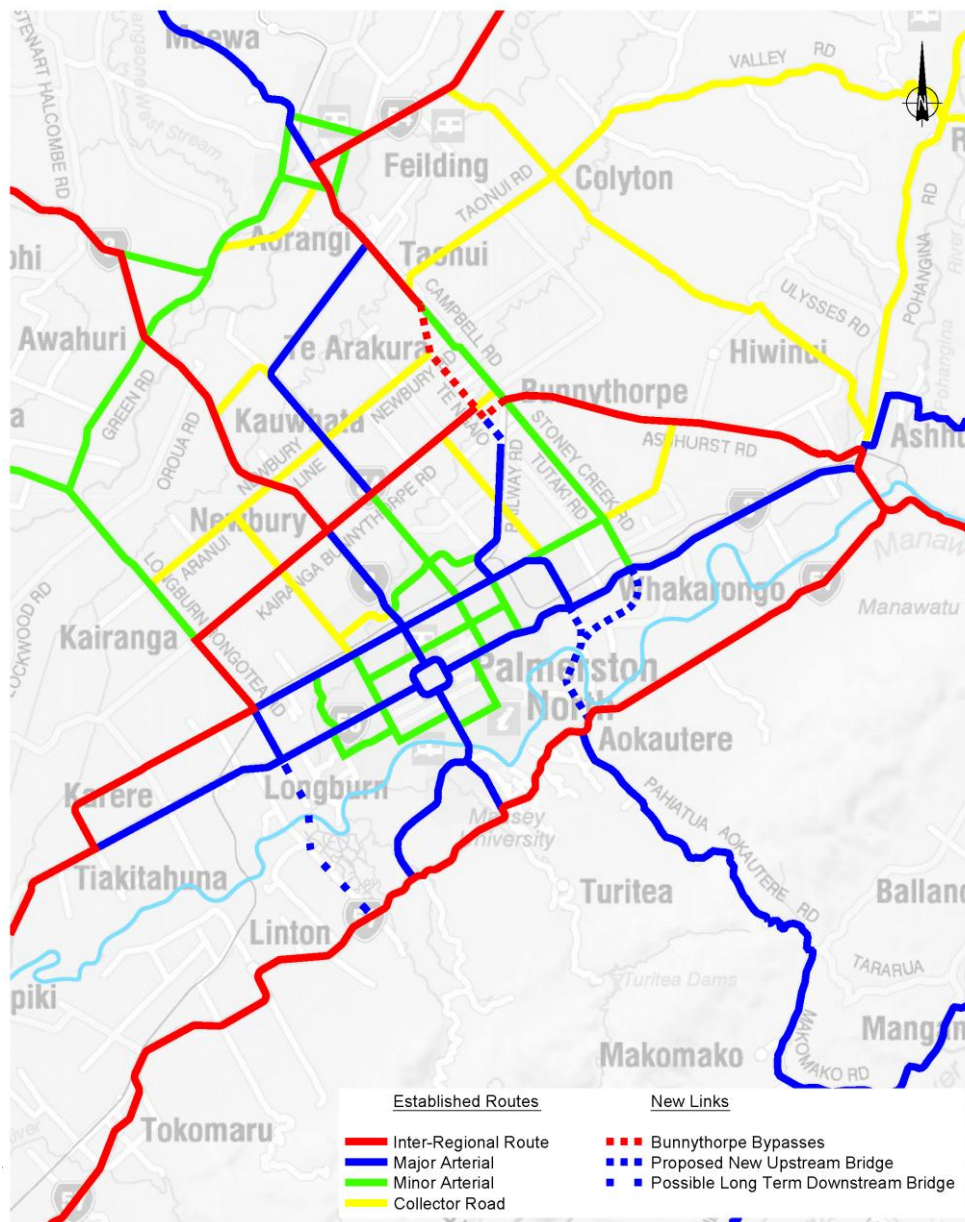


Figure 1.7 Proposed road hierarchy in the Palmerston North-Manawatu Strategic Transport Study. (Source: (Horizons Regional Council, 2010)).

The RLTS also supports the efficient and effective movement of freight as its policy. It aims at establishing and maintaining freight corridors that are “resilient to disruption from adverse weather and other hazards”. Ensuring the availability of alternate routes is also considered crucial to minimising disruption to freight flow in the case of adverse events (Horizons Regional Council, 2010).

The aforementioned transport disruptions and the objectives of efforts such as the joint strategic study highlight the vulnerability of transport networks and draw attention to methods of assessing their resilience. Resilience has been defined as “...the capacity of a system to absorb disturbance and still retain its basic function and structure” (Walker, Salt & Reid, 2006, as cited in Newman, Beatley, & Boyer, 2009, p. 6). In order to develop better transport networks which can cope with external shocks, such as natural hazards, methods of assessing resilience should be developed to better inform planning and investment decisions. This is particularly important given the expected consequences of climate change and its association with natural hazards. The purpose of this research is to explore the current state of knowledge on transport resilience assessment and present a case study example incorporating an assessment of the resilience of the road and rail infrastructure in the Manawatu-Wanganui Region? The New Zealand Transport Agency has recently commissioned research into measuring the resilience of transport infrastructure (Hughes & Healy, 2014). This project adds to the developing body of knowledge about transport resilience in New Zealand by providing a case study of a region outside the major metropolitan areas of New Zealand.

Section two discusses the relevant literature on transport resilience issues and efforts to measure the resilience of transport infrastructure. Section three explains the methodology employed in this research project to explore the topic, including the proposed Transport Resilience Indicator Framework (RIF). Section four presents the data gathered during this project. Section five is a discussion of the data with reference to the RIF. Section six is a concluding summary of the report.

2. Transport resilience - Literature review

There is a small body of research on transport resilience and its assessment methods. Institutions responsible for providing and maintaining transport networks and for natural hazards planning have also published material on these topics. This material informs this research and helps to develop a framework for measuring the resilience of the road and rail infrastructure in the Manawatu-Wanganui region. This review focuses firstly on literature on contemporary challenges to transport networks and the impact of transport disruptions. The next section reviews the literature on the definitions of resilience in the context of transport planning, the work that has been done in this area in New Zealand and the current state of knowledge relating to methods of assessing the resilience of transport infrastructure.

2.1 Challenges facing transport networks

Disruption to transport networks can be caused by events such as vehicle crashes, infrastructure and utilities failure, road works, industrial accidents, deliberate sabotage and natural hazards (Jenelius & Mattsson, 2012). Disruptions vary in their spatial and temporal extent, with some, such as vehicle crashes and road works, usually causing only short term disruption to a single part of the network, and others, like natural hazards, potentially causing more widespread problems (Ibid.). The United Kingdom's Department for Transport (2014) released a review of the resilience of that country's transport networks to extreme weather events following a particularly severe series of storms in winter 2013/2014 which caused several significant transport disruptions. Key findings include: authorities need to collaborate to identify critical routes and infrastructure; adequate funding must be available for maintenance, and to develop weather resilience and climate change adaptation plans; contingency plans must be tested and revised after disruptive events to reflect lessons learned; the economic rationale for investing in transport resilience must be strengthened; and communication with network users needs to be improved to enable them to make informed decisions about travelling during adverse weather events (Department of Transport, 2014). Extreme weather events represent just one of the hazards the Manawatu-Wanganui region is exposed to. The most significant hazards include particularly earthquakes, floods, landslides and volcanic eruptions (Gordon & Matheson, 2008a; Lloyd, 2009) which clearly can affect the road network.

Disruption to transport networks can have significant social, environmental and economic impacts. In New Zealand, transport networks are recognised as 'lifelines'; "...those essential 'utility' services which support the life of the community..." (Gordon & Matheson,

2008a, p. 18). In severe cases, a disruption could inhibit emergency services from reaching people in need (Jenelius, 2009; Jenelius & Mattsson, 2012). But most often the normal functioning of households and businesses is hampered, with transport delays resulting in disruption for the former and additional costs, delayed freight and potential to lose customers for the latter (Jenelius, 2009; Jenelius & Mattsson, 2012). Disruptions to key road infrastructure can have significant implications for traffic patterns and traveller behaviour, such as affected motorists cancelling planned journeys or changing destinations (Zhu, Levinson, Liu, & Harder, 2010).

2.1.1 Ageing transport infrastructure and funding shortfalls

Many New Zealand regions face particular challenges with ageing transport infrastructure and funding shortfalls. These challenges were identified in the Auditor-General's 2013 audit of the transport sector. The report notes that New Zealand is considered to be at high risk of natural hazards and that there are many recent examples, such as the Manawatu Gorge landslide and Christchurch earthquakes, of natural hazard events damaging transport networks (Office of the Auditor-General, 2013). There are significant direct costs involved in recovering from these events, but the indirect costs caused by an inability to respond or a slow recovery can have considerable long-term economic impacts (Office of the Auditor-General, 2013).

Many local authorities, particularly those outside the major metropolitan areas, will also face transport funding pressure in the near future as a result of changed levels of central government co-investment and shift of investment away from smaller population centres. A significant proportion of central government road transport funding for new and improved infrastructure is being allocated to Roads of National Significance (RONS), which are in or adjacent to major cities. In 2009/2010, 23.4% of funding for new and improved state highway infrastructure was allocated to these projects, and this increased to 61.8% in 2011/2012 (New Zealand Transport Agency, 2009, p. 24). Over the same period, the total funding allocated to new and improved infrastructure for local roads was reduced by 26.1% (New Zealand Transport Agency, 2009, p. 24). In 2011, the Ministry of Transport reported that Auckland was receiving almost half (46%) of the government's total transport funding (Ministry of Transport, 2011a). The Government Policy Statement (GPS) on Land Transport Funding argues that the RONS project is justified as these sections of state highway carry disproportionately high volumes of traffic, including heavy vehicles. "Investing in these routes will ease the most significant pressure points in the national network, reduce congestion in and around our five largest metropolitan areas, improve road safety and link our major sea and airports more effectively into the State highway network" (Ministry of Transport, 2011b, p. 8). There are other demands on transport

funding too, such as restoring Christchurch's earthquake-damaged transport networks, which could cost \$400 to \$500 million and might lead to reprioritisation of transport funding (Ministry of Transport, 2011a, p. 22). In 2014, the government released the draft GPS 2015, which shows some rebalancing between funding for different regions. For example, the draft GPS includes a \$212 million package for 14 regionally important State Highway projects in non-metropolitan regions such as Manawatu-Wanganui, Otago and Taranaki (Ministry of Transport, 2014). However, with 54% of funding still allocated to state highways, the draft GPS has been criticised for its continued bias against local roads and alternative forms of transport, which receive 21% and 11% of total funding respectively (Burgess, 2014; Fox, 2014).

The Auditor General's (2013) report states:

There is a risk that funding decisions made nationally do not consider the competing needs of all regions. The Government is prioritising Roads of National Significance and the Canterbury rebuild. This creates funding pressures in other aspects of the NLTP [National Land Transport Plan]. Local authorities rely heavily on central government subsidies for work on roads. Some local authorities have ageing roading networks and have to decide how best to maintain those assets as they will not receive all of the subsidies they anticipated from central government through the National Land Transport Fund (p. 14).

Funding shortfalls could lead to rates rises, reduced levels of service and maintenance or the cancellation of planned projects (Office of the Auditor-General, 2013). In some areas, such as Southland District, a large proportion of the road network will reach the end of its projected service life in the near future, meaning significant funding will be needed just to maintain current levels of service (Office of the Auditor-General, 2013).

Some non-metropolitan regions are arguing for more funding for regionally important state highways. For example, Venture Taranaki has recently published a report on options to improve parts of State Highway 3 in north Taranaki, which connect the region with Waikato and Auckland. The report states:

Our review of the government's transport funding policies highlights a potential imbalance of priorities away from regional investment. At present the policy of R [regional] funds provides a minimum level of funding for regions that can help offset any potential imbalance, but it is possible that these will not exist past 2015. Prevailing methods to prioritise investments are geared to only address certain kinds of transport problems. They do not routinely deal well with addressing transport problems that stifle development. Without minimum regional funding

levels some regional projects may be forgone at the expense of inferior value for money projects in the major centres (Venture Taranaki, 2012, p. 49).

The report also argues that state highways in non-metropolitan regions can be important alternate routes when major state highways are disrupted and can also play an important role in enabling access to co-located infrastructure, such as gas pipelines (Venture Taranaki, 2012). The report also argues that low-quality routes prone to closure can suppress regional economic development (Venture Taranaki, 2012).

There are other potentially significant funding changes on the horizon. This includes the proposed phasing out of regional or 'R' funds from 2015 mentioned above (Horizons Regional Council, 2012; Northland Regional Council, 2013; Otago Regional Council, 2012) and the review of the Funding Assistance Rates (FAR) scheme, which has confirmed that a new funding framework will be introduced (New Zealand Transport Agency, 2013a).

The R funds were raised via a 5 cent per litre increase in fuel excise duty and were allocated to regions on a per-population basis (Horizons Regional Council, 2012). They are due to expire on March 31, 2015 (Ministry of Transport, n.d.). The funds were allocated to projects via regional transport committees, with the NZTA having the final decision on whether to approve the spending (Otago Regional Council, 2012). The scheme was designed to ensure there was a minimum amount available to be spent on roading improvements in each region (Horizons Regional Council, 2012). This was to be spent on the highest-priority projects, with national or 'N' funds available for additional projects, albeit on a nationally-contested basis (Horizons Regional Council, 2012; Northland Regional Council, 2013). As of 2012, the total 'R' funds allocated to the Manawatu-Wanganui Region were \$116.8 million (Horizons Regional Council, 2012, p. 42).

The impending removal of this funding has raised concerns for several non-metropolitan regions about its impact on economic development and transport resilience. For example, Northland Regional Council (2013) argues:

Regional funds have proved to be a vital funding source for those regions that have worthwhile and economically viable transport improvement projects that are generally not considered to be of sufficient national priority to compete for "N" Funds (p. 7).

Representatives of several non-metropolitan regional councils met with the Minister of Transport in August 2013, and called on him to "acknowledge that on-going incremental transport improvements in provincial regions are crucial to achieving continued economic

growth and productivity throughout the country, as well as ensuring on-going resilience in the land transport network. This will not occur if they need to compete against RONS” (Northland Regional Council, 2013, p. 8). The Minister of Transport indicated that future funding mechanisms will be investigated and considered before the expiry of ‘R’ funds (Ministry of Transport, n.d.).

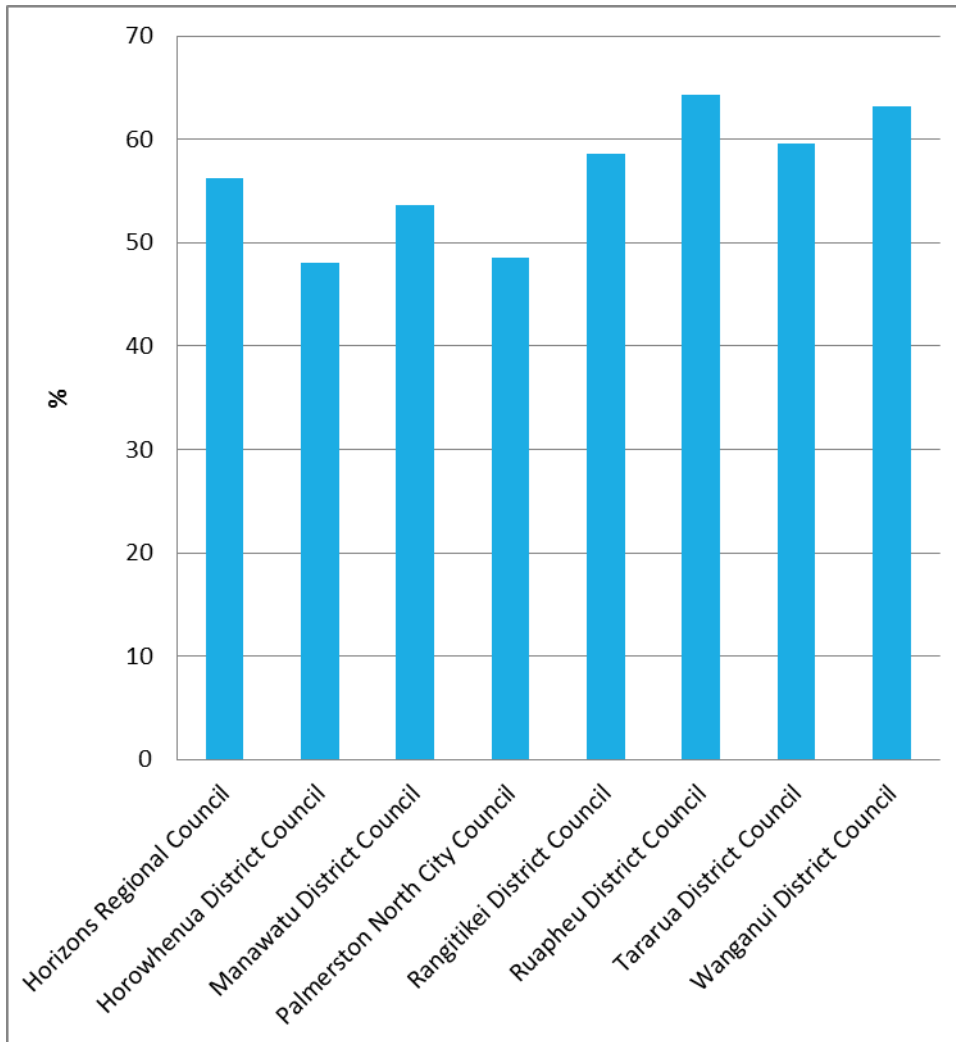


Figure 2.1 Overall effective FAR rate for Horizons Regional Council and constituent territorial authorities 2012-2013.

