Blueprint for a best practice measurement indicator set and benchmarking

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Abbreviations and acronyms

ACC	Accident Compensation Corporation
ATSB	Australian Transport Safety Board
BCR	benefit–cost ratio
BITRE	Bureau of Infrastructure, Transport and Regional Economics (Australia)
BTS	Bureau of Transport Statistics (USA)
CAU	census area unit
DfT	Department for Transport (UK)
DPSEEA	driving force, pressure, state, exposure, effect and action (environmental health indicators)
EEM	*Economic evaluation manual* (NZTA 2010)
EPA	Environmental Protection Agency (USA)
ETS	emissions trading scheme
ETSC	European Transport Safety Council
GDP	gross domestic product
GIS	geographical information system
GPS	global positioning system
IPI	individual performance indicator
IRI	International Roughness Index
LEED	linked employer-employee database
MED	Ministry of Economic Development (now the Ministry of Business, Innovation and Employment)
MoT	Ministry of Transport (New Zealand)
NLTF	National Land Transport Fund
NPI	network performance indicator
NRA	National Roads Authority (Ireland)
NZTA	New Zealand Transport Agency
OECD	Organisation for Economic Cooperation and Development
PIN	Road Safety Performance Index (ETSC)
ppm	parts per million
PSR	pressure-state-response (framework)
RoNS	roads of national significance
RSA	Road Safety Authority (Ireland)
RUC	road user charges
TAC	Transportation Association of Canada
TMIF	Transport Monitoring Indicator Framework
WEF	World Economic Forum
WoF	warrant of fitness

Contents

Executive summary

This report develops an indicator framework for measuring the contribution of land transport to the aggregate wellbeing of New Zealanders. Existing indicators used by the NZTA focus on measuring long-term impacts and achievement of strategic priorities. As such, the indicators are closely tied to policies and objectives that may change over time. There is also a lack of an overall framework of structure, making it difficult to understand relationships and trade-offs among the indicators.

In contrast, the concept of wellbeing and the principles of welfare economics provide a robust and consistent framework for measuring the overall contribution and effectiveness of land transport. The starting point is viewing transport as an input into the generation of wellbeing, reflecting the role of transport as a technology that enables human interaction, trade and other activities. Transport improves wellbeing if it better facilitates these activities and/or imposes lower costs.

This leads to categories of indicators based on observable *characteristics* of the transport system that are relevant to aggregate wellbeing, ie:

- *Network performance and capability:* Measures of the ability and performance of the transport system to move people and freight when and where demanded.
- *Safety:* Measures of the extent that individuals suffer physical injury and property damage from transport services or activities.
- *Health and environmental effects:* Indicators of the impact of transport activity on the natural environment, where those impacts have direct effects on human health or on wellbeing derived from the environment.
- *Cost:* Indicators of the financial cost to users of the transport system.

In each category, a set of indicators is chosen to measure the characteristics of the transport system that most closely relate to the category. Indicators and categories are also selected so that, where possible, there may be wellbeing trade-offs across categories but not within categories.

In addition, the Organisation for Economic Cooperation and Development's pressure-state-response framework is overlaid on the above indicator categories, to generate a two-dimensional classification of wellbeing indicators. This framework clearly separates indicators into those reflecting external forces (pressures), the current state of the transport system and policy responses over time. This separation allows the identification of external pressures and facilitates the isolation and evaluation of the impacts of responses over time.

Where possible, the recommended indicators are based on international best practice. There are established and widely used approaches for measuring some aspects of safety, health and environmental effects. This will also facilitate international benchmarking in these categories. However, for other indicators there is a wide variety of approaches used across countries, and there is no single 'best' practice. This represents an opportunity to innovate and develop indicators that are best suited for the objective of measuring wellbeing in the New Zealand context.

In addition, while indicator frameworks used in other countries may be implicitly based on wellbeing, it is not common for the linkages between transport and wellbeing to be clearly established and translated into a coherent set of indicators. A careful analysis of these linkages, as undertaken in this report, provides a useful and logically consistent basis for developing an indicator framework. In addition, the concept of wellbeing-based frameworks can be applied more generally to other sectors beyond transport, and there is an opportunity for the development of this framework to be a model for other government departments and stakeholders.

Other challenges and opportunities in the development of this framework include:

- There is a need to move away from vehicle-centric indicators and instead to focus on the efficiency of the transport system at moving *people* and *freight.*
- There is also a need to address data gaps that will affect the measurement of indicators of network performance, environmental effects and transport costs.
- Currently available data varies significantly in quality, particularly at the local or regional level, and close cooperation with regional authorities will be required to improve this.
- Data relating to public transport is currently relatively sparse and of variable quality, however integrated ticketing is expected to lead to significant improvements, and opportunities to use the data generated by integrated ticketing systems should be taken up at an early stage.

Abstract

This report develops an indicator framework for measuring the contribution of land transport to the aggregate wellbeing of New Zealanders. The starting point is viewing transport as an input into the generation of wellbeing, reflecting the role of transport as a technology that enables human interaction, trade and other activities. Transport improves wellbeing if it better facilitates these activities and/or imposes lower costs. This leads to categories of indicators based on observable *characteristics* of the transport system that are relevant to aggregate wellbeing, ie network performance and capability, safety, health and environmental effects, and cost.

1 Introduction

The NZ Transport Agency (NZTA) contracted Covec to develop a best practice indicator set for the following types of transport activity in New Zealand:

- road transport: private vehicle use, public transport and freight
- rail transport: public transport and freight.

Indicators are desired for these transport activities across economic, environmental and social dimensions. There is also a desire to use the indicators for benchmarking internationally, across regions within New Zealand and across time.

This report presents our findings and recommendations. Our research has been informed by:

- a literature review, covering land transport indicator framework structure and design, as well as actual indicators published in other countries that could be used for international benchmarking
- consultation with an NZTA expert group across various specialist fields (see appendix B for details)
- guidance from a steering group of representatives from the NZTA and the Ministry of Transport
- a data assessment of existing datasets available to the NZTA that could be used to populate proposed indicators
- our own experience in economic and policy analysis, and the development of indicator frameworks for other sectors including air and marine transport.

This report is divided into the following chapters:

- Context: Describes the frame of reference for this project and the key objectives in terms of the nature and scope of the indicators.
- Indicator framework design: Discusses high-level issues relating to the structure of the indicator framework and appropriate interpretation.
- Recommended indicators: Gives the specific details of our recommended indicator framework, the indicator definitions, the methodologies to calculate these indicators, and the data required to populate the framework.
- Data assessment: Reviews the existing datasets held by the NZTA and discusses the feasibility of populating the recommended indicators with existing data and whether any additional data is required.
- International benchmarking opportunities: Reviews the possibilities for benchmarking New Zealand land transport activities against other countries, based on indicators published internationally.
- Decision-making support assessment: Comments on the ways in which an indicator framework such as we have proposed could support land transport decision making in New Zealand.
- Summary of recommendations: Summarises our recommended indicator framework, data requirements, and interim indicators that may be used where data is currently unavailable.
- References: Works consulted during the research.
- Appendices: Details of international practice regarding transport indicators and members of our expert group.

2 Context

Land transport is a relatively data-rich sector and the NZTA has a number of datasets at its disposal. The NZTA uses these datasets in various ways, including:

- evaluating projects and programmes by monitoring specific external impacts and related research, eg environmental and safety outcomes
- measuring aggregate levels of travel demand and travel patterns
- monitoring costs and performance of specific sector investments ('output classes'), eg public transport, highways and local roads
- asset management planning and monitoring
- understanding the context ('external environment') in which land transport operates and how this context is changing over time
- measuring the NZTA's performance against its desired long-term impacts and achievement of 'strategic priorities'.

Many of these uses (and the corresponding data and indicators) are for specialised purposes. The result is a proliferation of 'micro' datasets and analyses, which are useful for those purposes but which makes it difficult to get a sense of the 'macro' contribution of land transport to the wellbeing of New Zealanders. There is no overall framework that can be used for high-level monitoring and for guiding and evaluating land transport policy development. This project seeks to fill that gap.