Source: New Zealand Transport Agency (2013a)

The FAR represents the proportion of funding territorial authorities and regional councils receive from central government’s National Land Transport Fund towards the total cost of various transport activities, such as maintaining and improving local roads, providing public transport services and improving road safety and transport planning (Horizons

Regional Council, 2014). Councils receive different overall effective FAR rates (Figure 2.1).

The FAR scheme was reviewed because the government considered that it was outdated, overly complex and unwieldy to administer (New Zealand Transport Agency, 2013a). The NZTA has confirmed that a new FAR framework will be phased in over a nine-year period from 2015. Under the new scheme, the NZTA has proposed an overall co-investment rate of 53%, meaning that on average 53% of local transport projects will be funded via the National Land Transport Fund (NLTF). In reality, however, the actual rate is expected to be 52% for most councils, with the rest receiving a *targeted enhanced* FAR, which would be higher than 52%. According to the NZTA:

In determining which councils get higher funding assistance rates we will take into account differences in local authorities' *ability to raise the local share of the costs of achieving land transport outcomes* [emphasis in original]." (New Zealand Transport Agency, 2013a, p. 6). This change in FAR could have considerable impact on territorial authorities' roading budgets, creating both winners and losers. Within the Manawatu-Wanganui region, it is likely that apart from Palmerston North City Council and Horowhenua District Council, all the other territorial authorities would face reduced funding as they have consistently received FAR significantly above 52% previously (Table 2.1) (New Zealand Transport Agency, 2013a).

Changes to emergency reinstatement funding were also considered as part of the FAR review (New Zealand Transport Agency, 2013a). This scheme is an important factor in the resilience of the roading network:

The role of those rates is to address the situation where an approved organisation has incurred significant expenditure in responding to 'out of the ordinary' short duration natural events, that is, natural events that a particular approved organisation could not reasonably be expected to plan and manage for as part of normal best practice management of the resilience of the land transport network (New Zealand Transport Agency, 2013a, p. 61).

The NZTA says the current scheme is intended to apply to major, short-duration natural hazard events, though there is a lack of clarity on what comprises a 'major' event and this may result in some funding being directed to responding to relatively common events in the location where they occur (New Zealand Transport Agency, 2013a). Transport managers should instead be encouraged to plan for and manage these relatively common events, such as by creating a reserve fund (New Zealand Transport Agency, 2013a).

Table 2.1 Overall emergency works funding assistance rates 2009/10 to 2013/14

Organisation name	2009/10 Average FAR	2010/11 Average FAR	2011/12 Average FAR	2012/13 Average FAR	2009-12 Average EW FAR	Current 2013/14 Base FAR
Ruapehu District Council	91%	91%	89%	79%	89%	60
Tararua District Council	67%	73%	73%	80%	75%	59
Wanganui District Council	64%	89%	86%	65%	84%	62
Horowhenua District Council	47%	48%	52%		49%	47
Manawatu District Council		70%			70%	53
Palmerston North City Council						40
Rangitikei District Council	87%	91%	89%		89%	58

Source: New Zealand Transport Agency (2013a)

Under the current proposal, the FAR may be increased for emergency works, which are a) caused by out of ordinary short duration natural events, and b) greater than 10% of the council's approved road maintenance, operations and renewals programme for the relevant year (New Zealand Transport Agency, 2013b). The elevated emergency rates are expected to be 20 percentage points higher than the normal FAR (52%) (New Zealand Transport Agency, 2014). This change may have an impact in the Manawatu-Wanganui region as some councils, such as Ruapehu District Council, Wanganui District Council and Tararua District Council, have required emergency reinstatement funding every year between the 2009/10 year and the 2012/13 year (New Zealand Transport Agency, 2013a).

2.1.2 Demographic and geographic factors

Demographic and geographic factors may also influence the challenges territorial local authorities face in providing transport infrastructure. In the Manawatu-Wanganui region there is considerable variation in these factors between the territorial authorities. For example, Figure 2.2 shows that several territorial authorities in the region with smaller

populations and lower rates revenue have significantly longer road networks than do more highly populated areas with larger rates bases, such as Palmerston North and Wanganui. A very similar pattern emerges with the data on road bridges (Figure 2.3). This raises some questions around the ability of the territorial authorities with smaller populations and rates bases to maintain and/or improve their road networks relative to the urban centres.

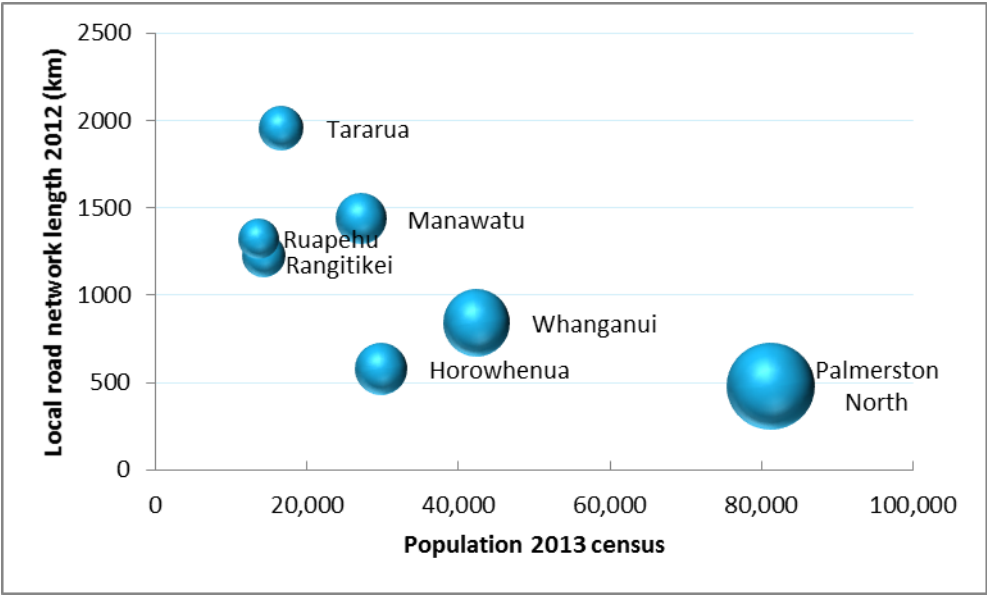


Figure 2.2 Local road network length and population size for the main territorial authorities in the Manawatu-Wanganui Region. The size of each bubble indicates relative rates revenue for the 2012/13 year.

Sources: Statistics New Zealand (n.d.), New Zealand Transport Agency (n.d.-d), Tararua District Council (2013), Ruapehu District Council (2013), Palmerston North City Council (2013), Manawatu District Council (2013), Horowhenua District Council (2013), Wanganui District Council (2013) and Rangitikei District Council (2013)

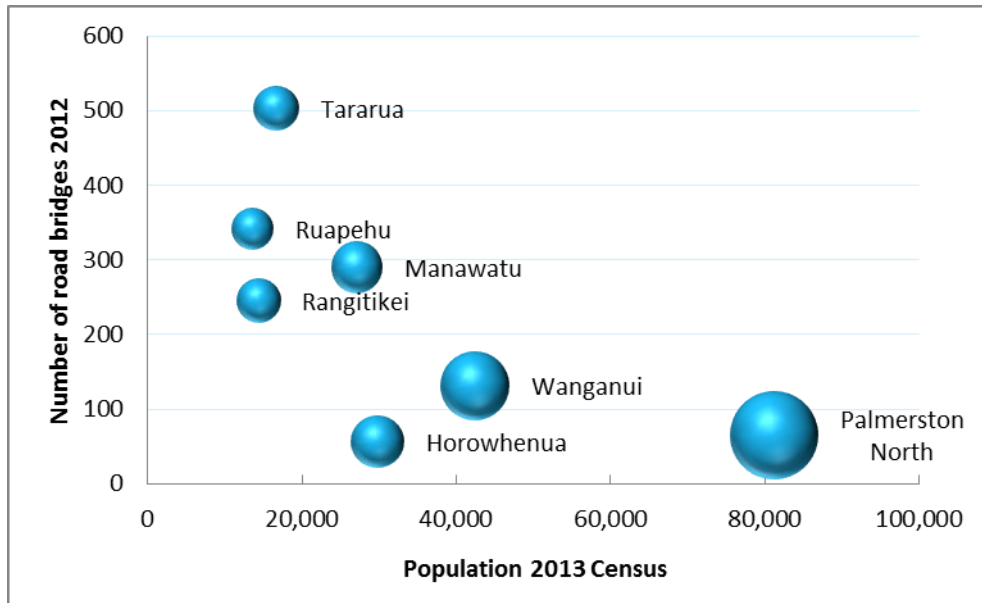


Figure 2.3 Number of road bridges and population size for the main territorial authorities in the Manawatu-Wanganui Region. The size of each bubble indicates relative rates revenue for the 2012/13 year.

Sources: Statistics New Zealand (n.d.), New Zealand Transport Agency (n.d.-d), Tararua District Council (2013), Ruapehu District Council (2013), Palmerston North City Council (2013), Manawatu District Council (2013), Horowhenua District Council (2013), Wanganui District Council (2013) and Rangitikei District Council (2013).

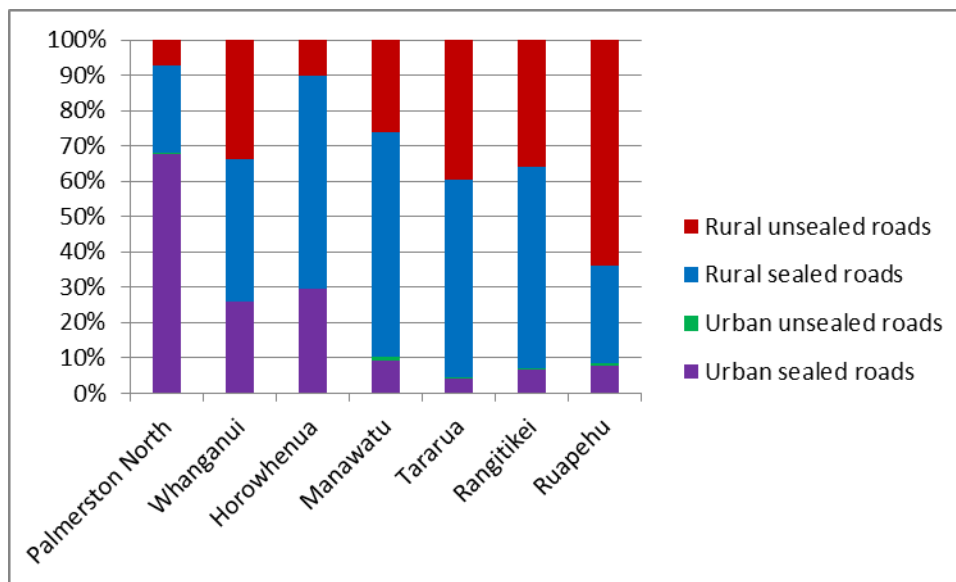


Figure 2.4 Proportions of the local road network of each major category for the main territorial authorities in the Manawatu-Wanganui Region.

Source: New Zealand Transport Agency (n.d.-d).

However, it must be noted that there are clear differences in the nature of the road networks between these areas as well. For example, Figure 2.4 shows that Palmerston North's local road network is largely made up of urban sealed roads, while Ruapehu District's network is dominated by unsealed rural roads. This, along with the variation in population distribution also indicates that different levels of service are required between these different local road networks. Nevertheless, it remains true that the smaller territorial local authorities in the region have to manage significantly larger road networks with a smaller rates base to draw upon. Currently, the smaller territorial authorities with large roading networks also tend to receive higher roading subsidies from central government. However, the FAR review will result in changes to the way these subsidies are provided (Horizons Regional Council, 2013).

2.2 Defining resilience in the context of transport

The concept of resilience has its origins in the field of ecology (Davoudi, 2012; Reggiani, 2012), but more recently it has spread to other fields. There are two major interpretations. The first, ecological resilience, refers to the degree of disturbance a system can absorb before being forced to move from its previous state of equilibrium to a new one (Davoudi, 2012; Reggiani, 2012). The other, engineering resilience, is concerned with the time required for a system to return to its original state of equilibrium following a disturbance. Bruneau et al. (2003) argue a resilient system has the following properties:

Reduced failure probabilities ... Reduced consequences from failures, in terms of lives lost, damage, and negative economic and social consequences ... Reduced time to recovery (restoration of a specific system or set of systems to their 'normal' level of performance) (p. 736).

The New Zealand Transport Agency (2012) defines resilience in the context of transport systems as "...the ability of network infrastructure to deal with a range of significant disruptions and shifting circumstances from natural disasters to changing demographics or economic shocks" (para. 4). According to Gordon and Matheson (2008a), resilience "relates to the ability of a roading network to continue to support the community and meet the community's social, economic and environmental needs, following a major hazard event" (p. 73). Thus, a resilient transport system should be able to absorb shocks as well as accommodate slow onset long-term events such as the effects of climate change, and/or adjust and accommodate the needs of users quickly and effectively following a major disruption.

2.3 Current projects in New Zealand

Some work has been carried out in New Zealand to assess and improve the resilience of transport networks. 'Lifelines' projects and groups have been established in most regions (Ministry of Civil Defence and Emergency Management, n.d.). These groups are made up of volunteer members, such as representatives from various regional utility operators (Ministry of Civil Defence and Emergency Management, n.d.). Their role is "...the identification and quantification of hazards and their likely impact on identified vulnerable infrastructural assets" including transportation networks (Gordon & Matheson, 2008a, p. 31). However, a 2008 survey of coordinators of these groups found that in many regions there was a perception that very little funding had been put towards improving the resilience of the road network (Gordon & Matheson, 2008a, p. 70). Specifically, among local authorities there was a "very low level of funding for specific works to mitigate or improve the transport network's resilience to natural hazards" (Gordon & Matheson, 2008b, p. 22). The groups were expected to create 'disaster resilience summaries' to aid in disaster planning and to strengthen infrastructure. This led to a need for a "systematic resilience based framework" to help asset managers better understand resilience, identify weaknesses and plan accordingly (Gordon & Matheson, 2008a, p. 73). Gordon and Matheson (2008b) found further work was needed "in defining resilience measures, against which the effectiveness of different investments in strengthening, risk reduction or readiness could be assessed" (p. 43).

Assessing the resilience of New Zealand's infrastructure networks, including transport networks, is currently a priority for the National Infrastructure Unit (Fairclough, 2013). The establishment of this priority has been driven by the National Infrastructure Plan 2011. The plan expresses the vision that: "New Zealand's infrastructure is resilient and coordinated and contributes to economic growth and increased quality of life" (New Zealand Government, 2011, p. 11). Resilience is one of the plan's guiding principles. That plan says New Zealand's infrastructure networks should be "able to deal with significant disruption and changing circumstances" (p. 14).

However, the plan also notes that one of the key challenges is that there is "insufficient knowledge of network resilience at a national level" (p. 2). Efforts are now being made to bridge this knowledge gap before the next iteration of the plan is published in 2015 (Fairclough, 2013). Resilience analysis is currently a key priority (Fairclough, 2013). The 2011 National Infrastructure Plan tended to focus on the major urban centres of Auckland, Christchurch and Wellington (New Zealand Government, 2011), but there is now some evidence of a greater recognition of the contribution other regions make to the national economy, including the Manawatu-Wanganui region (Fairclough, 2013).

2.4 Research in the Manawatu-Wanganui Region

Authorities in the Manawatu-Wanganui region have sought to identify natural hazards and their likely effects, including on the transport system. The New Zealand Transport Agency (n.d.-b) has identified four sections of the region's state highway network which have potential resilience issues. They are: State Highway 1 Turangi to Waiohuru, which can be affected by snow and ice, the Whirokino Bridge on State Highway 1 near Foxton, which is identified as a substandard bridge for High Productivity Motor Vehicles, the Manawatu Gorge State Highway 3 route, which is at risk of landslides and rockfalls and State Highway 56 Tiakitahuna to State Highway 57, which at risk of flooding.

The Manawatu Gorge is considered to pose the most significant resilience challenges because of the lack of a viable alternate route. It was also more likely to be closed for longer periods following an adverse event than the three other sites. The sites were given an overall resiliency ranking of high, medium or low, with a high ranking indicating "...that there is a high likelihood that an event will have a significant impact on the operation of a route" (New Zealand Transport Agency, n.d.-b). The Manawatu Gorge's overall resilience rating was medium, whereas the other three sites in the region had a low rating.

Nationally, the sites with high rankings were located in either the three major cities, or nearby in adjoining regions. As of 2008, work completed as part of the region's lifelines project included Geographic Information Systems mapping of hazards (Gordon & Matheson, 2008a). In 2009, Horizons Regional Council published a hazard risk assessment report to inform a review of the region's Civil Defence Emergency Management plan (Lloyd, 2009). The report considered the implications of several hazard scenarios, including their impacts on the transport system. It considered a landslide forcing a three-month long closure of the Manawatu Gorge (Lloyd, 2009) (a much shorter duration than the closure in 2011 to 2012). This work, along with Gordon and Matheson's (2008a) findings, indicates that work has been done to identify natural hazards which could affect the transport network in New Zealand and the Manawatu-Wanganui region. However, more work is needed to develop methods to measure the resilience of the network.

Research in the Manawatu-Wanagnui Region has highlighted the economic importance of the road transport network. The freight and logistics sector is of increasing importance to the local economy. The rate of growth in these sectors outstripped the national average in the past decade (Figure 2.5). A proposal to construct a \$20 million inland port and freight hub at Longburn, west of Palmerston North was announced in August 2014 (Wilkie and

Grocott, 2014), underscoring the importance and growth potential of these sectors in the region.

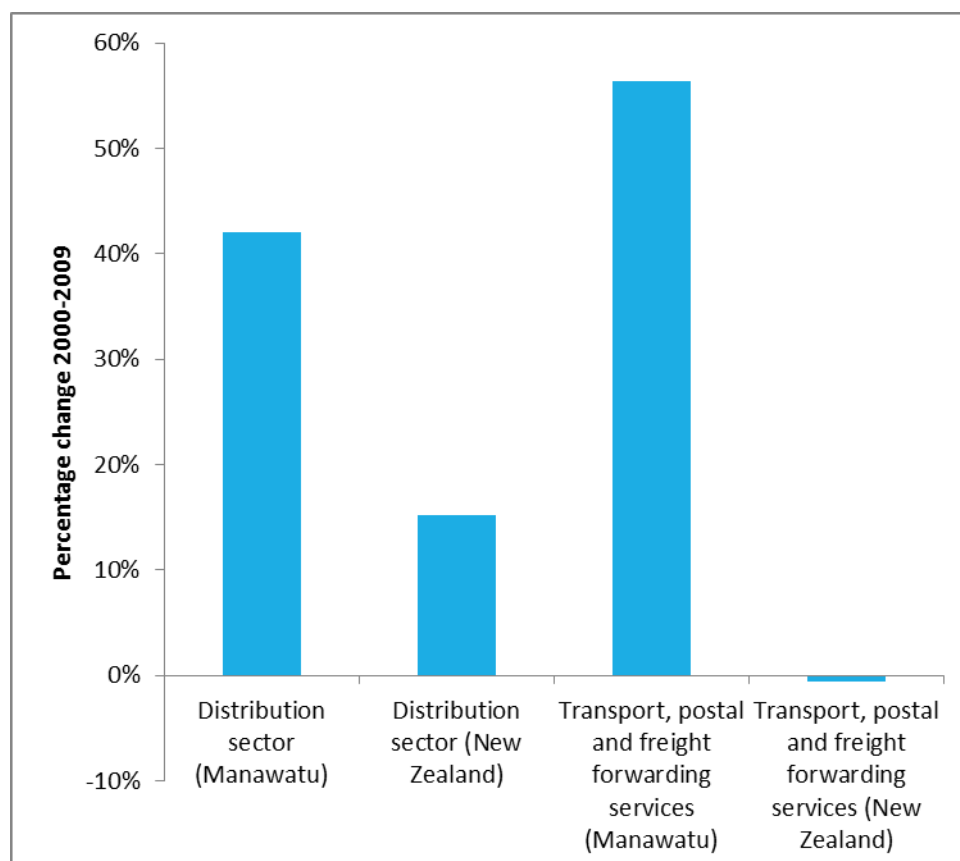


Figure 2.5 Change in total employment in the distribution and transport sectors in Manawatu and New Zealand, 2000 to 2009.

Source: Statistics New Zealand (n.d.) cited in Palmerston North City Council (2010)

Palmerston North has also been identified as a key retail destination for residents of many smaller towns near the city. A study commissioned by the Palmerston North City Council in 2003 found the city's retail sector was substantially larger and more diverse than that of other nearby towns like Dannevirke and provincial cities like Wanganui (Marketplace New Zealand, 2003). This makes Palmerston North an attractive retail destination for people in a large catchment area around the city. The study found that the average Palmerston North general merchandise retailer could expect that 25 to 30 per cent of their business would come from customers living outside the city (p. 12). This underlines the need for robust transport connections throughout the region.

Other work has quantified some of the costs of disruptions like the 2011 to 2012 Manawatu Gorge closure. Reinstating the State Highway 3 Manawatu Gorge road after the slip cost \$21.5 million according to the New Zealand Transport Agency's National Land Transport Plan 2012/2015 (New Zealand Transport Agency, 2013c, p. 3), with a further \$4.5 million earmarked for work on improving alternate routes (p. 4). However, the local economy benefited from the work because Palmerston North-based company Higgins was the lead contractor for clearing the slip (Higgins, n.d.). The closure also meant local freight and logistics firms had to spend more on fuel and wages. Early in the closure period, Vision Manawatu estimated these costs at \$20,000 and \$8,500 per day, respectively (Forbes, 2011). Much of this additional spending would have benefited the local economy overall, even though individual businesses would have suffered. Other recent transport disruptions have also been costly, with the initial cost of repairing roads and council infrastructure after the 2004 floods in the region put at \$120 million (Kumaran, 2004, p. 4)

There is also evidence that these events have influenced businesses' future planning. For example, the risk of future disruptions to the Manawatu Gorge was cited as part of the rationale for Fonterra's planned expansion of its Pahiatua milk processing facility (Fonterra Co-operative Group, 2013). Under the proposal, all milk that is currently transported by rail from Oringi, near Dannevirke, to Whareroa, near Hawera in Taranaki, would instead be taken by tanker truck to Pahiatua (Fonterra Co-operative Group, 2013). One of the key drivers was:

Reduced transport risks with milk being processed locally than relying on transportation to sites in Taranaki. This is especially important given the situation with the recent Manawatu Gorge slip (Fonterra Co-operative Group, 2013, p. 35).

Transport disruptions also affect people. Those in outlying areas who depend upon road transport to get to work or to access services are particularly vulnerable. Significant numbers of people from smaller towns commute to work in Palmerston North, while others may need to travel to the city to access facilities (Cheyne & Imran, 2010). For example, Palmerston North hosts the region's major hospital (Midcentral District Health Board, n.d.) and has several significant tertiary education institutions (Palmerston North City Council, n.d.).

2.5 Measuring resilience

The need for robust methods to measure transport infrastructure or network resilience is identified in a range of studies. For example, in his discussion of road network

vulnerability analysis, Taylor (2012) says: "Transport agencies need well-defined concepts and validated models and tools to test networks for their robustness and resilience to failure at different locations, as an integral part of network design and incident management planning, and indeed planning for emergencies" (p. 761).

Research funded by the New Zealand Transport Agency on measuring the resilience of transport infrastructure identified two dimensions of resilience: technical and organisational. (Hughes & Healy, 2014). Each dimension has three principles associated with it: robustness, redundancy and 'safe to fail' are associated with technical resilience; and change readiness, leadership and culture and networks are associated with organisational resilience. Hughes and Healy (2014) developed a "broadly qualitative framework for measuring resilience" (p. 8), in which a number of measurement categories relating to the principles were developed. This enabled an assessment to be made and a resilience score to be generated, ranging from 4 for very high resilience to 1 for low resilience. However, the authors concluded:

Due to project constraints, detailed real-scenario testing of the framework was not undertaken. Specific operator knowledge of assets and the relevant organisations would be required to undertake a meaningful assessment (p. 10).

This highlights the potential value of the present case study which focuses on a specific region and contains detailed information from operators of the transport network.

There have been efforts to develop methods to measuring or assess the resilience of transport infrastructure, with a focus on different aspects of the topic (see Table 2.2 below). Chang and Chamberlin (2004) point to a need for assessments of the resilience of key lifeline infrastructure to be carried out in a multifaceted way. However, because of the multifaceted nature of resilience, it is difficult to develop "quantifiable, succinct, and meaningful" assessment tools (Chang & Shinozuka, 2004, p. 741). Bruneau et al. (2003), in the context of community resilience to earthquake hazards, argue that resilience has four key properties: robustness, redundancy, resourcefulness, and rapidity. Robustness refers to the strength of the system or its elements to cope with shocks without losing functionality or failing. Redundancy refers to the availability of alternate means of providing key services when there is a disruption. Resourcefulness refers to the ability to identify and prioritise problems and direct resources towards solving problems. Lastly, rapidity refers to the capacity to respond to disruptions and resolve issues quickly. Bruneau et al. (2003) expand on this concept by identifying four key dimensions of resilience: technical, organizational, social, and economic dimensions. Technical dimensions refer to the capability of infrastructure or entire networks to perform to the

desired standard during a hazard event. Organizational dimensions relate to the capacity of institutions to improve the four properties of resilience identified above. The social and economic dimensions refer to the capacity to reduce social harm and economic losses respectively.

Table 2.2 Selected approaches to measuring the resilience of transport infrastructure or networks.

Author(s)	Approach
Freckleton, Heaslip, Louisell & Collura (2012)	Assessing resilience to natural hazards ex ante. A number of weighted variables were used to measure resilience at the individual and community level and to explore economic resilience and factors in the recovery phase. Method tested considering an earthquake scenario in Salt Lake City, Utah, U.S.A.
Serulle (2010)	Measuring resilience using a number of variables and metrics and a fuzzy systems approach. The approach is tested using the scenario of a hurricane passing over Santo Domingo, in the Dominican Republic.
Miller-Hooks, Zhang & Faturechi (2012)	Quantitative approach to measuring the resilience level of a transport network "and determining the optimal set of preparedness and recovery actions needed to achieve this level given budget and level of service constraints". Tested using various natural hazard and terrorism scenarios disrupting a freight network in the western U.S.A.
Ip & Wang (2011)	Quantitative approach to measuring transport network resilience. Method is tested using the Chinese rail network to identify vulnerable parts of the network.
Omer, Mostashari & Nilchiani (2011)	Quantitative, systems-model approach particularly focused on the differential in travel time before a disruption and after a disruption. Created a network model of the transport connections to Manhattan, New York City.

Quantitative methods of assessing the resilience of transport networks and infrastructure have been developed by some researchers. For example, Serulle's (2010) work examines a potential transport disruption using a range of metrics such as the average delay and reduction in network speed delays and costs to transport users (Table 2.3). Similar work has been carried out by Freckleton, Heaslip, Louisell and Collura (2012) (Table 2.4).

Table 2.3 Variables and corresponding metrics used to measure transport resilience
Source: Serulle, 2010, p. 32

Variable	Metric
Prevailing level of service	Highway capacity manual Level of Service
Road density	Ratio between lane length and area (ln-mi/sq-mi)
Average delay	Time measure (hours or min)
Average speed reduction	% below Free Flow Speed (or speed limit)
Personal transport cost	Monetary value per length (\$/mi)
Commercial/industrial cost	Monetary value per length (\$/mi)
Alternative infrastructure priority	Distance between key infrastructures/links (mi)
Level of intermodality	Linguistic variable (low to high)
Network management	Linguistic variable (Level I to Level V)

It appears that most methods of measuring the resilience of transport infrastructure developed to date are largely focused on quantitative techniques and were formulated by academics from fields other than planning, such as engineering. These methods certainly have merit; however, the challenge of achieving resilience calls for a collaborative interdisciplinary approach, as Godschalk (2003, p. 142) argues in the context of urban resilience: "If we are to take the achievement of urban resilience seriously, we need to build the goal of the resilient city into the everyday practice of city planners, engineers, architects, emergency managers, developers, and other urban professionals. This will require a long-term collaborative effort to increase knowledge and awareness about resilient city planning and design." Perspectives from the planning profession may be able to complement this work. In particular, planning's future-focused nature (Myers & Kitsuse, 2000) may help foster a more proactive approach. For example, Buckle (2006) says effective planning requires ex ante resilience and vulnerability assessment methods: "They indicate what the goals of planning are, what the outcomes to be driven for actually are, that is, to reduce exposure to risk and increase capacity to manage risk" (p. 88).

Table 2.4 Table of variables used to measure transport resilience
Source: Freckleton et al., 2012, p. 4

Variable	Measurement	Low	Medium	High
Mobility index	Level of service	E-F	C-D	A-B
Delay encountered	Travel time index	<1.13	1.13-1.15	>1.15
Food medicine index	[# of locations/10,000 ppl]	≤2	2-4	≥4
Personal transport cost index	[\$/km]	<\$0.40	\$0.40-\$0.47	>\$0.47
Personal mode choice	Modes of transport	≤1	2	≥3
Network redundancy	[Arterial ln-km/km ²]	<2	2-5	>5
Infrastructure alignment	[km]	<5	>15	5-15
Goods and material access	[# of locations/10km ²]	<0.5	0.5-1	>1
Commercial mode choice	Modes of transport	≤1	2	≥3
Industrial mode choice	Modes of transport	≤1	2	≥3
Network management	Level	I-II	II-IV	IV-V
Fuel and energy access	[# of locations/10km ²]	<3	3-6	>6
Commercial transport cost index	[\$/km]	<\$0.75	\$0.75-\$1.00	>\$1.00
Industrial transport cost index	[\$/km]	<\$0.75	\$0.75-\$1.00	>\$1.00
Emergency response	[hrs]	>2	0.25-2	<0.25
Resources available	Disaster response contractors	<10	10-20	>20

A more pro-active, future-focused approach to measuring transport resilience may enhance engineering methods. For example, Serulle's (2010) transport resilience measurement method draws on the concept of a transport resilience cycle (Figure 2.6). The four stages represent:

Normality: The network "operates under standard and sustained conditions".

Breakdown: The network is disrupted by a failure.

Self-annealing: The damaged network is strengthened via “transportation management practices and alternative behaviours by travellers”.

Recovery: “[F]acilities are replaced or restored and full network access is restored providing a return to normality or, in the case where restoration improves the network, to a new normality” (pp. 22-23).

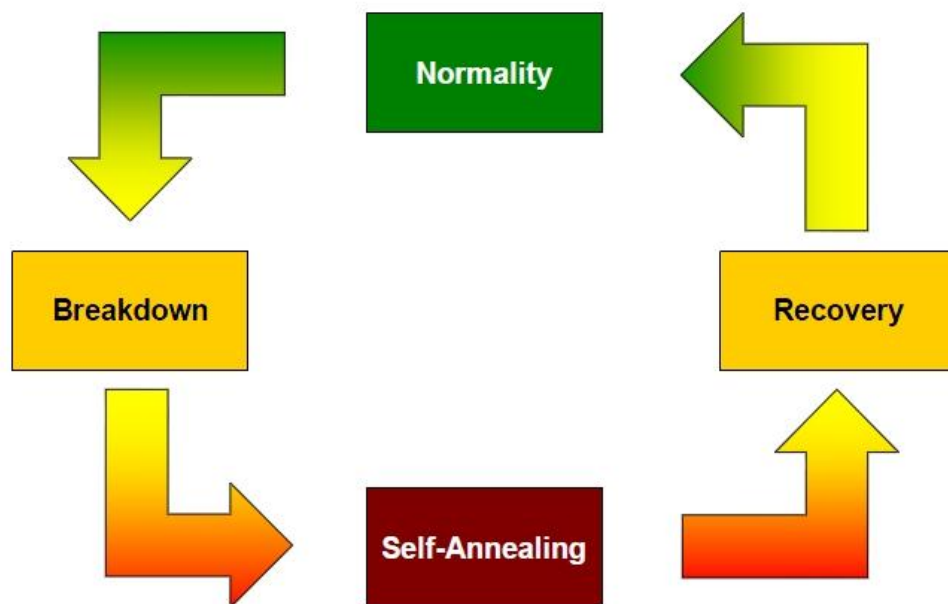


Figure 2.6 Transportation Network Resiliency Cycle
Source: Serulle, 2010, p. 23.

This conceptual model is useful for exploring the cycle of disruptions, improvements and recovery, but from a planning perspective it omits some important factors. For example, the model places limited emphasis on the future and it does not consider learning opportunities arising from adverse events. Instead, it is focused on returning to normality (albeit an enhanced normality in some cases). It does not consider ongoing efforts to enhance resilience after normality has been restored. It does not directly consider the role of institutions, which is an important factor in the planning literature on resilience (Buckle, 2006; Godschalk, 2003). As Godschalk (2003) argues, resilience requires strong leadership from government bodies, the private sector and non-governmental organisations:

Its leaders would be aware of the hazards it faces, but not afraid to take risks. They would eschew simple command and control leadership, preferring to develop networks of leadership and initiative. They would set goals and objectives, but be prepared to adapt these in light of new information and learning. They would recognize that the quest for resiliency is an ongoing long-term effort.

It is clear that developing methods for assessing the resilience of transport infrastructure is a complex and multifaceted task. There appears to be no widely accepted method for assessing road infrastructure and methods for other modes of transport appear to be even more scarce (Madhusudan & Ganapathy, 2011). Research in this area is also dominated by studies in the United States and there is an information gap for other countries (Madhusudan & Ganapathy, 2011). Gordon and Matheson (2008a, pp. 73-76) have outlined potential parameters for assessing transport network resilience in New Zealand:

Resistance: How a particular transport asset would respond a hazard event, including the likely extent of the damage and the level of functionality after the event.

Network layout: The availability of alternate routes can allow the network to continue to some extent if a key section is damaged. There are three major layouts: linear, where there is one main route and few or no alternates; dispersed, where there are some alternate routes but they are far apart; and grid, where there are many alternate routes.

Traffic volume: Disruptive events have greater impact on sections of the network with higher traffic volumes and vice versa.