2.1 Existing high-level indicators used by the NZTA

The last bullet point listed above is currently the closest to a macro-level indicator framework. This flows directly from the government's current key long-term outcomes for transport and the government's strategic priorities for the NZTA. In response to these policy directions, the NZTA has developed a set of eight long-term impacts and nine corresponding indicators to measure these impacts, shown in table 2.1. These indicators are tracked by the NZTA on an on-going basis, and the indicators and a comparison of actual and desired trends are published annually in the NZTA's (2011b) *Statement of intent 2011–2014*.

As noted above, the long-term impacts and the indicators used to measure them are closely linked to government policy directions. As such the indicators may change over time as policy changes. Furthermore the indicators shown in table 2.1 lack structure and there is only a single level of detail. Thus while being useful for tracking performance against current government policy objectives, these indicators are less useful in their existing form for longer term monitoring and for guiding policy development.

Table 2.1 NZTA long-term impacts and result indicators in the *Statement of intent 2011–2014*

Impact	Indicator(s)	Desired trend
Better use of existing transport capacity	Number of VKT per network km	Increase
More efficient freight supply chains	Average daily measured weight of freight vehicles (tonnes)	Increase
A resilient and secure network	Number of resolved road closures with a duration of 12 hours or longer	Decrease
Easing of severe congestion	Number of minutes delay per km during AM peak in Auckland	Decrease
More efficient vehicle fleets	Average diesel consumption per 100 VKT	Decrease
	Average petrol consumption per 100 VKT	Decrease
Reductions in deaths and serious injuries	Number of road deaths and serious injuries per million VKT	Decrease
More transport mode choices	Percentage of survey respondents that consider public transport as a good option for taking all their work or study trips in Auckland	Increase
Reduction in adverse environmental effects	Diversity of macro invertebrates	Increase

In addition to the long-term impact indicators, the NZTA also sets and monitors performance against a number of short- to medium-term strategic priorities. These priorities and the corresponding indicators are summarised in table 2.2. These suffer from the same problems as the long-term impact indicators discussed above, and in addition they are based on current strategic priorities which may change from year to year. Thus while useful for the purpose that they were designed for, these indicators present an incomplete picture of the wellbeing contribution of land transport, and may not be very robust over time.

Table 2.2 NZTA strategic priorities and indicators in the *Statement of intent 2011–2014*

Strategic priority	Indicator(s)	Desired trend
Plan and deliver the roads of national significance (RoNS)	Percentage of RoNS activities that are delivered to agreed performance standards and timeframes	Increasing
Improve the road safety system	Number of young drivers killed per 100,000 15–24 year olds (population)	Decreasing
Improve customer service and reduce compliance costs	Percentage change in the number of transactions completed online	Increasing
Improve the effectiveness of public transport	Public transport boardings per national Land Transport Fund (NLTF) dollar invested in public transport services	Increasing
Improve the efficiency of freight movements	Average daily measured weight of freight vehicles (tonnes)	Increasing

The NZTA also monitors the performance of investments from the National Land Transport Fund (NLTF) across a range of output classes. For each output class, the NZTA reports a number of 'contextual indicators' designed to shed light on investment performance in that class. These are summarised in table 2.3. Unlike the indicators for long-term impacts and strategic priorities, the indicators in table 2.3 do not have a 'desired direction'. This is sensible, as it is not clear, for example, whether more bridge replacements are better or worse. Instead these indicators seek only to describe the context that applies to each output class and measure how the context is changing over time. Thus while useful for providing context, many of these indicators are not useful for measuring wellbeing.

Table 2.3 NZTA output classes and contextual indicators in the *Statement of Intent 2011–2014*

Output class	Contextual indicator(s)
Public transport services	Number of passengers using urban public transport services (bus, train and ferry)
	Percentage of users that rate public transport services as good or better
	Farebox recovery across networks
New and improved infrastructure for local roads	Length of road reconstruction and new roads completed (lane km)
	Length of bridge replacements (lane metres)
Renewal of local roads	Percentage of sealed network resurfaced (lane km)
	Percentage of network rehabilitated (lane km)
	Percentage of unsealed network metalled (centreline km)
	Pavement integrity of the sealed network
	Surface condition of the sealed network
	Cost of renewal of the network excluding emergency reinstatement: dollars per network lane km and cents per VKT
Maintenance and operation of local roads	Percentage of travel on smooth roads
	Cost of emergency reinstatement
	Cost of maintaining and operating the network excluding emergency work: dollars per network lane km and cents per VKT
Walking and cycling facilities	Kilometres of new footpaths, cycle lanes and cycle paths
Renewal of state highways	Cost of renewal of the network excluding emergency work: dollars per network lane km and cents per VKT
Maintenance and operation of state highways	Cost of emergency reinstatement
	Cost of maintaining and operating the network excluding emergency reinstatement: dollars per network lane km and cents per VKT
Safer Journeys and the Road Policing Programme	Number of disqualified, unlicensed, fleeing or racing drivers in fatal/serious crashes
	Number of young drivers killed, per 100,000 15–24 year olds
	Accident Compensation Corporation (ACC) entitlement claims on the motor vehicle account from motorcyclists
	Fatalities or serious injuries in crashes with alcohol/drugs, per 100,000 population
	Percentage of vehicles exceeding 100km/h and 50km/h limits
	Percentage of vehicle occupant deaths where restraints have not been worn

Output class	Contextual indicator(s)
	Fatal/serious heavy vehicle crashes where driver is at fault, per 100 million heavy VKT
	Fatal or serious injury crashes on high-risk KiwiRAP state highway routes
	Percentage of fatal and serious injury crashes attended by NZ Police
	Percentage of new vehicles with 5-star safety rating
	Number per 100,000 population of pedestrians/cyclists killed or seriously injured enough to be hospitalised for longer than one day
	Fatalities and serious injuries in fatigue and/or distraction crashes per 100,000 population
	Number of road users aged 75 years and over killed in road crashes per 100,000

2.2 Transport Monitoring Indicator Framework

The Ministry of Transport publishes the Transport Monitoring Indicator Framework (TMIF) which contains national and some regional indicators of land transport activity, as well as indicators for other transport modes.[1] The TMIF groups indicators into a number of sets around common themes:

- transport volume
- network reliability
- freight
- access to the transport system
- travel patterns
- transport safety and security
- public health effects of transport
- infrastructure and investment
- environmental impact of transport
- transport-related price indices.

Most of these sets include indicators relating to road and rail transport (table 2.4).

[1] See www.transport.govt.nz/ourwork/TMIF/Pages/default.aspx

Table 2.4 Land transport indicators contained in the TMIF

Theme	Indicators
Transport volume	• VKT • Road VKT by vehicle type, per capita and in major urban areas • Road heavy VKT by road type • Light fleet road VKT by engine size • Road VKT by fuel type • Total person km travelled • Mean light four-wheeled vehicle occupancy • Distance travelled by single occupant vehicles in major urban areas on weekdays • Total public transport boardings • Total public transport boardings per capita • Vehicle fleet numbers • Total number of first registrations of road vehicles • Average age of fleet • Average engine size of light passenger and commercial road fleet • Light vehicle fleet by engine size • Road fleet by fuel type • Vehicle ownership per capita
Network reliability	• Network congestion* • Reliability of travel time • Percentage variability of travel time • Average journey times for key corridors* • Average reliability of journey times for key corridors*
Freight/transport industry	• Freight tonne-km growth • Total freight tonne-km • Freight tonne-km by mode share • Freight tonne-km by inter-regional mode share* • Average load of heavy vehicles* • Average load factor of heavy vehicles* • Percentage of heavy vehicle empty running
Access and perceptions of transport	• Access to essential services • Percentage of population who can get to key locations door-to-door by public transport* • Percentage of the population living within 500m of a bus route • Percentage of households with access to a motor vehicle • Number of households with access to nil, one, two or three motor vehicles • Travel perceptions for bus, train, public transport, car • Total mobility boardings per year • Fully accessible buses and trains as a percentage of the total fleet* • Pecentage of fully accessible bus stops and train stations* • Number of wheelchair-accessible taxis* • Availability of accessible information about public transport services* • Farebox recovery rates

Theme	Indicators
Travel patterns	• Mode share of total trip legs • Public transport mode share of total trip legs • Ratio of public transport trip legs to driver trip legs • Mode share of journeys to work • Mode share of journeys to school
Safety and security	• Number of accidents • Number of reported road injury accidents per 100 million VKT • Number of accidents per capita • Number of fatal accidents • Number of deaths • Number of deaths on roads per 100,000 population • Number of deaths on roads per 100 million VKT • Number of injuries • Number of serious road injuries • Nuber of reported road injuries per 100,000 population • Number of reported road injuries per 100 million VKT • Number of deaths on roads with alcohol as a contributing factor • Number of deaths on roads with speed as a contributing factor • Front and rear safety belt and child restraint wearing rates • Unimpeded speeds on urban and open roads • Social cost of accidents • Perceptions of personal security while using the transport system • Personal security incidents while using the transport system* • Resilience of the transport system* • Security of the transport system*
Public health	• Road traffic noise measurements* • NO_2 concentrations • Auckland light vehicle emissions
Infrastructure and investment	• Length of state highway • Length of local roads • Length of rail track • Road quality • Rail track quality* • Bus stop quality* • Rail station quality* • Expenditure on infrastructure and services
Environmental	• CO_2-equivalent (CO_{2-e}) emissions from domestic transport • Grams of CO_2 per km driven for new vehicles entering the light fleet • Tonnes of CO_{2-e} emitted from domestic transport per vehicle km • Tonnes of CO_{2-e} emitted from domestic transport per capita • Tonnes of CO_{2-e} emitted from domestic transport per tonne km* • Tonnes of CO_{2-e} emitted from domestic transport per person km* • Energy use by domestic transport compared with remaining sectors* • Energy use per VKT by domestic transport* • Energy use per capita by domestic transport*

Theme	Indicators
	• Energy use per tonne km by domestic transport • Energy use per person km travelled by domestic transport
Transport-related price indices	• Percentage of household consumption expenditure on transport • Consumers price index – road passenger transport • Consumers price index – rail passenger transport • Producers price index – road freight transport • Regular petrol pump prices • Diesel pump prices • International oil prices • Road user charges prices

* Data is not currently available in the TMIF

The TMIF therefore provides a broad overall view of transport sector activity and is largely independent of current policy. However the TMIF lacks a direct connection to wellbeing and it is mainly descriptive in nature.

2.3 Objectives of this project

The existence of the information gap identified above led to the generation of this project. In particular there is a need for an indicator framework able to measure the contribution of land transport to the wellbeing of New Zealanders but is durable and robust to changes in policy objectives and strategic priorities.

This need not conflict with existing indicators and monitoring processes, but can complement them and provide additional structure for existing data and give additional insights into high-level policy development and performance monitoring.

The main objectives of this project were to design an indicator framework that would:

- assist policymakers with decision making
- allow evaluation of past policies
- inform investment decision making
- inform operational and tactical decision making
- provide a basis to refresh existing transport indicator frameworks
- allow benchmarking against other countries, across time and across regions within New Zealand
- embody and measure the link between transport and wellbeing.

In addition, the steering group conveyed to us a desire for a relatively simple framework that could be readily used for high-level policy analysis and evaluation, but which was hierarchical and would also support ‘drilling down’ to greater levels of detail if required. In all cases, the link back to wellbeing should be apparent.

2.4 Best practice

We have interpreted ‘best practice’ as meaning the best possible framework given the project’s objectives set out above and in particular given the desire for indicators linked to wellbeing.

As can be observed from the international review in appendix A, in terms of an overall transport indicator framework, there is no single international 'best' practice that can simply be copied and applied in New Zealand. The same is true for many (but not all) individual indicators. Different countries implement a wide range of indicators and performance measurement frameworks, depending on their own requirements.

The theoretical performance measurement literature generally considers the existence of a single best practice to be a myth (NZIER 2012). We have therefore taken the pragmatic approach of interpreting this in the way explained above. This is consistent with the 'situation driven' approach to indicators advocated by Joumard et al (2010), ie that indicators should be relevant to whatever decision is being made. In our case, the relevant decisions are high-level policy decisions that relate to the relationship between transport and wellbeing.

For particular indicators, for example in relation to environmental wellbeing, we use indicators that have broad scientific and international support. In some other cases, we recommend indicators that are not in widespread use internationally, but which are, in our view, especially suited to achieving the objectives set out above.

Where possible we have borrowed from international indicators and from the related literature, but in our view it would be a mistake to constrain a New Zealand framework to follow that used in any particular country. This also has implications for the feasibility of international benchmarking, which we discuss in chapter 6.

3 Indicator framework design

In this section we consider some high-level issues relating to developing a land transport indicator framework in line with the objectives already listed, with reference to the literature and international practice. At this stage we refrain from suggesting specific indicators and concentrate on the overall structure of the framework.

It is useful to classify indicators into categories, and for this purpose we examine the general PSR framework for indicators as adopted by the Organisation for Economic Cooperation and Development (OECD).

We also examine the concept of wellbeing (or welfare) as the overarching objective towards which transport contributes. This will help to guide our selection and design of indicators for New Zealand.

This section concludes with a discussion of the practical aspects of selection and design of transport indicators.

3.1 The OECD pressure-state-response framework

The OECD (2003) suggests two major functions of indicators:

- They reduce the number of measurements and parameters that normally would be required to give a detailed presentation of a situation.

  As a consequence, the size of an indicator set and the level of detail contained in the set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.

- They simplify the communication process by which the results of measurement are provided to the user.

  Due to this simplification and adaptation to user needs, indicators may not always meet strict scientific demands to demonstrate causal chains. Indicators should therefore be regarded as an expression of 'the best knowledge available'.

The OECD developed a framework for its environmental indicators based around the concepts of pressures, state and response. In the context of environmental indicators, these were defined as:

- pressures are human activities that affect the underlying state of the environment
- state is a measure of the quality of the environment
- response is the set of societal responses to tackle environmental problems.

This framework has been widely used and copied. Translating this framework to transport can yield a useful classification system and a means for ensuring that the full set of issues and factors is considered. For transport:

- pressures can be considered as the set of external factors that determine people's requirements for transport services and the characteristics of the transport system
- state can be thought of as the current attributes of the transport system that contribute to the benefits we obtain from it, ie the quantity and quality (broadly measured) of the transport system

- responses include the set of government interventions to tackle transport issues (eg investment levels, taxes, regulations, etc) and/or the private responses of the population that respond to the existing state.

3.2 Wellbeing indicators

The overall objective for transport policy is the improvement in human wellbeing. The concept of wellbeing extends beyond standard measures of economic output (such as gross domestic product (GDP) or income levels) to include all facets of human behaviour and interaction that affect quality of life. Appendix C expands on the difference between improvements in wellbeing and economic growth.

Definition**:** *Wellbeing* refers to the total benefits that people obtain from all that they value, including but not limited to consumption of goods and services, participation in individual or communal activities, their environment, health and overall contentment with their life and actions.

Wellbeing (or total welfare) has broad acceptance as the basis of decision making by policymakers. It is the basis of cost-benefit analysis of investments performed by the NZTA, as captured in the *Economic evaluation manual* (NZTA 2010). Wellbeing is also widely used by other government departments in New Zealand, for example:

- The Ministry of Economic Development publishes a set of economic development indicators that include indicators of wellbeing.[2]
- The Code of Conduct of the State Services Commission includes a requirement to 'strive to make a difference to the wellbeing of New Zealand and all its people'.[3]
- The Treasury's Living Standards Framework is based on wellbeing.[4]
- The Ministry of Social Development monitors indicators of wellbeing of children and young people.[5]
- Statistics New Zealand publishes indicators of family wellbeing.[6]

Transport services are mostly used to facilitate activities that lead to wellbeing, for example travelling to shops to buy goods and services, moving and delivering goods, commuting to work and school, or travelling to sports events. To be useful to policymakers, transport indicators should therefore reflect the relationship between transport and wellbeing. In this section we review the evidence for the nature of that relationship.

The discussion in this section has two objectives. In section 3.2.1, we briefly review wellbeing measurement frameworks that have been used in New Zealand and highlight the transport-related components of these.