Time: The likely time required to restore functionality.

Gordon and Matheson (2008a) also note that transport disruptions impact upon community wellbeing. There can be social repercussions, such as inability to access education and health services; economic impacts, such as inability to trade or transport products; and environmental damage. Gordon and Matheson (2008a) argue these factors need to be taken into account when assessing resilience.

From Gordon and Matheson's (2008a) work, and the key concepts in the broader literature on resilience assessment, it is clear that methods of assessing transport

resilience are complex and there is no established standard method. This demonstrates the value of case study examples, such as in this research project, in further developing these concepts and testing them in a real-world setting. The literature suggests transport resilience assessment methodologies should take into account factors such as the spatial layout of the transport network and the availability of suitable alternate routes, the ability of key links to withstand natural hazard events, the likely time required to restore functionality to the network, the likely impact on traffic flows and the social, economic and environmental consequences. Resilience assessment tools can be used both to assess baseline resilience and to identify ways of improving resilience (Pettit, Croxton, & Fiksel, 2013).

2.6 Planning relevance

Internationally, resilience has emerged as a key concept for planners, spurred by perceptions of increasing uncertainty and risk due to the expected impacts of climate change, fear of terrorism, recent global financial problems and other issues (Davoudi, 2012). "Yet, it is not quite clear what resilience means, beyond the simple assumption that it is good to be resilient" (Davoudi, 2012, p. 299). The 'fuzziness' surrounding the concept of resilience means it may be challenging for practitioners to effectively operationalise (Shaw & Maythorne, 2011). In the United Kingdom, planning agencies have been found to be slow in developing indicators to enable resilience to be evaluated and monitored (Shaw & Maythorne, 2011). However, the current body of academic literature appears to provide little guidance to practitioners, as Wilkinson (2012) notes: "There are surprisingly few publications that address how a resilience approach to planning might be pursued in practice" (p. 320).

Nevertheless, planning is considered to have a key role in promoting resilience (Australian Business Roundtable for Disaster Resilience and Safer Communities, 2013; Burby, 1998; The United Nations Office for Disaster Risk Reduction, 2012). Planning enables multiple stakeholders to collaborate "to identify known risks, needs and potential solutions" (The United Nations Office for Disaster Risk Reduction, 2012, p. 73). Planning should facilitate the inclusion of risk assessments in decision-making, the selection of appropriate locations for developments (avoiding hazard-prone areas) and proactive planning of future infrastructure needs and post-disaster recovery (The United Nations Office for Disaster Risk Reduction, 2012). Decisions made before, during and after adverse events shape the resilience of infrastructure systems (McDaniels, Chang, Cole, Mikawoz, & Longstaff, 2008) (see figure 2.7 below). Considering the potentially significant social and economic ramifications of transport disruptions (Gordon & Matheson, 2008a; Jenelius & Mattsson, 2012), resilience should be a priority for transport planners.

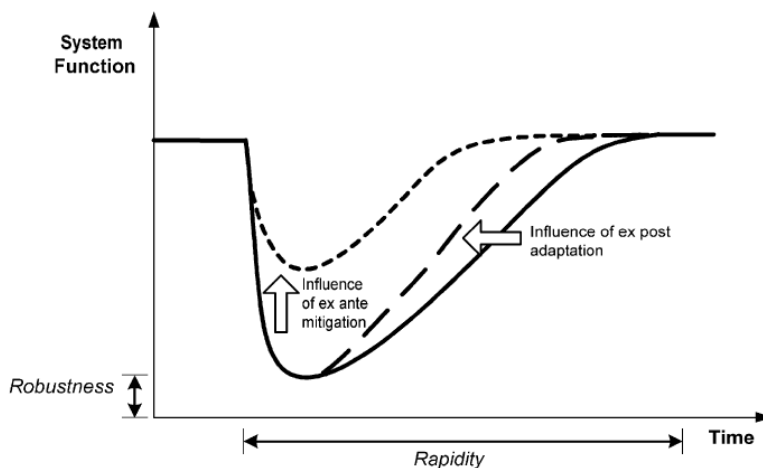


Figure 2.7 Dimensions of resilience and impacts of ex ante and ex post measures
Source: McDaniels et al. 2008, p. 312.

However, in order for effective planning decisions to be made to increase resilience, good information is required (Australian Business Roundtable for Disaster Resilience and Safer Communities, 2013). This highlights the benefits of establishing methods to measure resilience to inform transport planning.

2.7 Summary

Transport networks face a number of threats such as natural hazards and the risks of ageing infrastructure. This has led to interest in methods of assessing the resilience of transport infrastructure. Resilience in this context refers to the capacity of the transport system to absorb shocks, or to adjust and accommodate users' needs rapidly. Some work has been carried out in New Zealand on potential interactions between natural hazards and transport systems. However, further work is needed to build the resilience of transport infrastructure. Assessing resilience is a complex task, involving multiple factors. But transport resilience assessments should consider the layout of transport networks, redundancy, the capacity of key infrastructure to withstand hazard events, the time involved in restoring networks after events, and social, economic and environmental factors. Further research in this area, such as this project, is necessary to apply and further develop resilience assessment methods. Doing so should help to inform planning decisions to create more resilient transport networks and further test and develop resilience assessment methodologies.

3. Methodology

This chapter describes the methods used in this study to measure the resilience of the road and rail infrastructure in the Manawatu-Wanganui Region. Firstly, the proposed Transport Resilience Indicator Framework (RIF) will be outlined. Primarily qualitative data will be used to inform measurements of the dimensions of resilience outlined in the RIF. The quantitative data in this study came from existing data sources, while qualitative data were gathered from in-depth, semi-structured key informant interviews. This chapter discusses the strengths and weaknesses of the methods used as well as ethical considerations and the procedures to address these.

3.1 Proposed Transport Resilience Indicator Framework (RIF)

The literature review has identified that existing methods of measuring the resilience of transport infrastructure utilize mainly quantitative techniques and were developed by researchers from fields other than planning, such as engineering. However, approaching the task from a planning perspective might complement these efforts because a planning perspective might take a more future-focused approach than might, for example, an engineering approach, and considers a wider range of factors which can be assessed either quantitatively or qualitatively. Accordingly, the proposed Transport Resilience Indicator Framework (RIF) this study utilizes presents such a holistic approach (Figure 3.1). The RIF explores six key dimensions of transport infrastructure resilience:

- Engineering;
- Services;
- Ecological;
- Social;
- Economic; and
- Institutional.

By taking a holistic approach such as this, a greater number of facets of resilience can be explored. Each dimension is further explained in Table 3.1.

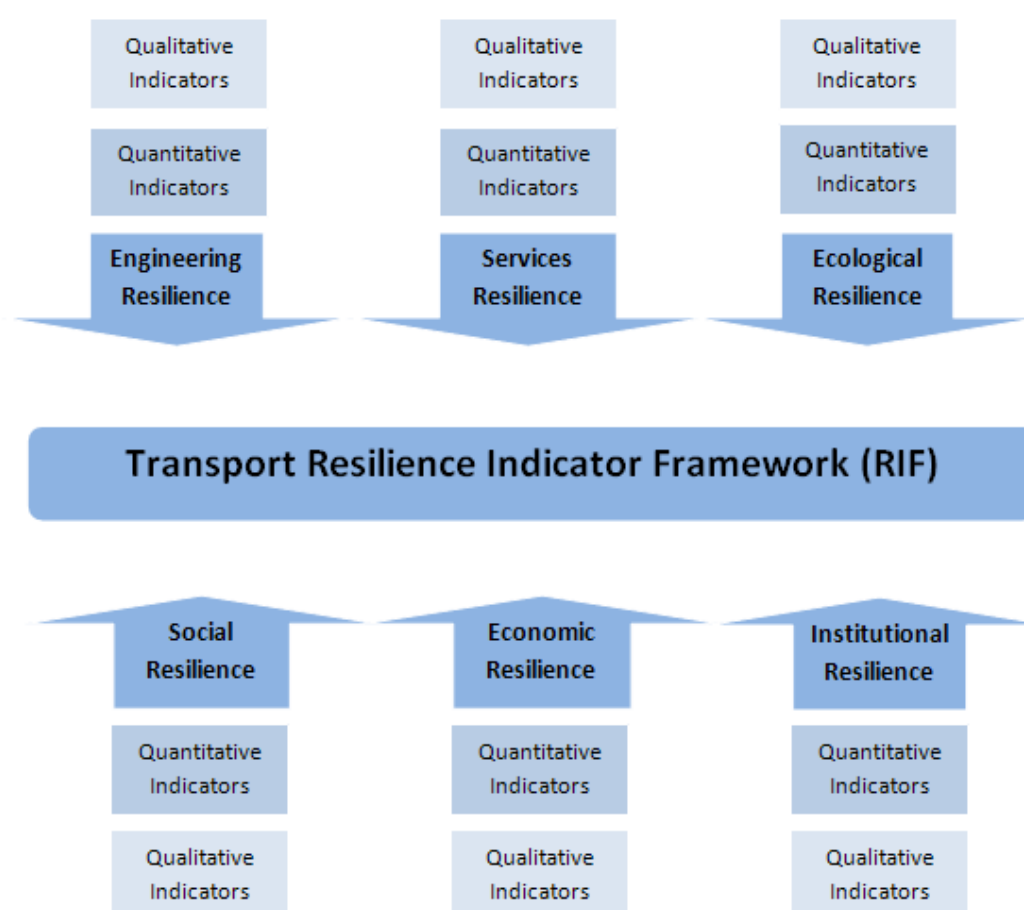


Figure 3.1 Proposed Transport Resilience Indicator Framework (RIF)

Table 3.1 Potential indicators of and data sources for the transport resilience indicator framework

Dimension	Potential indicators	Data sources
Engineering	<p>Robustness: Is new infrastructure designed and built to an appropriate standard to withstand adverse events? Do design standards take into account slow onset events such as the expected effects of climate change?</p> <p>Retrofitting/replacement: Are older, more vulnerable structures in important locations being systematically replaced or upgraded to improve performance during adverse events?</p> <p>Rapidity: How quickly can service be restored to damaged sections of the transport network? Are there any barriers to rapid restoration of service?</p>	<p>Document analysis/</p> <p>Interviews</p>
Services	<p>Choice of modes: Are there alternate modes of transport available</p>	<p>Analysis of geographic</p>

	<p>in the event of a disruption?</p> <p>Redundancy: Are there other viable routes to move people and goods if a disruption occurs on a key section of the transport network?</p>	information
Ecological	<p>Minimisation of harmful environmental impacts: Are infrastructure construction and repair works carried out in a manner which reduces environmental impacts? Are alternate routes/modes available which minimize the length of detours?</p> <p>Ecosystem services: Are ecosystem services which may help prevent or mitigate natural hazards which could disrupt the transport network (such as vegetation helping to control erosion and regulate flooding) being maintained and enhanced?</p>	<p>Document analysis/</p> <p>Interviews/ analysis of geographic information</p>
Social	<p>Emergency evacuation: Has an effective evacuation plan been formulated?</p> <p>Access to services: What measures have been put in place to ensure people, and vulnerable groups in particular, can access health and social services despite disruptions?</p> <p>Availability of alternate routes and modes</p>	Document analysis/ interviews
Economic	<p>Redundancy: Is there a range of alternate routes or modes for businesses to move goods?</p> <p>Continuity of service:</p> <p>Economic importance of transport:</p>	Document analysis/ interviews
Institutional	<p>Risk assessment and reduction: How well are transport agencies identifying and reducing risks?</p> <p>Collaboration/integration: How effectively are transport agencies working together and sharing information to reduce risks? Are they working together to manage or prevent disruptions using a network approach?</p> <p>Learning: How well are transport agencies learning from past disruptions and improving processes as a result?</p> <p>Policy: How well do transport policy documents and plans promote resilience?</p> <p>Allocation of resources: How well do funding mechanisms for transport infrastructure take resilience into account?</p>	<p>Interviews/</p> <p>document analysis</p>

3.2 Data sources

The analysis of secondary sources provided a great deal of valuable quantitative data to inform this research. As Hakim (1982) discusses, government agencies and other organisations collect a great deal of data that can aid researchers and which is available in archives. These repositories of data make large quantities of information available quickly (Hakim, 1982). Secondary data can be analysed in novel ways to inform research (Hakim, 1982). Secondary sources informing this research include traffic flow data held

by the New Zealand Transport Agency and economic data collated by the Palmerston North City Council.

In this research qualitative data were collected from key informants through in-depth interviews. Interviews have strengths and weaknesses. The key strength of interviewing is that it allows the collection of 'rich' data (Curtis & Curtis, 2011). This is because the interviewer can adapt the questions to elaborate on interesting points that are raised, and by discussing points one-on-one with informants there is more time and greater flexibility to discuss topics thoroughly (Curtis & Curtis, 2011; Ritchie & Lewis, 2003). The weaknesses include managing potentially sensitive information, the need to keep the discussion focused and deciphering the rich data that is gathered (Curtis & Curtis, 2011). However, the latter weakness can be mitigated via data management methods and issues with sensitive information can be managed by ensuring the participants are informed and comfortable with the process and the information that is revealed (Curtis & Curtis, 2011).

The following key informants were interviewed: a Destination Manawatu Board Member, Tararua District Council's Manager Strategy and District Development, a Senior Network Manager with the New Zealand Transport Agency, the St John Ambulance Dannevirke Area Committee Chairman, a Horizons Regional Council transport planner, a Mainfreight branch manager, Palmerston North City Council's road planning team leader, the Manawatu Chamber of Commerce chief executive officer and the Kiwirail Palmerston North area manager. The aim of the interviews was to elicit information about social, economic and environmental aspects of transport sector resilience in the Manawatu-Wanganui Region. The participants have considerable knowledge relating to the planning of the road network and/or its economic and social significance. They also had knowledge of the impacts and/or management of the 2011 to 2012 Manawatu Gorge closure. The gorge closure featured prominently in the interviews as it gave this project significant impetus and provided a case study of a significant transport disruption and subsequent recovery.

Potential participants were invited to take part in the project via email and telephone interviews that were undertaken in August 2013. . A participant information sheet was emailed to each participant. The interviews were semi-structured. An interview schedule was written prior to the interviews and discussed with the project supervisor. The questions were influenced by McDaniels et al.'s (2008) work that identified aspects of recovery and planning to explore dimensions of resilience in systems. Some questions were later modified, omitted or added. Before the interview, participants were asked to

complete a consent form. The interviews were digitally recorded, with the participants' consent, and then transcribed and analysed.

Before the interviews, the author and supervisor had an informal meeting with the Chief Executive of Vision Manawatu to identify previous work on this subject and how this project might add value to that work. Another informal meeting was held with Palmerston North City Council's Economic Policy Advisor to explore economic data relevant to this study. A significant amount of data, in the form of graphs and tables, was provided.

3.3 Limitations

Time constraints meant it was not possible to interview a larger number of key informants who might have added valuable qualitative data to this research, such as freight companies and staff from other councils in the region. In some cases, the short timeframe and lack of availability of potential interviewees was a factor. Also, not all of the data sought were obtained, including road crash statistics and traffic flow data during the Manawatu Gorge closure.

3.4 Summary

The research aims to develop a more comprehensive understanding of the resilience of land transport infrastructure in the Manawatu-Wanganui region through both qualitative and quantitative data. This, in turn, is intended to contribute to a critical analysis of how transport sector resilience might be measured. The research involved both desktop data collection and key informant interviews with land transport planners, operators and other stakeholders.

4. Results

The desktop and interview data collected for this project is organised into six sections. Each represents one dimension of the Transport Resilience Indicator Framework (RIF) discussed in chapter 3. This holistic approach will enable these important factors to be explored in depth.

4.1 Institutional factors

There are several key institutions responsible for managing transport networks in the region. They include: The New Zealand Transport Agency, which manages the state highway network and is involved in key strategic transport decisions; Horizons Regional Council, which plays a key role in setting the region's strategic direction for transport; territorial local authorities, which manage local road networks; and Kiwirail, which manages the rail network. This section explores how these institutions identify vulnerabilities in the transport network, collaborate and learn from disruptions and allocate resources to improve the resilience of the transport network.

4.1.1 Identifying vulnerabilities

The key informant interviews also explored the vulnerable parts of the Manawatu-Wanganui transport network, including the Manawatu Gorge and other areas. The New Zealand Transport Agency Senior Network Manager said the Whirokino Trestle and State Highway 56 near Opiki had been identified as vulnerable areas. The latter is flooded on a relatively frequent basis, but there are alternate routes available, while work is under way to assess the feasibility of replacing the former, he said. The agency is involved in the region's civil defence group, which enables collaboration with local authorities and utility providers to identify vulnerabilities. He considered that the Manawatu Gorge is likely to continue to pose challenges, as it is difficult to predict where and when large landslides may occur. He said this is due to the terrain the gorge is set in, with large amounts of loose rock lining the sides of the gorge as a result of erosion.

The Horizons Regional Council transport planner indicated some other potential hazards that could affect the transport network:

We also have volcanic [hazards]... not only just ... at Ruapehu but at Taranaki as well, where the predominant wind-flow will be coming from the west so a lot of the ash fall will be predicted to fall [at] Wanganui-Taumaranui, definitely as far as Palmerston North as well. Also you look at [for example,] the main rail line to Whareroa, if ... it got washed out at Wanganui for whatever reason there basically is no alternative route for rail to get to

Whareroa anymore because they've closed the Stratford-Ohakura Line. So everything would have to get trucked, you would imagine to Hawera, if the rail line got taken out. So that's certainly a bit of an issue with the large dairy component for our economy.