Then in section 3.2.2 we discuss the general relationship between transport and wellbeing, and identify the characteristics of transport that may affect wellbeing. The key idea underpinning our discussion in section 3.2.2 is that transport is an *intermediary service* that *enables* wellbeing to be generated. Most of

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[2] See www.med.govt.nz/about-us/publications/publications-by-topic/economic-indicators/economic-development-indicators-2011/2011-economic-development-indicators-ch1.pdf/view

[3] See www.ssc.govt.nz/upload/downloadable_files/Code-of-conduct-StateServices.pdf

[4] See www.treasury.govt.nz/publications/research-policy/tp/higherlivingstandards/10.htm

[5] See www.msd.govt.nz/about-msd-and-our-work/publications-resources/monitoring/children-young-indicators-wellbeing/index.html

[6] See www.stats.govt.nz/browse_for_stats/people_and_communities/Families/family-well-being-indicators-report.aspx

the time, people do not derive wellbeing from transport activities directly. Rather it is the activities that transport enables that generate almost all transport-related wellbeing.

3.2.1 Existing New Zealand wellbeing measurement frameworks

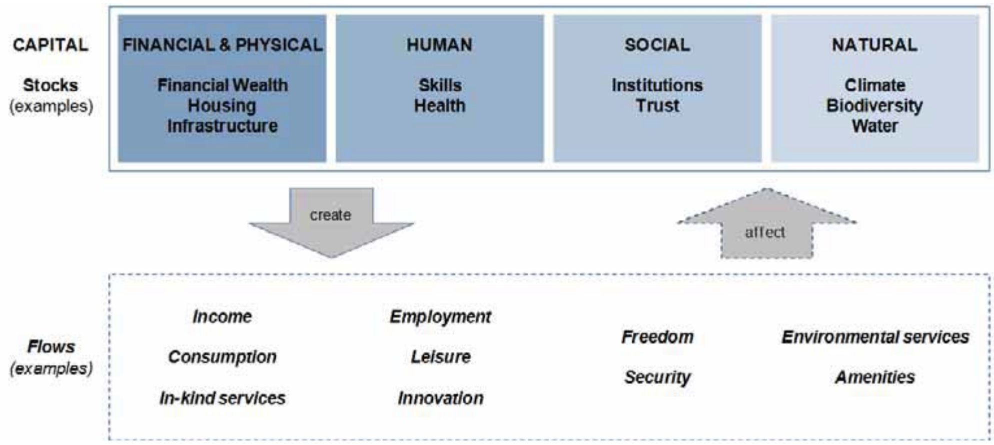
3.2.1.1 Treasury's Living Standards Report

NZ Treasury undertook research to improve its understanding of the concept of living standards as part of its work on defining and clarifying its role. It resulted in the development of a 'Living Standards Framework' intended to help Treasury to 'consistently provide Ministers with robust, theoretically grounded and evidenced-based advice that aims to improve the lives of all New Zealanders' (Gleisner et al 2011). The framework uses a capital 'stocks and flows' type approach (figure 3.1).

Consistent with the above framework, Treasury set out a series of indicators to measure the component parts. These included indicators of income, health, wealth, trust, employment, security, leisure, environment, education/skills and subjective wellbeing. Only the environment section included indicators of direct relevance to transport. It included two indicators relating to greenhouse gas emissions:

- per capita emissions
- the costs (as % of GDP) of meeting proposed 2020 targets.

Figure 3.1 Treasury's Living Standards Framework (Gleisner et al 2011)



While not being directly measured by the other indicators used by Treasury, transport is relevant to the achievement of many of the other indicators. For example, an effective transport system is a necessary underlying infrastructure to enable wealth creation and employment, to facilitate leisure activities, and to allow access to training to obtain education and skills.

3.2.1.2 New Zealand Quality of Life Survey

The regular quality of life survey of New Zealand cities measures progress against social/cultural, economic and environmental wellbeing indicators (Quality of Life Project 2007). The indicators included are described as being 'related to outcomes that are identified as being essential to maintaining and improving the quality of life in our cities'.

This includes indicators spread across 11 'domains' or areas of people's lives:

- people
- knowledge and skills
- civil and political rights
- economic standard of living

- health
- safety
- housing
- social connectedness
- economic development
- the natural environment
- built environment

There does not appear to be an empirical basis for the choice of indicators. However, with some exceptions,[7] the indicators appear to be generally related to wellbeing. Of direct relevance to transport, things measured include road safety, air quality and transport-specific indicators (table 3.1).

Table 3.1 Transport-relevant indicators in the New Zealand Quality of Life Survey

Category	Sub-category	Indicators
Safety	Road safety	Rate of serious and fatal road injuries per 10,000 population Average length of stay (nights) in hospital due to serious or fatal road crash injuries, by region Social cost of accidents ($ millions) Percentage of observed front seat adult safety belt wearers Percentage of child restraint use by children under five years
Environment	Air quality	Number of exceedances of the national environmental standard for PM_{10} (days per year) (2001 to 2005) Annual levels of PM_{10} per year (2001 to 2005) Maximum carbon monoxide (CO) level (μgm) per year, by city (2001 to 2005) Maximum nitrogen dioxide (NO_2) level (μgm-3) per year (2001 to 2005) Maximum sulphur dioxide (SO_2) level (μgm-3) per year (2001 to 2005) Maximum ozone (03) level (μgm-3) per year (2001 to 2005) Residents' rating of air pollution as a city problem (2006)
Built environment	Traffic and transport	Motor vehicle ownership per household Percentage of households with no motor vehicle – net number of vehicles registered per 1000 people Percentage of employed people aged 15 years and over who used a motor vehicle to get to work on census day Distance travelled by modes of transport Travelling time by modes of transport Percentage of employed people aged 15 years and over who travelled outside their city to work on census day
Built environment	Public transport	Residents' frequency of use of public transport in previous 12 months (2006) Percentage of residents rating 'strongly agree' and 'agree' with factors relating to public transport (2006) Residents' rating of ease of access to public transport facilities (2006)

Source: Quality of Life Project (2007)

[7] For example, 'urban housing intensification' is described as, amongst other things, being 'seen as a policy objective, linked to the development of compact cities that make more efficient use of transport systems and other infrastructure, compared to extensive suburban development'. This would appear to be a contribution towards other components of wellbeing rather than a measure of wellbeing in its own right.

3.2.1.3 Core set of national environmental indicators

The Ministry for the Environment (MfE) published a set of 22 core environmental indicators, divided among 10 domains (air, atmosphere, biodiversity, consumption, energy, fresh water, land, oceans, transport and waste); 66 variables are measured (MfE 2009).

Six criteria were used to select the 22 core national environmental indicators from a wider set of 160 indicators (table 3.2).

Table 3.2 Core environmental indicators published by the Ministry for the Environment

Criterion	Explanation
Nationally significant	There is broad agreement in New Zealand society that the environmental wellbeing that is measured has national priority. The indicator reflects progress towards environmental outcomes at a national level and is not confined to particular geographical locations. The indicator contributes to reporting across a breadth of priority national environmental outcomes.
Relevant	The indicator provides information to a level appropriate for making decisions on national policies, strategies and legislation. The indicator provides representative information on the environmental wellbeing that is measured.
Measurable and statistically sound	The indicator can be measured regularly and consistently over time to enable accurate reporting of trends. The indicator is derived from high-quality data, and is statistically and methodologically sound. Where possible, the indicator can be disaggregated to show a finer breakdown of information.
Simple and easily understood	The indicator is readily understood by a broad audience. The indicator is easy to interpret, so that change clearly represents an improvement or deterioration in what is measured.
Cost effective	Where possible, the indicator uses existing data and information. Collecting data on the indicator does not incur unreasonable costs.
Internationally comparable	Where possible, the indicator is consistent with international indicators to enable comparison of New Zealand results against international benchmarks.

The core set of indicators includes a transport domain under which VKT is measured by fuel type, vehicle age and vehicle type. In addition, of relevance to transport, concentrations of air pollutants are measured (PM_{10}, nitrogen dioxide, carbon monoxide, sulphur dioxide and ground-level ozone) and emissions of greenhouse gases.

It may be useful for the transport indicator framework to use indicators that are common to this national environmental framework. However, we note that the overall approach is currently being reviewed (MfE 2011), including institutional arrangements for indicator collection and publication.

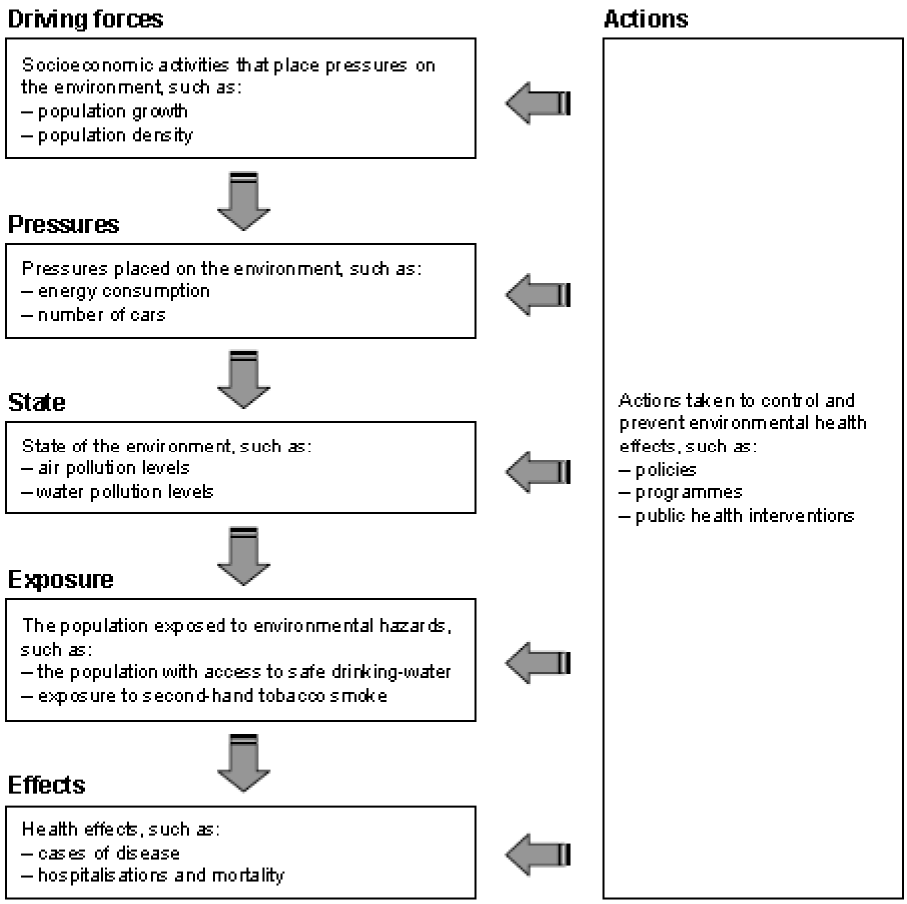
3.2.1.4 Environmental health indicators reports

The Ministry of Health has published reports on indicators of environmental health in New Zealand, the most recent of which was published for 2008 (Ministry of Health 2009). More recently a report of the same format was produced by the Centre for Public Health Research (nd). It used a World Health Organisation framework that organised indicators under the following headings: driving force, pressure, state, exposure, effect and action (DPSEEA) – see figure 3.1.

Indicators of relevance to transport included:

- pressures
  - number of vehicles by vehicle type and per person
  - average age of vehicle fleet
- state
  - exceedance of national environmental standards for particulate matter, CO, SO_2 and NO_2 in airsheds
  - hospitalisations for respiratory disease.

Figure 3.2 DPSEEA framework for environmental health indicators



Source: Centre for Public Health Research (undated)

3.2.1.5 The social report

A set of social indicators was collected and published to provide a picture of progress towards social outcomes for New Zealanders (Ministry of Social Development 2010). It reported on 43 social wellbeing indicators in 10 outcome domains (health, knowledge and skills, paid work, economic standard of living, civil and political rights, cultural identity, leisure and recreation, safety, social connectedness, life satisfaction). The criteria used in selecting the indicators were as follows:

- relevant to the social outcome of interest – the indicator should be the most accurate statistic for measuring both the level and extent of change in the social outcome of interest, and it should adequately reflect what it is intended to measure (ie it should be valid)
- based on broad support – there should be wide support for the indicators chosen so they report on a broadly shared understanding of wellbeing
- grounded in research – there should be sound evidence on key influences and factors affecting outcomes
- able to be disaggregated – ideally, it should be possible to break the data down by age, sex, socio-economic status, ethnicity, family or household type and region, so outcomes can be compared for different population groups
- consistent over time – the indicator should be able to be defined and measured consistently over time to enable the accurate monitoring of trends
- statistically sound – the indicator uses high-quality data and the method used to construct it is statistically robust
- timely – data should be collected and reported regularly to ensure indicators are providing up-to-date information
- nationally significant – the indicator reflects progress at a national level and is not confined to particular areas
- internationally comparable – as well as reflecting the social goals of New Zealanders, indicators should be consistent with those used in international monitoring programmes to enable comparisons.

Many of these seem relevant to the task of producing a set of transport indicators and were kept in mind as the indictor framework was developed.

In terms of individual indicators, a number are relevant to transport. These include:

- health – life expectancy
- safety – road casualties
- social connectedness – eg contact with family and friends.

3.2.1.6 Economic development indicators reports

The Ministry of Economic Development, the Treasury and Statistics New Zealand report on New Zealand's economic development and its contribution to wellbeing. The most recent report was published in 2011 (MED et al 2011) and updated and expanded on previous reports, published in 2003, 2005 and 2007.

The report sets out the objectives of the indicator framework:

- They are useful in monitoring progress towards economic goals and to benchmark New Zealand's performance against that of other countries. Indicators allow users to track and compare performance both in terms of high-level outcomes (such as income levels) and the underlying factors that may influence these outcomes over time (such as levels of innovation and skills).
- They help to identify potential issues with the effectiveness of economic policy that can then be investigated in greater depth. Over time the direction or pace of change in a particular indicator or set of indicators can provide information on whether policy is broadly on the right track.

- They provide information on areas of both strength and weakness within the New Zealand economy. Information on areas where New Zealand performs poorly relative to other countries may help to identify areas for policy consideration or intervention. They do not alone confirm the existence or the nature of a policy problem, but they can help highlight areas that may warrant deeper inquiry.

In other words, the indicators aim to be policy relevant, to provide information that covers the underlying causes as well as outcomes, and to be internationally comparable. These are very similar objectives to those for the transport framework.

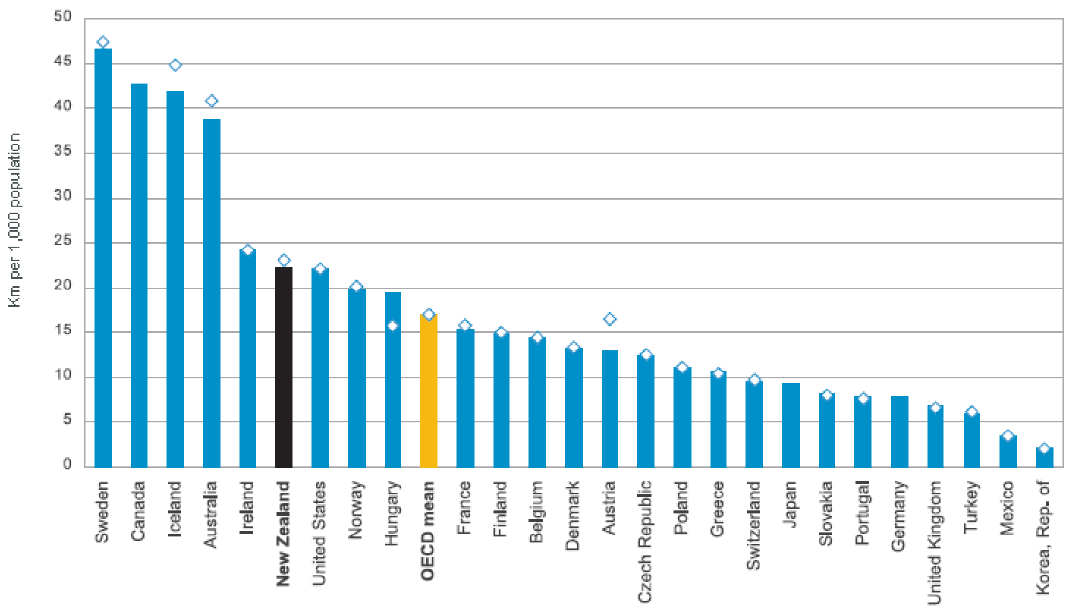
Seven core domains were used in MED et al (2011):

- wellbeing and prosperity
- immediate drivers of income growth
- composition of the New Zealand economy
- underlying determinants of productivity growth – firm and market performance
- underlying determinants of productivity growth – business environment
- New Zealand's economic relationship with Australia and its states
- Auckland – an internationally competitive city.