However, the Horizons Regional Council transport planner said he believed the region's network was reasonably resilient:

...we are quite lucky that in the majority of our region we have quite a resilient network. If you go up through National Park you've got options. If State Highway 1 is closed, you can take State Highway 4 and the other state highways which skirt around the mountain ... There tend to be... a number of options that people can use if there are closures and what have you. But it's really that Manawatu Gorge that [has] been the issue. And of course ... the Napier-Taihapa road ... has now been sealed the whole way, [which] was identified a number of years ago by the RTC as being an issue and ... needed to be sealed, not only for tourism but also for heavy vehicles. So again that's now complete, so that is another viable alternative route.

The New Zealand Transport Agency considers resilience to some extent when it evaluates proposed infrastructure projects. The Transport Agency's Senior Network Manager said projects are assessed using a benefit-cost ratio process, and resilience is considered as part of the 'strategic fit' assessment, which is designed to test how projects align with the strategic direction of transport investment (New Zealand Transport Agency, 2013d). However it must be noted that resilience is only one of a number of factors, and many are based on economic considerations (New Zealand Transport Agency, 2013d).

The Tararua District Manager Strategy and District Development said that the 2004 floods had tested the district's transport network, including the closure of 70 roads, which had identified flood-prone sections of road. He said the council has been incorporating flood mitigation measures into road upgrades and renewals since then, such as installing larger diameter pipes in culverts and replacing bridges, which has improved performance during smaller-scale flash floods.

The Palmerston North City Council road planning team leader said the council had mechanisms in place to identify and reduce natural hazards which could disrupt the local road network:

Our asset management plan ultimately lays the template for the level of service that we think we should be providing. We've also got an established road hierarchy and that would influence what decisions were made in terms of responding and ensuring good quality routes and so forth. We've got a

reasonably well established road hierarchy and that's been reviewed in the last 18 months and we've had a major investment over the last 10 years of putting in roundabouts and traffic signals where necessary to address priority on some of those routes. And so we've probably got a much better functioning strategic roading network than we had 10 years ago, in terms of ease of getting around. And that's been reflected in traffic volumes. [In] Cook St for example when we invested in the roundabouts and traffic signals down there we've more than doubled the traffic flow on that road and that really shows us that the road users now can use that road the way that it was actually intended as part of the roading hierarchy, whereas before it was having considerable crash problems. So by improving the intersections, the key nodes, we've actually improved the resilience of the network by making that road more usable by traffic and removing some of the barriers to ... flowing traffic.

The Kiwirail Palmerston North area manager said the company kept records of potential risks:

...we have a risk register which has known trouble spots and certainly if you look at them in terms of risks that are going to cause us disruptions, like whether it be landslips or dropouts or things like that, those are ranked, using a rating system. It's not perfect, no system is, and sometimes we'll get failures on something which is ranked a lot lower, but of course when you're dealing with this type of beast you can assess a risk based on slope stability, soils, water ingress, all these sorts of things, but if you've got a cloud that chooses to park itself over somewhere else and dump its load that changes the picture somewhat dramatically. It's important to identify the risks but what we can't control is the trigger event...

He said once a potential hazard was recorded in the register funding could be sought to reduce it, though this was prioritised:

...it's a sort of a national risk thing... If we've got something on a very minor line... the consequences of a failure are perhaps not as great as some other routes which carry significant traffic or passengers or things like that.

Kiwirail also had a training programme to increase staff skills in this area, he said:

... aside from our internal, sort of in-house knowledge and in-house process... we're just going through a programme of field engineering training at the moment where all our field engineers are going through a new course and a component of that is built around resilience and future proofing and so forth, so yeah we are doing that. That's being done nationally...

4.1.2 Collaboration and learning

Events such as the Manawatu Gorge closure in 2011 to 2012 also draw attention to the institutions responsible for managing the transport network, how well they work together and what they learn from such events. The Horizons Regional Council transport planner said that the Regional Transport Committee enabled collaboration between elected members from the regional council and territorial local authorities, as well as a representative of the NZTA. Council officers also had an important role in providing advice and information. Resilience was discussed in this forum as it was a key outcome of the current Regional Land Transport Strategy, which had aided the response to the Manawatu Gorge landslip:

[O]bviously then you had the Manawatu Gorge which happened about a year or so after the strategy was put into place. And so that helped in terms of when we're looking at the alternative scenarios, saying to NZTA: 'Well look actually this is big for the region in our strategy, we need to think about how we are going to get the alternative... solutions put in place as quickly as possible'. So we can say to NZTA, 'Look it's our strategy, let's work on it as quickly as possible'.

Despite the concept of resilience featuring as a key outcome in the Regional Land Transport Strategy, it had taken time to translate into action, apart from the Saddle Road upgrade, he said:

But... it's kind of funny because I guess in 2010 [when] we started that resilience is kind of one of those catchwords and people were saying 'oh things need to be resilient' and whether or not people actually knew precisely what resilience actually meant is probably a story for another day. ... [S]o actually the projects which have come through from then, they may not necessarily be looking at a resilient transport network.

Later, in response to another question about identifying hazards which may affect the region's transport network, he added:

But yeah ... I think the resiliency thing is... starting to gain a bit more of a focus I guess ... and I think people are starting to more understand what it actually means.

The Horizons Regional Council Transport Planner said council officers also had important relationships with other agencies:

But ... at officer level [we also have] quite a strong relationship with the NZTA. We've got the regional office here in Palmerston North so we work with them... pretty closely and we also ... have quite a strong relationship with officers from other regional councils as well. We... have quarterly ... regional

transport officers' meetings where we meet at a central location ... and we also have NZTA representation there at most of those meetings as well. So, we get a really good flavour of what's happening not only at national level but also at local level through our RTC. Yeah, we do have ... ongoing dialogue with all those people.

The Kiwirail Palmerston North area manager said the Engineering Lifelines Group also enabled collaboration between key institutions:

Oh, I'm a firm believer in engineering lifelines as being a good vehicle for that. Having been involved in the Hawke's Bay one a few years back, it was particularly good at bringing people together and forming those relationships and networks that are quite important when something goes bung. I think it's just been one of those things that the Manawatu Engineering Lifelines Group ... hasn't had quite the same vigour that some other groups around the country have had, which is a shame because it is a good [forum].

The ability of different parties to collaborate can be tested during disruptions, and in the case of the 2011 to 2012 Manawatu Gorge closure, State Highway 3, managed by the New Zealand Transport Agency, was blocked and the main alternate route was the Saddle Road, a local road. The Tararua District Council is responsible for managing the eastern portion of the road. The Tararua District Council Manager Strategy and District Development said the council's relationship with the New Zealand Transport Agency was strengthened by the event:

We found the way it worked in terms of us providing control back to NZTA for that temporary time as effective for their management of the complete crisis. And the changeover back, it was dealt with very fairly. So ... it was unusual but it ... showed that we were partners and we recognise that NZTA had major interest to make sure that the state highway continued to function, or the network continued to function

This productive relationship has continued after the event, he said:

Recently [the NZTA] agreed to give our engineering services in Woodville the job to professionally oversee the Saddle [road upgrade] project. So that's them returning the favour essentially to allow us the opportunity to make a difference now that it's gone from a crisis to a more stable state.

The New Zealand Transport Agency Senior Network Manager comments indicated that the agency's relationship with Tararua District Council may have influenced its planning for other vulnerable parts of the road network:

I think the lessons learned is probably working with our local authority people and tell them where our risk is ... [For example,] if it closed down we'll need to use your local road for a longer period of time. Because at the moment if it's like a day closure they're happy... but if it's longer than 2, 3 [or] 4 days you can actually see the damage on their road. That's when they'll start saying, 'Well hang on a moment, we'll need a bit of help here.' So it's just identifying these bits of road, working with the council and get a memorandum of understanding so that if this happens then we'll take over and so forth.

He said that other institutions had responded promptly while the slip was cleared and the road remediated, which meant the long duration of the closure was attributed to the magnitude of the landslide.

I thought we fast-tracked everything. Everyone came to the party. Even getting the resource consent was a quicker process. There really [were not] any issues.

... if you're in a normal project, to build a new bridge would take anywhere from 3 to 10 years because of all the processes that we have to go through. But this one we built a 60 metre long bridge and a 100 metre long retaining wall in less than 4 months.

However, the Destination Manawatu Board Member believed the 2011 to 2012 Manawatu Gorge closure had shown that local authorities across the central North Island needed to advocate more strongly to central government:

Well one of the learnings for me, was that it reinforced for me that the region, and I'm talking about not just the Manawatu, but also the Hawke's Bay [and] New Plymouth, are not well organized in terms of articulating the strength of the issue and the solutions that should be addressed.

Business people expressed some concerns about a perceived lack of communication during the closure. The Mainfreight branch manager said that while he was not sure of the challenges the authorities faced in restoring the road, he was not informed of what was happening:

...communication about where it was at, what was happening was pretty poor. It was ... basically non-existent, I don't think we heard from anybody about what was happening or what potential decisions needed to be made or who was making them.

The Manawatu Chamber of Commerce chief executive officer said that communicating with central government was difficult during the gorge closure:

I think the biggest frustration for us was trying to get central government to understand the impact it was having and to try to get them up here to have a look. And it wasn't just a little landslide; it was quite an enormous natural disaster for us as a region and for our business community. So that probably was the biggest frustration, trying to get them to understand that it was impacting.

The Manawatu Chamber of Commerce chief executive officer attributed this to the impact of the Christchurch earthquakes at the time:

I think it was just terrible timing. It sounds bad but, I think if Christchurch hadn't happened this would have been seen as quite a significant event, however you have a landslide versus a whole city crumbling – it's really nothing. So I don't think it got fixed quite as quickly or got the attention it would have got otherwise as quickly.

The Destination Manawatu Board Member said a bolder solution to the Manawatu Gorge's vulnerability to landslips was needed, funded by a user-pays system:

...the way I look at it is we are dependent upon central government policies that determine funding priorities, and they're largely about cost-benefit to determine priorities between spending and that doesn't necessarily look at what the value is to the users who may well be prepared to put a dollar on having the route through the gorge open as distinct from using an alternative over the Pahiatua Track or the Saddle Road. I would suggest that the sort of dollars that they would be prepared to put on each trip would be talking dramatic improvements to the gorge as being a possibility. But that doesn't fit necessarily with the way prioritising of funding occurs at the moment.

The Manawatu Chamber of Commerce chief executive officer said the Manawatu Gorge closure had prompted businesses to look at other modes of transport:

Well some of them were the trains of course and then others we ... were actually working with the airport on possibly getting stuff out on the planes. And then because of that we're kind of looking at now what do we have here in the region, and where does it go, and how can we get it out and do we try and extend the runway to get freight planes in here. So ... it was definitely bad at the time but it's had quite some good initiatives come from that.

4.1.3 Allocation of resources

There were some concerns expressed about the potential impacts of changes to central government funding schemes for local roads, particularly the FAR review. The Horizons

Regional Council transport planner indicated it could have a significant effect on some territorial authorities, such as Tararua District Council:

I think Tararua [has] got one of the largest... roading networks in the country for their size and [a] declining ratepayer base. If also they get a decline from [central] government for their subsidy rate then that's going to have a double effect, a double whammy really for them. So, they're asking the hard questions in terms of 'hey look, do we go to just an unsealed road, let it go to an unsealed road?' And that's [going to] have a huge impact on their network and who knows what's going to happen in the future?

The Horizons Regional Council transport planner said there were also concerns about potential changes to emergency reinstatement funding outlined in the FAR review:

...one of the major uncertainties around the discussion document was what the NZTA are going to term a major event. And that really does throw up a number of questions that need to be answered. Because of course you look at Ruapehu [District], which does get a number of big events, say you get 4 or 5 big events... now do those 4 or 5 big events get called major events or are they just [classed] as business as usual? The ... NZTA are... saying ... a solution is basically that Ruapehu should set aside, for lack of a better word, a slush fund for emergency events, but with the Local Government Act ... they effectively can't do that, they need to be spending their money as transparently as possible and you just can't rate for a rainy day.

The Horizons Regional Council transport planner said there could be difficulty getting funding to replace ageing transport infrastructure, particularly for new capital projects:

Yeah, I mean if it's going to be a new capital project then there certainly [are] issues because most of the money for capital projects is tied up with Roads of National Significance. If it sort of comes to the end of its life then it can go through under the ... maintenance and ops ... category. So then things might be ... easier. But it's not easy because you've still [got to] find that local share component from your ratepayers and any major investment on infrastructure is really hard to get that local share component these days ... And again with the FAR rates, who knows how that's going to work out ... particularly with your Tararuas and your Ruapehus, they're potentially facing quite a large loss of subsidy from NZTA.

The Palmerston North City Council road planning team leader said there was sufficient funding to maintain the local road network, but there were some issues with capital improvement projects:

Maintaining the network is generally still well funded and resources are adequate for that to occur. There's a little bit of tension in the system over

capital improvements to networks and where this probably most manifests itself is actually, it's difficult for us to replace ageing structures.

He said the Milson Line rail overbridge was an example of this:

Ultimately the best option is to replace that bridge and next decade that's coming up 100 years old, and so at some stage what tends to happen is that bridges get older, they lose their strength and so the level of service ultimately diminishes. In an ideal world the funding would be available to replace it. But such is the demand on the capital improvements budget that it probably usually takes a little bit more time. Now we haven't tested that yet. We're not yet at the stage where the bridge has got a reduced carrying capacity. It can't carry overweight loads but it can carry loads to the legal weight restriction at the moment. So it's operating with an acceptable level of service. At some stage in the future that level of service will diminish and we'll have to start banning larger trucks from it. Given its proximity to the airport and the industrial areas that might or might not become a significant issue.

The Palmerston North City Council road planning team leader said central government's funding policy made it difficult for places like Palmerston North to acquire funding for capital projects:

...any applications for NZTA funding have to be looked at from a national priority perspective and at the moment the government policy statement on road funding allocates priority based on three considerations; the efficiency of the solution, the effectiveness of the solution and the strategic fit of the solution. Probably the one we have the most trouble with in Palmerston North is the strategic fit because basically ... our roading network in the national sense, is a lower priority simply because [it is] not that congested, not carrying such heavy loads as others, there are alternate routes available, those sorts of things. So the roads that are tending to get funding at the moment are in the heavily populated or congested networks. Our network generally isn't that congested so it's seen as a lower priority. That's ... the government's funding priorities. Unfortunately ... we're in this situation where we've probably have lag funding for infrastructure investment which means that ... roads are going to be developed after they're needed rather than just in time or before they're needed.

He added:

We're probably in the situation ...that many of our roading projects are resulting in some inconvenience to motorists. In other parts of the country the deficiencies in the network might be creating significant barriers to

economic activity, so at the moment we're not yet so badly affected by congestion that it is a significant barrier to economic activity and the GPS is driven by economic activity. Congested roads ultimately cost the community a great deal. So in the pecking order nationally most of our roads aren't stacking up. We have periods of congestion but they never last very long. From the city's point of view we want to keep ahead of the game. And we'd prefer to accelerate some of the roading improvements we'd like to see because there are deficiencies ... there's trucks using routes that are inappropriate for their use. There's ... pedestrian and cycle safety issues that aren't being addressed, but they don't rate in a national scheme of things as high priority.

The Palmerston North City Council road planning team leader said resilience was a consideration in the funding framework, but on a national level the region's resilience issues were not significant:

Take probably the most telling example that we have in Palmerston North, the Manawatu Gorge. When it was out for a year there were two alternate routes for motorists, albeit conceded they were offering a lower level of service. But you're talking about a 15, 20-minute delay on a long distance journey in most cases. And so from the government's perspective not really a significant barrier at all, sorry there's a bit of inconvenience here, [a] 15-minute delay. Well I think most Aucklanders would gratefully accept a 15 minute delay if they could still get to their destination. So in those terms we simply don't have the problems that other regions are having.

Acquiring funding for preventative maintenance could also be an issue for some councils, the Horizons Regional Council transport planner said:

Yeah, it is an issue ... and it all ... gets tied back again to the fact that they're not getting funding on a national level or through their local share and districts are just really keeping the asset maintained to minimum level of service and are not doing that preventative maintenance anymore because they just can't afford to. And whether or not it's going to be an issue again in the future ... it probably is, particularly if FARs get reduced, they just won't have the funding available to do the preventative maintenance. And whether or not it's too much of an issue ... [Palmerston North] City Council have ... when they haven't got the subsidy from NZTA they have just done it unsubsidised works. So whether or not that is an option for some councils, it might be for someone like the City Council, who I guess for lack of a better term are a little bit more richer than some of the smaller councils and can afford to do that. But I think for some of the smaller councils they're just not going to have the funding available to do preventative maintenance.

The Horizons Regional Council transport planner said that central government had indicated the regional or 'R' funds that are due to expire in 2015 would likely be retained in some form, though this is yet to be officially announced. Completely removing these funds would have a significant impact on the region, he said:

If it did get taken out ... it does have a major impact. Because some of the major funding we've had in recent years.... they have all come through with R funds. The way that the national prioritisation of projects now works with projects at the top levels getting N funds first and then if they still stack up they'll get R funds, potentially means that you might not be spending any of your R funds any time soon... So there's a real issue that the projects that the regions want aren't going to get funding at all. But as I say, I think the R funding mechanism will still be there, so... it's not official yet, but I think there's a very good chance.