Relevant to transport, the 'Underlying determinants of productivity growth – business environment' category included indicators of the road infrastructure, which measured:

- the extent of road network per inhabitant (km per 1000 population) (see figure 3.3)
- road traffic (VKT).

Figure 3.3 Road network per 1000 inhabitants



Source: MED et al (2011)

3.2.1.7 New Zealand Institute report card

The New Zealand Institute produced a report card on New Zealand's social, economic and environmental wellbeing (table 3.3).

Table 3.3 New Zealand Institute report card

Social	Economic	Environmental
Life expectancy	GDP per capita	Agricultural land per capita
Unemployment	Household wealth	Water quality
Income inequality	Labour productivity	CO_2 concentration in the atmosphere
Assault mortality	Innovation and business sophistication	CO_2-equivalent emissions per capita
Suicide	Educational achievement	Invasive species

Source: New Zealand Institute (2011)

There are no transport-specific indicators and only the 'CO_2-equivalent emissions per capita' indicator is directly linked to transport.

3.2.2 Transport indicators and wellbeing

Most of the wellbeing indicators reviewed above do not provide a straightforward link to transport or to transport indicators. Transport contributes to wellbeing but does not generally do so directly. In other words, human wellbeing is not generally improved by transport itself, but wellbeing is improved by the activities that transport enables.[8] Most directly, aggregate wellbeing is affected by:

- Human interaction, including for business and social/family purposes. This includes the concept of social inclusion, ie the extent to which people participate in the normal activities of a society. Transport facilitates interaction and social inclusion.
- Trade – transport enables goods to be moved to supply productive sectors (ie freight services), to consumers or to export markets.
- Commuting – transport enables people to get to work and to school.
- External costs – transport results in a range of external costs, ie impacts on people that are separate from its primary role of moving people and things. These external costs include crashes, environmental and health impacts, which reduce wellbeing.

Therefore, transport improves aggregate wellbeing if it better facilitates activities such as human interaction, trade and commuting, and has lower external costs. This is consistent with the 'outcome-oriented' approach to indicators recommended by Hughes et al (2011). Meaningful indicators of transport's contribution to wellbeing should reflect the ways that transport may become 'better' at facilitating these activities. For example, if transport becomes faster, everything else equal, wellbeing should be higher. Similarly, wellbeing should be higher if transport becomes safer, everything else equal.

This suggests that one way to capture the relationship between transport and wellbeing is to focus on relevant characteristics, ie those that reflect the ability of the system to facilitate the generation of wellbeing, such as speed, safety, comfort, cost, and so on. An improvement in any one of these characteristics (everything else equal) means that wellbeing should be greater.

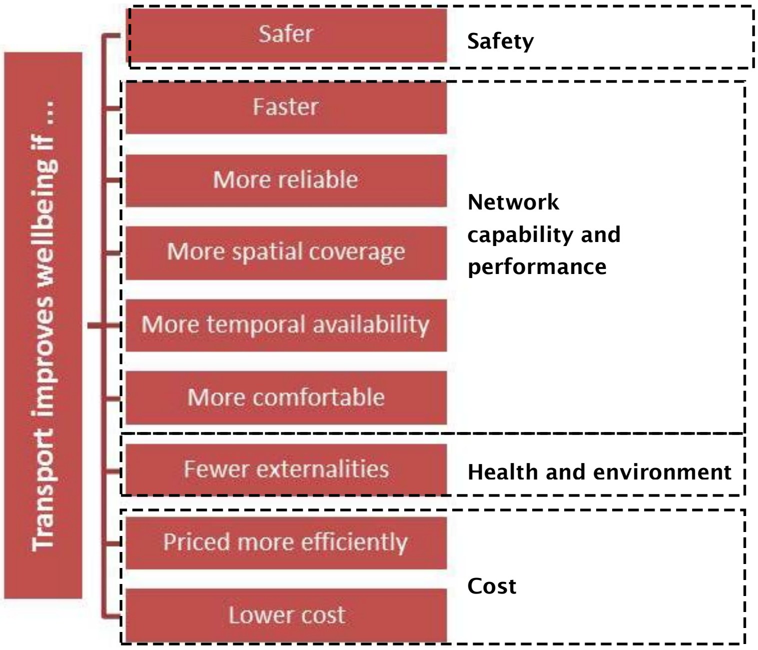
Of course, there may be trade-offs between transport characteristics. For example, an improvement in safety may require a reduction in speed. Such trade-offs will need to be taken into account by policymakers seeking to alter the characteristics of the transport system.

[8] There are some exceptions, for example some motorcyclists ride for pleasure. However we expect the wellbeing generated from such activities to be minor in comparison to the total wellbeing generated by land transport, and therefore we have not included indicators of such activities in the proposed framework.

Nevertheless, in our view, a useful starting point for a transport indicator framework would be an identification of all the relevant transport characteristics for which an improvement in the characteristic relates to an improvement in wellbeing, everything else equal. Indicators of these characteristics could then be combined with information about the relevant trade-offs when making policy decisions.

With this in mind, figure 3.4 summarises the conditions under which wellbeing from transport is improved, everything else equal. In other words, figure 3.4 lists the conditions under which wellbeing from transport will be higher if all the other conditions in the figure remain constant. Indicators that seek to measure the contribution of transport to wellbeing should aim to measure these characteristics. At this stage we have not attempted to identify all the trade-offs that may exist between these characteristics, but acknowledge that such trade-offs do exist and will need to be taken into account in policy analysis.

Figure 3.4 Conditions where wellbeing from transport is improved, everything else equal



Source: Covec

Most of these categories of wellbeing accrue directly to users of transport. More efficient pricing is somewhat different from the other wellbeing-improving items because the impacts fall to a greater extent at the level of society than they do for an individual. An individual's wellbeing is enhanced by faster, safer more reliable transport, but society is enhanced when prices are more efficient because this results in efficient allocation of resources more widely across society as a whole, ie it helps ensure that resources are allocated to those that value them most. This may generate benefits to transport users as well as those who do not use transport services, at any given time.

The transport characteristics listed in figure 3.4 are consistent with the economic benefits identified in the NZTA's *Economic evaluation model* (EEM) (NZTA 2010). In particular, the EEM identifies the following specific benefits for road projects:

- travel time cost savings
- vehicle operating cost savings
- accident cost savings
- seal extension benefits

- driver frustration reduction benefits
- risk reduction benefits
- vehicle emission reduction benefits

All these benefits are covered by one or more of the transport characteristics listed in figure 3.4.

3.3 Indicator selection and design

A number of practical issues arise in the selection and design of transport indicators. While these are relatively basic issues, it is important they are given due consideration so that the resulting indicator set is useful. This section briefly summarises discussion in the international literature on fundamental issues of selection and design of transport indicators.