The austere funding environment had led to innovative and collaborative responses from local government, the Horizons Regional Council transport planner said:

...basically after the last GPS where it was indicated that your maintenance and ops for local government was basically flat-lined across the country, Local Government New Zealand came up with an idea to get this Rooding Efficiency Group together and to get key players in the industry to say, 'Hey look, we've got this problem of basically flat-lined cost for maintenance and ops, how do we get better bang for our buck?' And one thing which has come up through that is this Rooding Efficiency Group and they're working [in] all TAs or most TAs and we have a group here in our region working with our roading managers to identify efficiencies and how we can do things better. And one of the possible solutions to that is in particular getting sort of a centre of excellence around geotech[nology] and bridging structures because at the moment there's probably only a few structural engineers who tend to be consultants who have that knowledge about the structures in the region. So that Rooding Efficiency Group may look at getting the sort of centre of excellence set up in the near future and where all the TAs can then say, 'Hey look... can you come out and check out our infrastructure and our structures'.

Changes in the demographic nature of some territorial local authority areas were also likely to have an impact on transport resilience in the future, the Horizons Regional Council transport planner said:

Ratepayer funding bases are declining for a lot of the rural communities. So again there's ... a resilience issue there in terms of well how do they resolve some of these issues in terms of they're not getting the ratepayer funding but they are getting increased costs where their major spend is, which is transport, which is roading, and that's an issue that a lot of these TAs are

grappling with. Whether or not it's amalgamations or things like that. That may solve some of those issues, it may create more issues, who knows?

The Kiwirail Palmerston North area manager said lack of resources could also be a problem for maintaining the rail network:

...preventative maintenance is funded primarily by the size of our trains, in other words revenue. There is an overall shortfall, see we're about well into what was called the turn-around plan, which is a plan to try and make railways self-sustainable. If we were, we'd be one of the few in the world that would be self-sustainable. Railways are a very capital-intensive organisation ... it would be fair to say that even... if everything went according to the turnaround plan ... we're going to be a little bit shy of the mark to be fully self-funding. That's funding our own capital replacements as well as maintenance, but maintenance is primarily funded out of revenue.

He added:

...when I'm talking about preventative maintenance, I'm talking about [when] we've had a failure, something's gone beyond its maintenance tolerance, we're not doing an intervention type, reliability type maintenance, we're still a long way away from that. So there's a proportion of reactive maintenance, which is quite high, rather than preventative maintenance. What we do is as things wear out we do capital replacements which I suppose in a way could be seen as preventative maintenance, but really they're replacing a life-expired component of the asset. Because ... our asset is a railway line, it's made up of lots of bits and pieces. It's not like a machine that you can predict the life and you replace it at a certain number of hours. There's so many variables that you really condition monitor and then plan replacements on condition monitoring.

The Kiwirail Palmerston North area manager said there were also issues acquiring funding for replacing infrastructure:

I've got bridges, two bridges, one in particular which is an old structure, in fact there's timber dating from 1908 and it just gives me endless grief and it is very difficult to fund replacing it.

However, he also indicated that recently there had been increased funding for maintenance compared to previous years:

I think it would be fair to say that after [the 2004 Manawatu flood] there was a dramatic change from ignoring things like drains and culverts which was... because railway money is always tight, but it was particularly tight when the company was looking to be privatised and leading up to privatisation. That

was really the last years of the previous government ownership before it was privatised. Those years really have a lot to answer for because it was in that time, that this time of the year [just before Christmas] was always the classic, oh there's no money, send all the diggers away, so all the diggers [would] get turned off and that means that none of the drains or the culverts would get dealt to and [in the 2004 Manawatu flood] all the chickens came home to roost and certainly some of our woes were caused through that lack of maintenance money. I think it would be fair to say that after that the money was certainly a lot freer for maintenance. We were allowed to do maintenance rather than have the accountants tell us that 'you will not do this', which was good.

4.2 Services

The Horizons Regional Council transport planner said public transport services could only play a limited role in assisting the movement of people during disruptions, as they were largely dependent upon the road network:

[Public transport] doesn't play a huge role because ... if a road's closed then ... trucks, cars, buses aren't [going to] go anywhere, they can't do a heck of a lot. If I was sort of scraping the bottom of the barrel, the Capital Connection could play a bit of a role in getting people from [Palmerston North] to Wellington and back if State Highway 1 is closed then that can play a role, assuming the rail's not closed as well. But general day to day I don't think really there's much of a role that we do play and I probably can't see too much of a role in the future. We've got a couple of commuter services say from Marton to [Palmerston North] and Levin to [Palmerston North], but as I say if the roads are closed then there's not a lot we can do.

The Mainfreight branch manager said that although the company utilizes the rail network for part of its operations, it had a limited role in assisting the movement of freight during the Manawatu Gorge closure:

There [are] two parts to our business, the first part is the inbound goods to the region and... Mainfreight works on a hub and spoke. So basically everything is consolidated here at the branch and then distributed throughout the region by vehicles. The rail network is limited in terms of its infrastructure, so there's not ... a rail siding in Woodville or Pahiatua, so it's not like we can just de-van [move freight from rail containers to other vehicles] ... in the likes of Woodville and then distribute from there. Everything's done from a hub here. So a lot of the inbound goods are de-vanned here, loaded onto vehicles and then moved over for delivery. Outbound goods from the area, it's just the reverse ... the vehicles are out

picking up the freight, bring[ing] it back to the hub and then we consolidate per destination and then rail from there. So in terms of our... ability to be able to service customers in terms of the outbound goods, no effect... but certainly inbound... getting goods to the customers... on that east side was certainly greatly affected.

The Kiwirail Palmerston North area manager said the company could afford to play only a limited role in providing passenger rail services, so therefore rail could not play a significant role in moving people during disruptions affecting other modes of transport:

Oh no, we're not into that sort of transport [passenger transport]. In Wellington it's a public transport thing that's run by the regional council. And of course [in Wellington] it's funded entirely out of revenue. So it's bums on seats who pay for it. It doesn't get subsidy from anywhere. And unless the bums are on the seats ... we can't afford to run it. And the Northern Explorer is perhaps the tourist market, it's not [public] transport.

4.3 Economic impacts

Transport disruptions such as the State Highway 3 Manawatu Gorge closure can have significant economic impacts. However, the data paints a nuanced picture. Data provided by Palmerston North City Council's Economic Policy Advisor (Figure 4.1) indicates that domestic visitor spending in Palmerston North City and Manawatu District remained relatively buoyant throughout the Manawatu Gorge closure. However, there appears to have been a slowing in spending in Tararua District, on the eastern side of the gorge. The Tararua District Council Manager Strategy and District Development said Woodville retailers were particularly affected by a reduction in traffic moving through the town, though this was compounded at times by other factors.

Traffic flow data from the New Zealand Transport Agency (New Zealand Transport Agency, 2011) show that the State Highway 3 Manawatu Gorge Road is an important and well-utilized link between the Manawatu-Wanganui and eastern areas. The data also show that the State Highway 3 Manawatu Gorge route is, in terms of traffic flow and utilisation by heavy vehicles, of comparable significance to the other state highways connecting Manawatu-Wanganui with southern and northern areas (Figure 4.2).

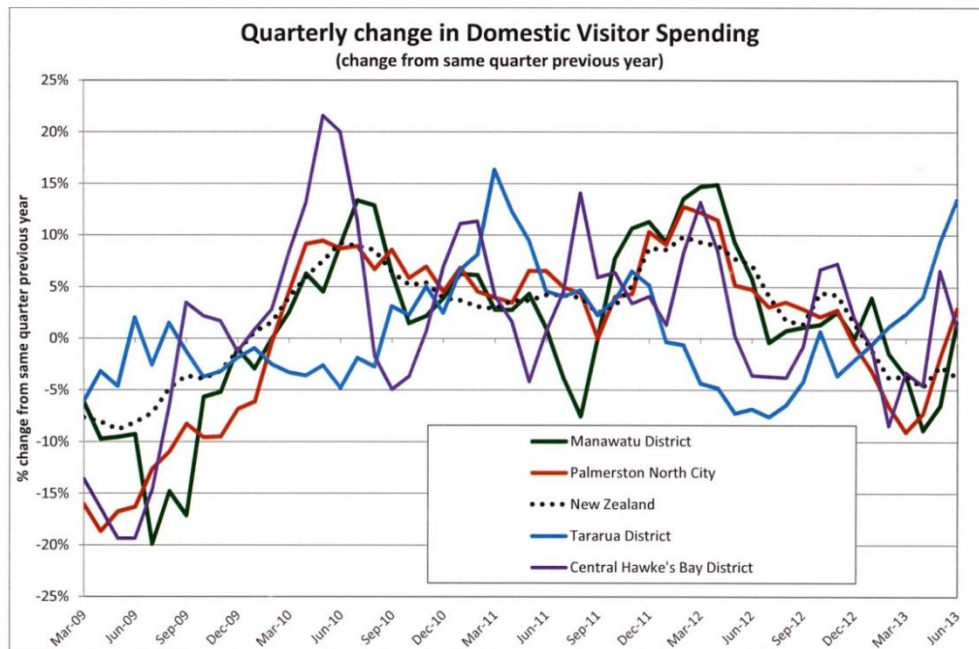


Figure 4.1 Quarterly change in domestic visitor spending March 2009 to June 2013 in selected areas of New Zealand.

Source: Palmerston North City Council Economic Policy Advisor, August 5, 2013.

During the interviews, the Destination Manawatu Board Member expressed concern that the gorge closure may have dissuaded freight businesses who were considering moving operations to the area:

I think it created a question mark for industries that are potentially looking at the Manawatu as a central place for doing distribution, in that suddenly, the east-west connection appeared vulnerable. It's always been vulnerable, but I think the scale of this highlighted the potential risks and that the solutions appeared to be having a backup that's climbing over the hills and that's almost accepted as an acceptable alternative. So I think it's quite damaging. One of the things that I believe is that the strategic strength of the Manawatu and its economy is its central location and if central location is to be exploited the economy here is dependent upon good transport linkages. It becomes more important than for any other part of the country, in my view.

The Mainfreight branch manager said the Manawatu Gorge closure highlighted the importance of the route and the inadequacy of the alternate routes:

[The Manawatu Gorge] is... an important little bit of road and it probably wasn't evident until we actually didn't have it, how important it was... As it

went on we sort of realised how much it was impacting not only our business but our ability to do business for our customers as well. The ... alternative [routes were] the biggest problem. It's not ideal for the sort of heavy traffic that needs to go across it and then I think there's wear and tear problems with the road the more the heavy traffic starting using the... alternatives, so ... operationally it was quite a big impact and again financially to the drivers and to the business, it was quite significant as well.

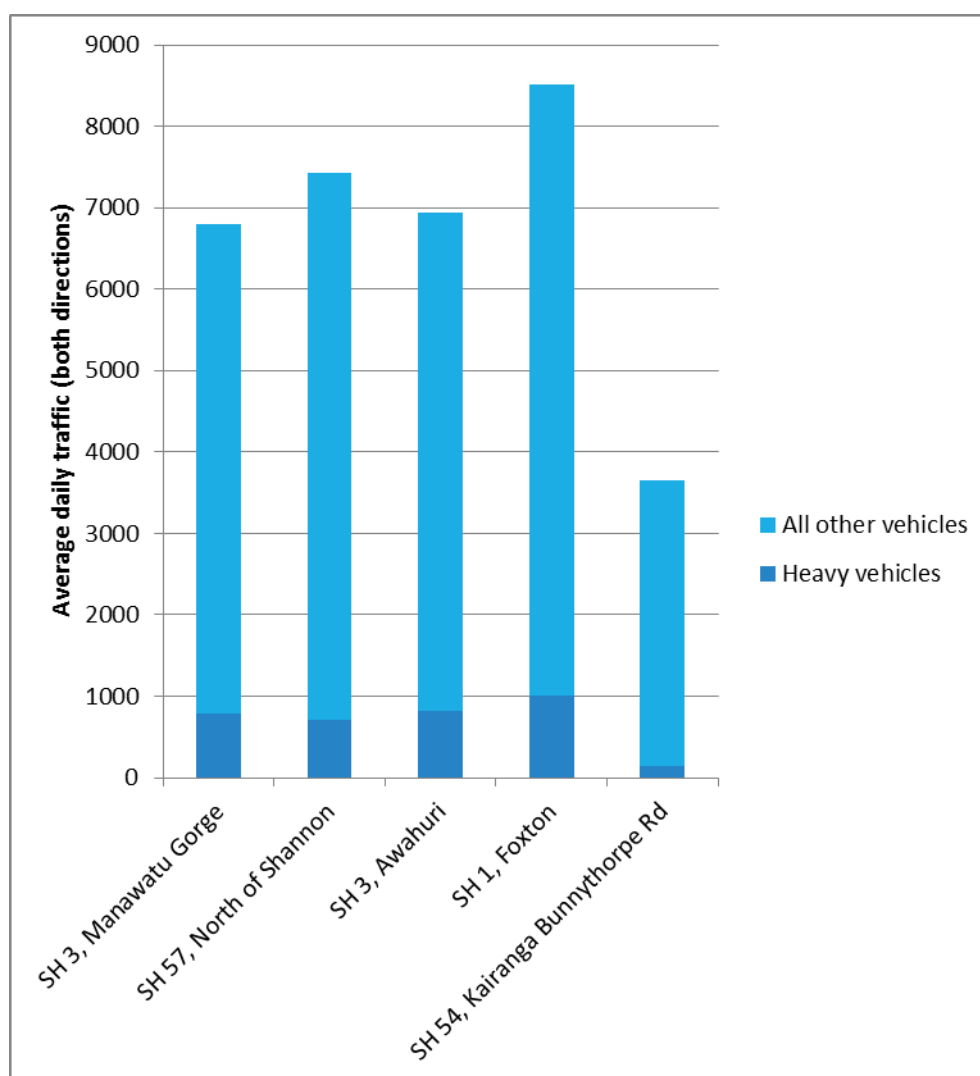


Figure 4.2 The 2006 to 2010 average traffic flow (both directions) at selected monitoring sites around Palmerston North.

Source: New Zealand Transport Agency (2011) data, compiled by authors.

It negatively affected driver productivity and increased costs in a range of areas, the Mainfreight branch manager said:

[The additional time required] was close to an hour at times, close to an hour. You do have wear and tear on the gear, but the fuel economy certainly plummeted because the truck's working a lot harder to get up... a [road] that's a lot steeper than what the gorge is, so ... all those auxiliary costs to the actual unit going across was pretty significant.

He estimated the additional costs imposed by the disruptions at approximately \$20,000 per week, although there were variations from week to week based on the freight volumes being transported. Having a reliable transport network was very important to the company:

It's huge, it's what our business is based on. If we haven't got a road or if we haven't got rail then we're not moving the freight, and that's every single commodity you can think of, ... and it just doesn't happen if those roads aren't there for whatever reason.

The Manawatu Gorge remained an area of concern and he believed alternate routes needed upgrades:

It will happen again, it's not question of if, it'll be when. And if we want to be a lot better prepared for it then ... I think the alternatives have to be [improved]. Why don't we start looking at that now rather than wait for it to happen again ... and ... not learn from the mistakes from the first time ... and delay decision-making or action.

But the Mainfreight branch manager said that overall the state of the region's transport network was not a barrier to the growth of the freight and distribution sector:

To be honest we don't have too many issues. And again ... we do cover more than the Manawatu Region, we're covering parts of the Horowhenua ... we're as far down as sort of Masterton, Dannevirke on the east, ... as far as Ohakuhne, Raetahi, National Park going north, and as far as Wanganui out to the [west]. So, in general for the Manawatu, generally not a lot of concern there in terms of the transport infrastructure... it satisfies the needs at this stage.

He later added:

I think the only limitations are the businesses themselves, but in terms of the infrastructure, no, it's not limiting.

The Manawatu Chamber of Commerce chief executive officer said the closure also had widespread impacts for other sectors of the local economy:

It was more ... people ... just wanted to go home because it was going to take a lot longer so they probably didn't spend time here after work as they normally would. There is probably a great deal of visitors that didn't come because of the [Manawatu Gorge] being closed so it would have been easier to go either up State Highway 1 or not even go over there ... and to be in Palmerston North and then try to get to the Hawke's Bay, I think a lot of visitors just went up to Taupo.

But it was difficult to quantify the economic impacts of the event, she said:

It was very, very difficult to do that. I mean we did work with [a Palmerston North City Council economist]... it was just ... too tangible for us to be able to ... a really good example is the gyms and the restaurants ... they did have decrease in usage over that time but you can't say that that was specifically [because] of the slip so...

The Manawatu Chamber of Commerce chief executive officer said that the gorge closure also showed that Palmerston North was a viable location for freight and distribution, despite the disruption to the gorge route:

... another aspect of that was it proved what a great spot we are logistically for getting stuff out because yes we couldn't get to the Hawke's Bay, or to Napier port, but we can still get to Taranaki, you can still get to Tauranga, we can still get to Auckland, so Wellington, I mean it's not hard.

4.4 Engineering

The Palmerston North City Council road planning team leader said private contractors played a key role in responding to natural hazard events that affected the road network:

...operationally, most of our response capacity exists through our maintenance contractors, which is a private contract for maintenance of the roading network. So if, for example, there was a road closure ... then there's an automatic response. The council has a 24/7 response capability through its call centre and ... so if say a road was closed, then the first response is actually to call our private contract arm out and they deal with the initial issue. Now, as and when that happens, council's roading division acts as the owner of the assets and starts making management decisions and determines whether other steps in the process need to be done and, depending on their scale, then that would depend how we would respond. But the 2004 floods that was obviously an ongoing situation. There were Civil Defence activations throughout the region. I don't think Palmerston North actually got to a full activation because we weren't immediately threatened, but the rest of the region was. But ... there's well established links there. My

boss, the roading manager, has direct responsibilities under civil defence plans so he would be primarily responsible for ensuring contact is made as necessary. But ... we do rely heavily on our maintenance contractors. And there is a little bit of issue in that our maintenance contractor might also hold contracts with the state highway. That can occasionally lead to conflict where one is given priority over another by the same firm. Basically, they have to make rationing choices and... that occasionally needs some monitoring. But generally [it] works out that... our level [of] service that we expect is being [delivered]. Obviously there's performance conditions within the contracts to ensure that ... we're not left behind, but in a major event obviously there's going to be some constraints on what can be done and how quickly it can be done.

He added:

Their main driver is safety, but obviously high volume roads such as the state highways might be seen as a higher priority than some lower volume roads. So ... some rational judgements have to be made sometimes. If it's a back country road that's carrying only a few hundred vehicles a day then it might not achieve the same level of priority under an emergency management situation.

He did not expect contractor capacity issues to lead to significant problems:

... clearly if they need to bring in any extra resources there's mechanisms for them to do that. And this is not a situation that arises often ... because these are typically rare events that we're talking about. But obviously one of the main issues is the quality of the information that's available. Obviously [if] there's a bridge out and there's ready evidence that there's a clear safety issue that would be given a high priority. If there's a slip blocking part of the road well traffic can't move around the slip and they've just got to wait. And sending up a truck to deal with that slip there's obviously going to be a response time, but nobody's going to get hurt if they can't drive past the point, so that might be a lower priority. So generally it's just common sense principles that would occur and in practice it works very well.

The Kiwirail Palmerston North area manager also identified contractor capacity as an issue:

...we learnt very early on in [the 2004 Manawatu floods] that you just brought contractors on and start paying them even if you don't use them because otherwise they will get snaffled by the road people, you'll never get anyone.

The Palmerston North City Council road planning team leader said the city's local road network was reasonably resilient as there is a high degree of redundancy in most places:

....probably one of our biggest strengths is the grid network of the city and the fact that we have alternate routes. And you can see that by some of the things that happen. [For example] we've just dug up the Fitzherbert-Fergusson intersection in town there, but generally the traffic problems there are fairly small because people are already adopting alternative routes to avoid that intersection. The nature of our network is that there is spare capacity of parallel routes and people will make use of that at times. And it's only those people that absolutely have to go to that area that will continue to use it. And so the very nature of our roading network is that it is a reasonably resilient network.

The Kiwirail Palmerston North area manager indicated that the lack of redundancy in the local rail network had led the company to instead focus on rapidity:

... the thing with rail is we can't go around things, so if we have a disruption with rail we're totally off the air, unlike roads where you can go around things easily....

He added:

...let's just say for us there's more incentive to get things working because we're out of business. We're not like NZTA, if they've got a slip in the gorge it doesn't matter if it's shut for a year, they'd just [divert traffic] over the Saddle Road. If we had a slip in the gorge for a year the company's crippled, absolutely crippled.

He said Kiwirail had a track record of restoring services after hazard events relatively quickly, which he put down to staff skills and innovation:

There's a lot of Kiwi ingenuity and a lot of very clever thinking by some very clever people that we do have or have access to for disaster recovery. We don't have time for elegantly engineered things, it just has to work. So we do have some rail specialised machinery, but that's becoming rarer and rarer now as there's less and less money, so we're reliant on trying to come up with more off the wall solutions.

The Palmerston North road planning team leader said current engineering standards were appropriate:

*... generally the standards today are much higher than they were in the past
... so assuming we build all roads to that standard we should ultimately have*

a better product, however, generally our standards follow the New Zealand Standard 4404. We have our own subdivision standards for roads, so new developments, no problem, it is being built to standard. Sometimes there will be variations on those standards dictated by circumstances. [For example,] if a road is catering for potentially a very low volume use, lifestyle block subdivisions for example won't get the intensity of development that residential areas will, so the standard can be lower. Things like absence of street lighting, footpaths, in those rural areas. Obviously it's a very different environment to what you expect when you get into the urban areas, where in the urban areas we're looking at full residential standards, kerbs, gutters, berms, footpaths, streetlights, all of those. So generally we're following the national standards, but some developments, particularly lifestyle-directed elements/developments tends to be of a lower standard and generally a higher speed limit because of the lower level of development. We're using AUROADS standards for road design when we do upgrades. We're following NZTA best practice by getting safety audits done of all our design work, so generally we're pretty well versed. If you look at a roundabout that was built 30 years ago in the city and compare it to one that's built today, it's a very different standard. What we got away with a generation ago we wouldn't get away with today. The downside of that is that there's generally a much higher cost and if anything that can slow down the potential delivery time for some of these things.

4.5 Ecological

Transport disruptions might have environmental impacts. In the case of the Manawatu Gorge closure, the alternate routes are considerably longer, suggesting that overall vehicle emissions and fuel consumption would increase if overall traffic flows on this transport corridor remained stable. While traffic flow data relating to the closure period could not be obtained, it can be inferred that overall traffic flows in this corridor did not drop significantly, based on data from the 2004 floods. In the wake of the floods both the Manawatu Gorge and Saddle Road were closed, leaving the Pahiatua Track as the only remaining route. Approximately 6,000 to 7,000 vehicles used the Pahiatua Track route per day after the storm, compared with 1000 vehicles per day in normal conditions (Horizons Regional Council, 2004, p. 2) and the annual average daily traffic flow on the Manawatu Gorge road was 6,357 vehicles (New Zealand Transport Agency, 2009, p. 30). This shows that in 2004 the overall change in the traffic flow in this corridor was relatively small, despite the disruption. It is therefore inferred that the 2011 to 2012 closure would also not have resulted in a significant reduction in vehicles using the corridor and that there was likely to have been an increase in vehicle emissions and fuel consumption, though it cannot be quantified.

The Kiwirail Palmerston North area manager said that for some time the company had been utilising ecosystem services to better manage natural hazards that may affect the rail network:

Plantings and things like that are very, very important for water control, slope control ... we're pretty well up with that. That's been business as usual since probably the 1930s and '40s.

He also said the company had taken some measures to reduce the potential environmental damage from rail accidents:

...we carry things which are environmentally not nice. One of the biggest 'environmentally-not-nices' would be milk. On the milk trains, the locomotives will carry spill kits and things like that. But it's one of those things that's been identified as quite a big risk [and it is] very, very difficult to manage it.

4.6 Social

The study sought to explore one key aspect of the social impacts of transport disruptions: the impact on health services. The interview with the St John Dannevirke Area Committee Chairman primarily explored the impacts of the 2011 to 2012 gorge closure on the Dannevirke St John health shuttle service. The chairman said most of the service's clients, including many requiring chemotherapy and dialysis, are transported to medical appointments in Palmerston North. The gorge closure had several impacts on the service, including increased overall costs due to wear and tear on vehicles and increased fuel use:

I would say it [the cost] would be about 10 per cent more... it costs us now about \$35,000 a year... to run it and with the depreciation on that it would go up to about \$60,000 I would say. So you put another 10 to 15 per cent on top of that for going over the gorge.

It also affected clients:

...it was harder on our clients... the going over the Saddle [Road] so lots of times we went round through the Pahiatua Track, but that's not really much better. And also ... it took a lot longer getting over there. And so therefore we had to start off a lot earlier in the morning and so people were sitting in the buses longer and therefore they were a bit ... grumpier. And winding up over there if you got behind a truck or something like that ... and you just imagine after a procedure in the hospital and all you want to do is get home and then you have to sit in a ... van and wind up all over those hills.

And it also placed additional demands on volunteers, which lead to rosters having to be changed:

Lots of times we wouldn't send [them] back for a second trip. Now they come back in the morning, the 6 o'clock one, the one that leaves here at half past 5, 6 o'clock will come back at about 8 and do a second trip, but lots of times we wouldn't let [them] do a second trip, we'd put someone else on, because it would be just a lot more stress on [them].

Despite the additional cost and time needed to operate the service as a result of the closure, it did not receive any additional funding or support from central government or local authorities, the St John Dannevirke Area Committee Chairman said. However, the community supported the service with donations and he said that there was nothing that central government or local authorities could have done to make coping with the closure easier for the service.

4.7 Summary

The data shows that the institutions responsible for managing the Manawatu-Wanganui Region's transport networks have systems in place to identify sections of the transport network that are vulnerable to natural hazards. They have also demonstrated that they can collaborate with one another effectively and they have learned from past disruptions. There are, however some issues around accessing funding for some projects to enhance resilience. In terms of services, the data shows the road network plays a vital role in the movement of people and goods in the region and that other modes, such as rail, can only play a limited supporting role during disruptions due to the nature of the rail network and the way it is financed. The economic data suggests that transport disruptions can have an impact on the regional economy, though it is difficult to quantify this precisely. The data also indicates that key figures in the local business community do not see the state of the region's transport infrastructure as a major barrier to economic growth. The data on engineering resilience shows that private contractors play an important role in restoring transport networks after disruptions. It also shows that managers of different networks utilize the network's inherent strengths or staff capacity to facilitate recovery from disruptions. The data also shows that transport infrastructure is important in meeting social needs, particularly for those in the adjoining Tararua District. Transport disruptions such as the Manawatu Gorge closure can also have environmental consequences, such as increased emissions and fuel consumption. Some efforts have been made to utilize ecosystem services to increase the resilience of transport networks.

5. Discussion

The data presented in the previous chapter have shown some of the impacts that disruptions to Manawatu-Wanganui Region's transport network can have. Attention will now be turned to measuring the resilience of the region's transport infrastructure utilizing the Transport Resilience Indicator Framework. Each of the dimensions of the RIF will be considered in turn.

5.1 Institutional indicators

The institutions responsible for managing the region's transport network have effective means of identifying vulnerabilities in the network. These efforts indicate that the ongoing risk of landslides and rockfall in the Manawatu Gorge State Highway 3 route makes it the most significant resilience issue facing the region's road network. The Whirokino Trestle is another key part of the region's transport network which is currently vulnerable. Whilst there clearly are vulnerabilities in some of the Manawatu's road and rail infrastructure, it must be acknowledged that some work has been carried out to make many of these areas more resilient. As discussed in the previous chapter, the 2004 floods posed a stern challenge to the region's transport infrastructure, and work has been carried out to strengthen weak areas of the network since then. Some infrastructure failed, such as the Saddle Road bridge over the Pohangina River, near Ashhurst, and was subsequently replaced (Galloway, 2006), improving robustness as a by-product of replacing such structures with newer ones. The Saddle Road was also upgraded during the Manawatu Gorge closure, with a further \$4.5 million upgrade planned (New Zealand Transport Agency, 2013c), improving this alternate route to the Manawatu Gorge. Work is also currently under way to consider a replacement for the Whirokino Trestle.

There is an appropriate degree of collaboration between the institutions responsible for managing the region's transport networks. Forums such as the Regional Transport Committee and Engineering Lifelines Group enable key institutions to work collaboratively on resilience issues. There are also less formal, but nevertheless important, relationships between council officers which allow for information sharing. However, the business people interviewed expressed some concern that they had not been informed of progress on restoring damaged transport networks and had not been able to put their concerns to some of the key figures involved.

Procuring funding for resilience-enhancing projects is also an area of concern. Funding is already difficult to source in some areas, such as for new capital roading projects, as central government's funding policy favours projects in the major metropolitan regions.

Potential changes to the funding regime, particularly the FAR review, could further limit the resources that territorial local authorities have to maintain and improve their local road networks. This is a particular concern for territorial local authorities with lengthy roading networks and relatively small populations and rates bases. This raises concerns about the future resilience of the local roading network.

5.2 Services indicators

The data suggested that the road network is the most important network for moving people and goods in the region. Public transport plays a very limited role in facilitating the movement of people in a hazardous event as it is entirely road-based. Kiwirail plays virtually no role in this regard because, due its funding arrangements, it does not offer public transport services within the region. Therefore, any disruption to the road network necessarily means that public transport services will be affected too.

The road network plays an essential role in the movement of freight. At times rail has provided an alternate means of transport during disruptions to key roads, such as during the 2011-2012 Manawatu Gorge closure (albeit in a limited fashion). But the region's rail network is mostly focused on long-distance freight movements and the rail network and infrastructure is not well placed to play a supporting role during such disruptions.

5.3 Economic indicators

Transport disruptions such as the 2011-2012 Manawatu Gorge closure have wide economic impacts. Although the data indicate such effects appeared to be reasonably well contained, they did highlight the necessity for building resilient transport networks. Firstly, the region's freight and distribution sector is particularly affected by transport disruptions. The closure of the Manawatu Gorge, for example, meant that freight trucks had to be redirected to a longer route, which significantly increased their operation costs. However, the state of the region's transport infrastructure does not appear to be a significant barrier to the continuing growth of this sector. Secondly, although Palmerston North City and Manawatu District did not experience any noticeable reduction in domestic visitor numbers during the period of the Gorge closure, Woodville retailers, who are on the other side of the transport corridor, did report weaker traffic volume. Nonetheless, the reduction could have been affected by other factors, hence no formal conclusion can be drawn. Lastly, there are also other possible, albeit unconfirmed, impacts on the local economy due to the road closure in the Manawatu Gorge. For example, commuters who used the Manawatu Gorge route might have spent less time in Palmerston North after work as it took them longer to drive back home via the alternate routes. Further studies

are required to confirm and accurately quantify the impacts of hazard events on the region's road network and economy.

5.4 Engineering indicators

This research has shown that road and rail operators face different engineering challenges in responding to hazards. The region's road network has a high degree of redundancy, most roads having alternate routes to help cope with disruptions. In terms of road maintenance and repair, most of the works are carried out by private contractors. Although these contractors have a key role in responding to transport disruptions, it appears that they sometimes lack adequate capacity to deal with disruptions in an efficient manner. Due to the fact that many private contractors involved in local roading works are also responsible for state highways, conflicts occasionally arise because the contractors have to prioritise between different roading demands. Although prioritisation of conflict goals is a relatively straightforward process and rarely becomes a major issue, it would be prudent to further examine contractors' capacity to deal with large-scale events affecting a broad geographical area.

On the other hand, Kiwirail notes that in responding to disruptions caused by hazards, rapidity overrides redundancy. This is because the rail network often lacks alternate routes, which makes the speed of recovery of a damaged route the top concern. Contractor capacity could also potentially be an issue for rail maintenance: the interview with the Kiwirail Palmerston North area manager suggested that Kiwirail may have to compete with road transport authorities for contractors in the aftermath of a hazardous event. In addition to private contractors, Kiwirail also recognises the importance of human capital and innovation in ensuring the speedy restoration of disrupted rail lines. Overall, the data suggest asset managers are using modern engineering standards and adapt their management appropriately to reflect the nature of the network they manage and its strengths and weaknesses.

5.5 Ecological indicators

The data show that the 2011 to 2012 Manawatu Gorge closure is likely to have had a range of environmental impacts, such as increased emissions and fuel consumption, though it is difficult to quantify them. These impacts would vary depending upon the location of the disruption and the length of detour routes. The data also show that some efforts have been made to utilize the ecosystems services benefits of planting to reduce the threat of natural hazards to transport infrastructure. Kiwirail has also taken measures to reduce the impact of rail operation on the environment along the rail lines, for example

by installing spill kits on trains to help prevent milk on cargo trains from spilling onto the ground or into waterways.

5.6 Social indicators

Transport network disruptions inevitably affect the movement of people and their access to social services, employment and amenities. This study looked at the impact of the 2011 to 2012 Manawatu Gorge closure on a health shuttle service. It found that although the closure led to increased operation costs and inconvenience for the service operators as well as users, the service was able to absorb the impacts of the closure thanks to the support of volunteers and the community. This highlights the need to build social capital as a means to increase community resilience to hazards.

5.7 Summary

When assessed using the six dimensions of the RIF, the strengths and weaknesses of Manawatu-Wanganui Region's transport network are revealed. The assessment shows that the institutions responsible for managing the region's transport network can effectively identify vulnerabilities in the network and collaborate and learn from past disruptions. However, concern remains over the level of funding for maintaining and upgrading the region's transport networks, particularly the local road networks managed by territorial local authorities with large networks and small rates bases. Transport services in the region are strongly dependent on the roading network, with rail playing a limited role. This means there are limited alternatives during roading network disruptions. A reliable transport network is important for the region's economy: however, despite the impacts of the 2011 to 2012 Manawatu Gorge closure, it would appear that the region's transport network is reasonably robust and does not impede economic growth. Private contractors play a crucial role in restoring services after a disruption, and their capacity to deal with major and widespread events warrants further investigation. Transport disruptions also have environmental impacts, but these are difficult to quantify. Lastly, a case study of the response of a local health shuttle service has shown Transport disruptions also have environmental impacts, but these are difficult to quantify. Lastly, a case study of the response of a local health shuttle service has shown an example of how a community service was able to adapt and respond appropriately to transport disruptions utilising social capital.