Litman (2011a; b) summarises some of the key issues:

- Indicators must be carefully selected to actually provide useful information, and this usually means that a set of indicators (rather than a single indicator) is required.
- Ease of collection is another important criterion for selecting indicators – some indicators may be too costly to collect relative to the information they provide.
- Different types of indicators reflect different perspectives and assumptions, and care needs to be taken that the indicators are representative. At the same time, we must also be careful that some dimensions are not over-represented through being captured by multiple indicators.
- Many types of impacts are best evaluated using relative indicators, such as time trends, comparisons between groups or activities, or comparisons with other jurisdictions.
- The selection of reference units to normalise statistics and facilitate comparisons (eg per year, per capita, per km, etc) can affect the definition of problems and measurement of activity. For example, measuring crashes per vehicle km ignores the effects of changes in vehicle distance travelled on an individual's risk of being in a crash.[9]

From this, Litman (2011a) determines a number of best practices to apply when designing transport performance indicators:

- Comprehensive: Indicators should reflect various economic, social and environmental impacts, and various transport activities (such as both personal and freight transport).
- Data quality: Data collection practices should reflect high standards to ensure information is accurate and consistent.
- Comparable: Data collection should be standardised so the results are suitable for comparison between various jurisdictions, times and groups. Indicators should be clearly defined.
- Easy to understand: Indicators must be useful to decision makers and understandable to the general public. The more information condensed into a single index, the less meaning it has for specific policy targets and the greater the likelihood of double counting.
- Accessible and transparent: Indicators (and the data they are based on) and analysis details should be available to all stakeholders.

[9] An individual's risk of being in a crash would increase if crashes per VKT remained constant but VKT increased. The key point here is that the choice of reference units must be borne in mind when interpreting changes in indicators.

- Cost effective: The suite of indicators should be cost effective to collect. The decision-making value of the indicators must outweigh the cost of collecting them.
- Net effects: Indicators should differentiate between net (total) impacts and shifts of impacts to different locations and times.
- Performance targets: Select indicators that are suitable for establishing usable performance targets.

Similarly, Hughes et al (2011) recommended that indicators for transport performance reporting be based on the following criteria:

- Policy relevance: Indicators are relevant and important to governments and road users, monitor issues where there is a clear gap between actual and desired outcome, and have a high probability of being influenced by policy.
- Accessibility: Indicators are currently available in a timely fashion, based on nationally comparable data, with a reasonable measurement burden and free from data ownership issues.
- Representativeness and validity: Indicators measure what they are actually intended to measure and there is a policy-focused evidence base to support indicator choices.
- Reliability: Data is of high quality, is accessible and regularly updated, and indicators provide stable results across various populations and across time.
- Simplicity: Indicators are able to manage and reduce complex relationships.
- Outcomes-focused: Indicators focus on desired outcomes, not inputs, processes or outputs of policy.

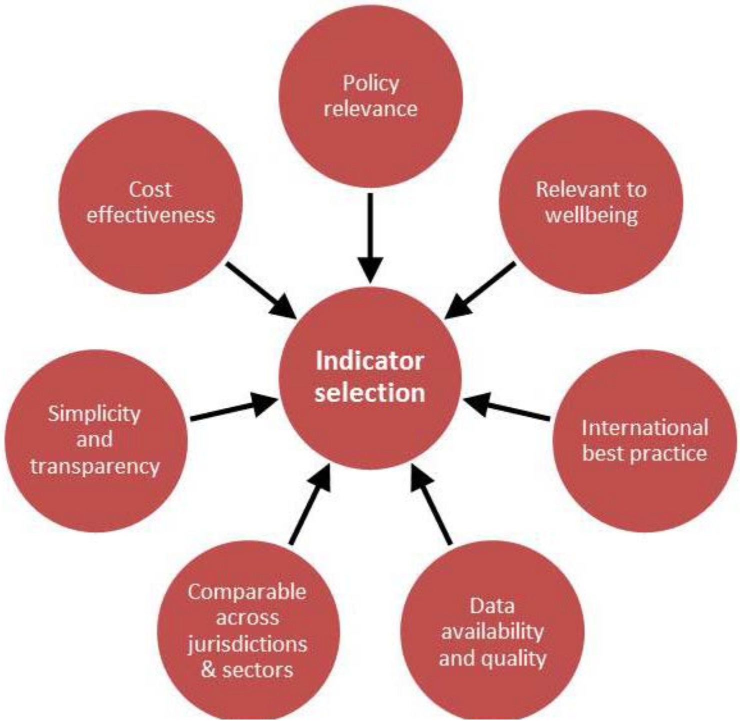
Based on an international review of transport performance benchmarking, the US Department of Transportation arrived at the following practical recommendations for the design of indicators (DOT 2004):

- Meaningful performance measurement requires extensive outreach, discussion and collaboration with partners.
- The number of performance measures should be sufficient to be useful but not so many as to be burdensome.
- Successful measurement requires accountability, to ensure high quality and reliable data.

Performance measurement is most relevant when linked to decision making, especially resource allocation.

Taking the above issues into consideration, figure 3.5 summarises the factors that we recommend be used to select indicators for use in a wellbeing-based framework.

Figure 3.5 Factors affecting selection of indicators



Source: Covec

In particular, when selecting indicators it is important to consider:

- Policy relevance: Indicators must be relevant to the actual policy 'levers' available to transport policymakers, but robust to changes in policy directions over time.
- Wellbeing: Indicators must have a clear connection to wellbeing.
- International best practice: Indicators should be consistent with international best practice and be suitable for international benchmarking, where possible.
- Data availability and quality: The actual data that is available and its quality are practical considerations in the selection of indicators.
- Comparability: To facilitate benchmarking, indicators should be comparable across jurisdictions, across time and across sectors where possible.
- Simplicity and transparency: Indicators should not be unnecessarily complex, and the data they are based on and the method of calculation should be transparent.
- Cost effectiveness: The cost of any necessary data collection or manipulation to generate indicators should be balanced against their usefulness.

3.4 Recent international developments

Appendix A contains a detailed review of the land transport indicators used and published by various organisations around the world. In this section we summarise some recent developments that are of particular relevance for this project.

3.4.1 Austroads next generation indicators

For the past 10 years, Austroads has published a set of transport measures for Australian states and New Zealand, for road transport only (Austroads 2011a). These indicators allow benchmarking across the members and over time.

Further development of the Austroads indicators between 2008 and 2011 resulted in a recommendation of a 'next generation' set of indicators (Austroads 2011b). These indicators are designed to be used for benchmarking road asset management performance. The Austroads recommendation is for a tiered set of indicators, with four high-level network performance indicators (NPIs) composed of varying numbers of individual performance indicators (IPIs). Each NPI is calculated for each Austroads member state as a weighted sum of the relevant IPIs in that state. The NPIs are summarised in table 3.4 and we give further details of each below.

Table 3.4 Structure of the Austroads proposed next generation road performance indicators

Network performance indicators (NPIs)	**Pavement condition**	**Environmental**	**Safety**	**Efficiency**
Individual performance indicators (IPIs)	• Roughness • Rutting • Cracking • Texture • Deflection	• Air quality • Fuel consumption • Noise	• Road geometry • Surface condition • Intersections • Roadside condition	• Average travel time • Variation from posted speed • Congestion • Variability of travel time • Speed and flow productivity

Source: Austroads (2011b)

The Austroads next generation framework is of interest because it is hierarchical, with the individual performance indicators aggregated to derive the four network performance indicators. There are two challenges in doing so.

One is that IPIs are measured in different units, which must be standardised prior to aggregation. Austroads recommend the use of non-linear 'transfer functions' for this purpose. These are mathematical functions that scale the values of indicators so that they are within the same range. While this is possible in some cases, using transfer functions requires making some arbitrary choices about factors used for scaling.

The second challenge is that the scaled indicators must be weighted in order to be aggregated into a single index. Again this is likely to be arbitrary and controversial and it is unlikely that a solid empirical basis can be found for all weights. The natural tendency is therefore to use equal weights, but again this is an arbitrary choice and does not necessarily reflect the relationship to wellbeing.

3.4.2 Curtin–Monash recommendations

A joint study by Curtin and Monash universities made detailed recommendations for the design and implementation of transport performance indicators in Australia (Hughes et al 2011). A key principle underlying the recommended indicators is that of 'output orientation', ie a focus on the transport outcomes that are realised rather than how these are attained. This results in indicators that 'are intended to most closely represent those attributes which people … ascribe a value to'.

The Curtin–Monash recommendations therefore specifically exclude indicators such as VKT, asset values, expenditure, and so on, as these are intermediate indicators which do not directly reflect value to road users. For example, it is not possible to interpret an increase in VKT as being a desirable or undesirable effect, as it could be driven by either people choosing to travel more (which is presumably desirable) or by an inefficiently designed road network (which is undesirable). In our view, this outcome orientation is entirely consistent with a focus on transport's contribution to wellbeing, as discussed in section 3.5.2.