6. Conclusion

This research project sought an answer to the question: How resilient is the road and rail infrastructure in the Manawatu-Wanganui Region? The question is important as there have been a number of significant disruptions to the region's transport network in recent times, with economic, social and environmental consequences. Therefore, in the Manawatu-Wanganui Region, as in many other areas, methods of measuring the resilience of transport infrastructure would be useful tools for decision-makers to determine priorities for investment.

Due to the multifaceted nature of resilience this project utilized a holistic method of assessing transport resilience: the Transport Resilience Indicator Framework (RIF). The RIF explored six dimensions of resilience: institutional, services, economic, engineering, ecological and social factors. That exploration identified strengths and weaknesses in the region's transport network and the way it is managed. The key area of concern identified was the availability of funding for resilience-enhancing projects. That area of concern might become even more significant, particularly for territorial authorities with larger roading networks and smaller rates bases, if funding is reduced as a result of the FAR review.

Other areas could be explored to strengthen this work: the research has identified some of them, such as assessing the capacity of private contractors to respond to natural hazard events of varying magnitudes. The RIF also envisages the use of indicators based on quantitative data, in addition to qualitative data. Perhaps a fuller picture of transport resilience in the Manawatu-Wanganui Region could be built with the addition of quantitative indicators. One method of achieving this could be to adopt a multi-disciplinary approach, drawing on expertise, methods and perspectives from related professions, such as engineering and economics.

7. References

- Australian Business Roundtable for Disaster Resilience and Safer Communities. (2013). Building our nation's resilience to natural disasters.
- Bruneau, Michel, Chang, Stephanie E, Eguchi, Ronald T, Lee, George C, O'Rourke, Thomas D, Reinhorn, Andrei M, . . . von Winterfeldt, Detlof. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra*, 19(4), 733-752.
- Buckle, Philip. (2006). Assessing social resilience. In D. Paton & D. Johnston (Eds.), *Disaster resilience: An integrated approach* (pp. 88-104). Springfield, IL: Charles C Thomas Publisher.
- Burby, Raymond J. (1998). Natural hazards and land use: An introduction. In R. J. Burby (Ed.), *Cooperating with nature: Confronting natural hazards with land-use planning for sustainable communities* (pp. 1-26). Washington, D.C.: Joseph Henry Press.
- Burgess, D. (2014, July 2). Road boost welcomed but funds concern, *Stuff*. Retrieved from <http://www.stuff.co.nz/business/industries/10220806/Road-boost-welcomed-but-funds-concern>
- Chang, S. E., & Chamberlin, C. (2004). Assessing the role of lifeline systems in community disaster resilience. Buffalo, New York: Multidisciplinary Centre for Earthquake Engineering Research (MCEER).
- Chang, S. E., & Shinozuka, Masanobu. (2004). Measuring Improvements in the Disaster Resilience of Communities. *Earthquake Spectra*, 20(3), 739-755.
- Cheyne, C., & Imran, M. . (2010). Attitudes and behaviour in relation to public transport in New Zealand's non-metropolitan regions. New Zealand Transport Agency research report 419. Wellington, New Zealand: New Zealand Transport Agency.
- Curtis, Bruce, & Curtis, Cate. (2011). *Social research: A practical introduction*. London, England: SAGE Publications.
- Davoudi, Simin. (2012). Resilience: A bridging concept or a dead end? *Planning Theory & Practice*, 13(2), 299-307.
- Department for Transport, UK (2014). Transport resilience review: A review of the resilience of the transport network to extreme weather events. Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335115/transport-resilience-review-web.pdf
- Duff, Michelle. (2010, September 27). Drivers keen to snap slip, *Manawatu Standard*. Retrieved from <http://www.stuff.co.nz/manawatu-standard/news/4171002/Drivers-keen-to-snap-slip>
- Ellingham, Jimmy. (2013, August 19). Railway line nears end of slip repairs, *Manawatu Standard*. Retrieved from <http://www.stuff.co.nz/manawatu-standard/news/9059333/Railway-line-nears-end-of-slip-repairs>

- Fairclough, Roger. (2013). *Resilient Transport Infrastructure*. Paper presented at the Auckland transport infrastructure forum: Unlocking Auckland's potential, Auckland, New Zealand.
- Fonterra Co-operative Group. (2013). Expansion to Pahiatua manufacturing plant, Pahiatua Mangahao Road. Resource consent application to the Tararua District Council and Horizons Regional Council.
- Forbes, Michael. (2011, September 22). Manawatu Gorge closure costs about \$62,000 a day, *The Dominion Post*. Retrieved from <http://www.stuff.co.nz/dominion-post/news/5664229/Manawatu-Gorge-closure-costs-about-62-000-a-day>
- Fox, M. (2014). Opposition parties slate land transport plan. <http://www.stuff.co.nz/national/politics/10162805/Opposition-parties-slate-land-transport-plan>
- Freckleton, Derek, Heaslip, Kevin, Louisell, William, & Collura, John. (2012). *Evaluation of transportation network resiliency with consideration for disaster magnitude*. Paper presented at the 91st annual meeting of the Transportation Research Board, Washington, DC.
- Galloway, Jill. (2006, July 1). Saddle Road bridge finally opened, *Manawatu Standard*.
- Godschalk, David R. (2003). Urban hazard mitigation: Creating resilient cities. *Natural Hazards Review*, 4(3), 136-143.
- Google Earth. (n.d.). Google Earth version 5.2.1.1588 [cartographic software].
- Gordon, M., & Matheson, S. (2008a). Engineering lifelines and transport - should New Zealand be doing it better? Part one. Phase 1: Situation scan. Phase 2: New Zealand risk exposure. New Zealand Transport Agency Research Report 355A. Wellington, New Zealand: New Zealand Transport Agency.
- Gordon, M., & Matheson, S. (2008b). Engineering lifelines and transport – should New Zealand be doing it better? Part two. Phases 3 and 4: Gap analysis and solution development. NZ Transport Agency Research Report 355B. Wellington, New Zealand: New Zealand Transport Agency.
- Hakim, Catherine. (1982). *Secondary analysis in social research: A guide to data sources and methods with examples*. London, England: George Allen & Unwin.
- Higgins. (n.d.). *Manawatu Gorge slip project*. from <http://www.higgins.co.nz/our-projects/contractors-projects/infrastructure/manawatu-gorge-slip-project>
- Horizons Regional Council. (2010). Regional land transport strategy 2010 to 2040. Palmerston North, New Zealand: Author.
- Horizons Regional Council. (2012). The Regional Land Transport Programme 2012 - 2015.
- Horizons Regional Council. (2013). Regional Transport Committee Agenda, 03 December, 2013: Current Regional Transport Committee Work Programme.
- Horizons Regional Council. (2014). Regional Transport Committee meeting agenda, 05 March 2014. Item 7: New Zealand Transport Agency funding assistance rate review.

- Horowhenua District Council. (2013). Annual report 2012/2013.
- Hughes, J.F., & Healy, K. (2014). Measuring the resilience of transport infrastructure. NZ Transport Agency research report 546. Wellington, New Zealand: New Zealand Transport Agency,.
- Ip, WH, & Wang, Dingwei. (2011). Resilience and friability of transportation networks: evaluation, analysis and optimization. *Systems Journal, IEEE*, 5(2), 189-198.
- Jenelius, Erik. (2009). Network structure and travel patterns: explaining the geographical disparities of road network vulnerability. *Journal of Transport Geography*, 17(3), 234-244. doi: <http://dx.doi.org/10.1016/j.jtrangeo.2008.06.002>
- Jenelius, Erik, & Mattsson, Lars-Göran. (2012). Road network vulnerability analysis of area-covering disruptions: A grid-based approach with case study. *Transportation Research Part A: Policy and Practice*, 46(5), 746-760. doi: <http://dx.doi.org/10.1016/j.tra.2012.02.003>
- Kumaran, Chandrika. (2004). The floods of February 2004. *Impact*, 17.
- Lloyd, Evan. (2009). Hazard risk assessment for the Manawatu-Wanganui Region. Palmerston North, New Zealand: Horizons Regional Council.
- MacIntyre, Dave. (2012). Long term gorge solution needed, say Manawatu logistics firms. from <http://www.ftdmag.co.nz/articles/aprilmay12/manawatu.php>
- Madhusudan, C., & Ganapathy, G.P. (2011). Disaster resilience of transportation infrastructure and ports – an overview. *International Journal of Geomatics and Geosciences*, 2(2), 443-455.
- Manawatu District Council. (2013). Annual report 2012/13.
- Marketplace New Zealand. (2003). The Palmerston North retail study: Final report for Palmerston North City Council. Auckland, New Zealand: Author.
- McDaniels, Timothy, Chang, Stephanie, Cole, Darren, Mikawoz, Joseph, & Longstaff, Holly. (2008). Fostering resilience to extreme events within infrastructure systems: Characterizing decision contexts for mitigation and adaptation. *Global Environmental Change*, 18, 310-318.
- Midcentral District Health Board. (n.d.). *Palmerston North Hospital*. from <http://www.midcentralthb.govt.nz/PatientsandVisitors/PalmerstonNorthHospital/Pages/default.aspx>
- Miller-Hooks, Elise, Zhang, Xiaodong, & Faturechi, Reza. (2012). Measuring and maximizing resilience of freight transportation networks. *Computers & Operations Research*, 39(7), 1633-1643. doi: <http://dx.doi.org/10.1016/j.cor.2011.09.017>
- Ministry of Civil Defence and Emergency Management. (n.d.). Lifelines groups. from http://www.civildefence.govt.nz/memwebsite.nsf/wpg_url/for-the-cdem-sector-lifeline-utilities-lifelines-groups?opendocument
- Ministry of Transport. (2011a). Connecting New Zealand: A summary of the government's policy direction for transport. Wellington, New Zealand: Author.

- Ministry of Transport. (2011b). Government policy statement on land transport funding 2012/12-2021/22. Wellington, New Zealand: Author.
- Ministry of Transport. (2014). *Engagement draft: Government Policy Statement on Land Transport 2015/16-2024/25*.
- Ministry of Transport. (n.d.). *Questions and answers about GPS 2012*. from <http://www.transport.govt.nz/ourwork/keystrategiesandplans/gpsonlandtransportfunding/questionsandanswersaboutgps2012/>
- Myers, Dowell, & Kitsuse, Alicia. (2000). Constructing the future in planning: A survey of theories and tools. *Journal of Planning Education and Research*, 19(3), 221-231.
- New Zealand Government. (2011). National Infrastructure Plan 2011. Wellington, New Zealand: Author.
- New Zealand Transport Agency. (2009). National Land Transport Programme 2009 to 2012. Wellington, New Zealand: Author.
- New Zealand Transport Agency. (2011). State highway traffic data booklet 2006 - 2010. Wellington, New Zealand: Author.
- New Zealand Transport Agency. (2012). Network resilience. from <http://www.nzta.govt.nz/planning/nltp-2012-2015/resilience.html>
- New Zealand Transport Agency. (2013a). Funding assistance rates (FAR) review: Options discussion document. Wellington, New Zealand: Author.
- New Zealand Transport Agency. (2013b). *Funding assistance rates review: Provisional framework at a glance*. Retrieved from <http://www.nzta.govt.nz/planning/investment/docs/far-glance.pdf>.
- New Zealand Transport Agency. (2013c). NLTP Extract 2012/2015. Region: Manawatu/Wanganui. Wellington, New Zealand: Author.
- New Zealand Transport Agency. (2013d). Strategic fit for new and improved infrastructure for state highways. from <http://www.pikb.co.nz/assessment-framework/strategic-fit-2/strategic-fit-for-new-and-improved-infrastructure-for-state-highways/>
- New Zealand Transport Agency. (2014). Funding assistance rates (FAR) review. from <http://www.nzta.govt.nz/planning/investment/far-review/index.html>
- New Zealand Transport Agency. (n.d.-a). Classification of the State Highway network. from <http://www.nzta.govt.nz/planning/process/doc/final-classification.pdf>
- New Zealand Transport Agency. (n.d.-b). New Zealand state highway network resiliency.
- New Zealand Transport Agency. (n.d.-c). Roads for Manawatu-Wanganui. from <http://ipond.nzta.govt.nz/reporting/performance/workspace/ihhtml/OpenDoc?DocInstanceID=1&DocUUID=00000144ccb22021-0000-edd8-0a120385&DocVersion=1&isSmartcut=true>
- New Zealand Transport Agency. (n.d.-d). *Roads tables for selected local authorities*. from <http://ipond.nzta.govt.nz/reporting/performance/workspace/ihhtml/OpenDoc?DocI>

[nstanceID=5&DocUUID=0000013d196b8028-0000-2c8c-0a120385&DocVersion=1&isSmartcut=true](#)

- New Zealand Transport Agency. (n.d.-e). Untitled photograph of the Manawatu Gorge landslip. from <http://www.nzta.govt.nz/traffic/current-conditions/highway-info/img/manawatu-gorge-20111003.jpg>
- Newman, Peter, Beatley, Timothy, & Boyer, Heather. (2009). *Resilient cities: Responding to peak oil and climate change*. Washington, D.C.: Island Press.
- Northland Regional Council. (2013). Regional Transport Committee Agenda, November 11, 2013. Item 4.1: Decision Report: Request for the continuation of Regional ("R") Funding Post June 2015.
- Office of the Auditor-General. (2013). Transport sector: Results of the 2011/12 audits. Wellington, New Zealand: Author.
- Omer, Mayada, Mostashari, Ali, & Nilchiani, Roshanak. (2011). Measuring the Resiliency of the Manhattan Points of Entry in the Face of Severe Disruption. *American Journal of Engineering and Applied Sciences*, 4(1), 153.
- Otago Regional Council. (2012). Otago Regional Land Transport Programme 2012 - 2015.
- Palmerston North City Council. (2010). Manawatu region sector profiles 2010: Logistics and supply chain. Palmerston North, New Zealand: Author.
- Palmerston North City Council. (2011). *Mini Sector Profiles 2011 Manawatu Region: Logistics & Supply Chain*.
- Palmerston North City Council. (2013). Annual report 2012/13: Vibrant, caring, innovative & sustainable city.
- Palmerston North City Council. (n.d.). *Tertiary education providers in Palmerston North*. from <http://www.pncc.govt.nz/learning/tertiaryeducation/tertiary-education-providers-in-palmerston-north/>
- Pettit, Timothy J. , Croxton, Keely L., & Fiksel, Joseph. (2013). Ensuring Supply Chain Resilience: Development and Implementation of an Assessment Tool. *Journal of Business Logistics*, 34(1), 46-76. doi: 10.1111/jbl.12009
- Radio New Zealand. (2012, September 19). Manawatu Gorge about to fully reopen. Retrieved from <http://www.radionz.co.nz/news/national/116206/manawatu-gorge-about-to-fully-reopen>
- Rangitikei District Council. (2013). Annual report 2012-2013.
- Rankin, J. (2012, July 21). Bridge the only lifeline for Palmerston North, *Manawatu Standard*.
- Reggiani, Aura. (2012). Network resilience for transport security: Some methodological considerations. *Transport Policy*(In press). doi: <http://dx.doi.org/10.1016/j.tranpol.2012.09.007>
- Ritchie, Jane, & Lewis, Jane. (2003). *Qualitative research practice: A guide for social science students and researchers*. London, England: SAGE Publications.

- Ruapehu District Council. (2013). Annual Report 2012/13.
- Serulle, Nayel Urena. (2010). *Transportation network resiliency: A fuzzy systems approach*. ((Master of science thesis)), Utah State University, Logan, UT.
- Shaw, K, & Maythorne, L. (2011). Managing for local resilience: towards a strategic approach. *Public Policy & Administration*, 28(1), 43-65.
- Statistics New Zealand. (n.d.). *2013 Census population and dwelling tables: Manawatu-Wanganui Region: Area unit counts by territorial authority*. from <http://www.stats.govt.nz/Census/2013-census/data-tables/population-dwelling-tables/manawatu-wanganui.aspx>
- Tararua District Council. (2013). Tararua District Council annual report 1 July 2012-30 June 2013.
- Taylor, Michael A. P. (2012). Remoteness and accessibility in the vulnerability analysis of regional road networks. *Transportation Research Part A: Policy and Practice*, 46(5), 761-771. doi: <http://dx.doi.org/10.1016/j.trra.2012.02.008>
- The United Nations Office for Disaster Risk Reduction. (2012). Making cities resilient report 2012.
- Venture Taranaki. (2012). The road ahead – an economic development study into State Highway 3 north of Taranaki. New Plymouth, New Zealand: Author.
- Wanganui District Council. (2013). Annual report for the year ended 30 June 2013.
- Wilkinson, Cathy. (2012). Urban resilience: What does it mean in planning practice? *Planning Theory & Practice*, 13(2), 319-324.
- Wilkie, K & Grocott, M. (2014, August 13). Region gets \$20m inland port, *Manawatu Standard*. Retrieved from: <http://www.stuff.co.nz/manawatu-standard/news/10378186/Region-gets-20m-inland-port>
- Zhu, Shanjiang, Levinson, David, Liu, Henry X., & Harder, Kathleen. (2010). The traffic and behavioral effects of the I-35W Mississippi River bridge collapse. *Transportation Research Part A: Policy and Practice*, 44(10), 771-784.

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