Five categories of indicators are recommended in the Curtin–Monash report: productivity and efficiency, environment, safety, regulatory efficiency, and organisational strategy. Below we briefly describe the Curtin–Monash recommended indicators in each of these categories.

In our view, many of the Curtin–Monash indicators are useful and relevant because of their outcome orientation. However, we do not agree with all of the desirable indicator directions assumed by the authors. For example, the authors assert that higher household expenditure per week on public transport is 'better'. Higher expenditure could be driven by increased public transport usage or increased public transport prices, since expenditure equals usage multiplied by price. To the extent that expenditure is higher due to higher prices (everything else equal), this is a worse outcome rather than a better one.

Table 3.5 Summary of the Curtin–Monash recommended indicators (from Hughes et al 2011)

Indicator	Metric(s)
Productivity and performance indicators	
Passenger and freight costs	Percentage change in producer price index for the transport industry
	Household expenditure per week on private and public transport
	Private vehicle ownership and operating costs
Transport system competitiveness	VKT per dollar of GDP
	Percentage distribution of programmed expenditures by benefit-cost ratio
	Real GDP per person and capital-labour ratio by transport mode
Network and vehicle efficiency	Length and proportion of the road network in accordance with various quality standards
	Total and average tonne-km for road freight
	Total and average load per trip for road freight
	Laden kilometres as a proportion of business trips for road freight
	Rail network length by load limit, speed restriction and train length limit
	Number of double stack container obstructions on interstate standard gauge rail network
	Number of weight restricted rail lines
	Number of rail movements affected by weight restricted lines
	Rail tonnes carried compared with changes in rolling stock
Service quality	Travel time per road link
	Transit time per rail link
	Percentage of arrival or on-time delivery
	Number and percentages of services and delays
Social inclusion	Number of trips per household
	Average trip cost per km travelled
	Household expenditure on transport

Indicator	Metric(s)
	Number of reported public transport incidents
	Multimodal level of service indices
City density	Population per hectare for capital cities
Environmental performance indicators	
Car greenhouse gas emissions	Gigajoules of energy consumed by private cars
	Gigatonnes of CO_{2-e} emitted by private cars
Freight greenhouse gas emissions	Gigajoules of energy consumed by road and rail freight
	Gigatonnes of CO_{2-e} emitted by road and rail freight
Adoption of lower carbon passenger transport modes	Public transport proportion of urban travel
	Growth rate in cycling or walking to work as a proportion of all journeys to work
	Number of motor vehicles per 1000 resident population
Adoption of lower carbon freight transport modes	Ratio of total freight travel by mode (road or rail)
Fuel efficiency of cars	Average litres of fuel per 100km
	Average megajoules per 100km
	Average grams of CO_{2-e} per km
Fuel efficiency of freight	Average litres of fuel per 1000 net tonne-km
	Average megajoules per net tonne-km
	Average grams of CO_{2-e} per net tonne-km
Exposure to road traffic noise	Percentage of population exposed to various noise level bands
Exposure to poor air quality	Indicators of whether various air standards are met by pollutant and jurisdiction
Environmental incidents	Total number of environmental incidents reported
Safety performance indicators	
Fatalities and serious injuries	Number of people killed
	Number of people seriously injured
Safe vehicles	Percentage of new passenger car sales which are 5 star ANCAP rated
Safe roads	Traffic weighted percentage of state road length which meets AusRAP standards
Safe drivers	Percentage of vehicle occupants using seatbelts
	Percentage of drivers not exceeding drug and alcohol thresholds
Safe speeds	Percentage of vehicles not exceeding the speed limit
Fatality and serious injury rates for passenger travel	The number of people killed and seriously injured divided by passenger-km
Fatality and serious injury rates for freight	The number of people killed and seriously injured in crashes involving freight vehicles divided by freight tonne-km
Social costs of transport crashes	Annual dollar costs
Signal violations	The proportion of signals passed by train and road drivers
Regulatory efficiency performance indicators	
The value of new transport regulation	Average benefit-cost ratio of new transport regulation

Indicator	Metric(s)
Cost of regulatory compliance	Financial cost of compliance
The existing stock of regulation	Count of existing road and rail regulations
Quality of new regulation	Percentage of regulation which complies with OBPR guidelines
Age of regulation	Age of regulations in years
Time to legislate	Time taken from proposal of new regulation to time when it becomes legally binding
Organisational strategy performance indicators	
Proportion of annual objectives achieved successfully	KPI targets successfully achieved as a proportion of all KPI targets
Stakeholder survey	A survey of the views of customers, stakeholders and employees on competency, capacity, systems, innovation, leadership, delivery of services, customer focus, expectations, information and communications of transport agencies, and the performance of the road and rail transport sector
Proportion of transport reforms that align with clients' priorities	A survey-based numeric score of the consistency of transport agencies' activities with community and industry requirements

3.5 Recommended framework structure

The proposed framework is based on the core idea that the most important indicators are those that measure the direct and indirect contribution of transport to the wellbeing of New Zealanders. This is framed by thinking of transport as an *input* that enables other activities, and recognising that in most cases wellbeing is generated by the activities enabled by transport and not the transport itself. This is consistent with the latest international developments in transport indicator frameworks, as detailed in section 3.4.[10] This focus on wellbeing is also consistent with the NZTA's EEM and the recommendations of the Curtin–Monash study discussed above.

3.5.1 Measuring the transport system as a whole

Historically, transport indicators in New Zealand and elsewhere have been mode- or vehicle-centric. This is likely due to the fact that vehicle-centric indicators are relatively easy to obtain, because vehicles are relatively easy to count and track. However the ultimate purpose of the transport system is to facilitate the movement of people and freight into, out of, and around New Zealand. When there are effective mode choices, for example as public transport systems improve and become more attractive, vehicle-centric measures may present a misleading picture of the performance of the transport system as a whole. Vehicle-centric indicators also ignore changes in the productivity of vehicles, eg changes in the average load of passengers or freight carried by each vehicle. The high-level indicators recommended below

[10] For example, the recent joint Curtin–Monash University study (Hughes et al 2011) strongly recommends indicators have an *output* focus, and for this reason omit simple transport activity indicators (such as VKT) from their recommended framework. Similarly the next generation Austroads framework (Austroads 2011) contains indicators that are entirely output focused.

therefore seek to move away from vehicle- and mode-centric indicators where possible to build up a more holistic picture.

In addition, we recommend that purely activity-related indicators be de-emphasised and distinguished from other indicators that have a clear link to wellbeing. For example, many of the indicators in the TMIF relate to 'transport volume' (eg VKT, size of the vehicle fleet, etc). While useful for measuring aggregate transport activity and planning the overall scale of transport investment and funding, such indicators do not provide useful information about the performance of the transport system in moving people and freight. There is no sense in which an increase in a measure like VKT is better or worse, and such indicators are not especially useful for policy analysis or evaluation, relative to more direct measures of transport network performance.

3.5.2 Relationship to wellbeing

In particular, as explained in section 3.2.2, transport affects wellbeing by facilitating human interaction (for business and social/family purposes), trade (ie freight), and commuting, and transport also generates external costs (crashes, environmental and health effects). Transport therefore improves wellbeing if it is 'better' at facilitating human interaction, trade and commuting, and has lower external costs.

In our view, the indicator framework should focus on transport's ability to do these things.[11] For example, if transport becomes faster, *everything else equal*, wellbeing should be higher. This suggests a focus on the *characteristics* of transport that reflect the ability of the system to facilitate the generation of wellbeing, such as speed, safety, comfort, cost, etc. Within this context, figure 3.4 summarises the characteristics of transport that affect wellbeing.

The potential trade-offs between transport characteristics also provide a useful way of organising indicators into groups. It is desirable to organise indicators into groups that can provide an overview, with the ability to drill down to greater details if required. A consistent and logical way of doing this is to group the indicators so that there are potential trade-offs *between* the groups but not within each group, to the greatest extent possible. Based on the characteristics identified in figure 3.4, five indicator groups are appropriate:

- safety
- health
- environment
- network capability and performance
- cost.

3.5.3 Activity indicators

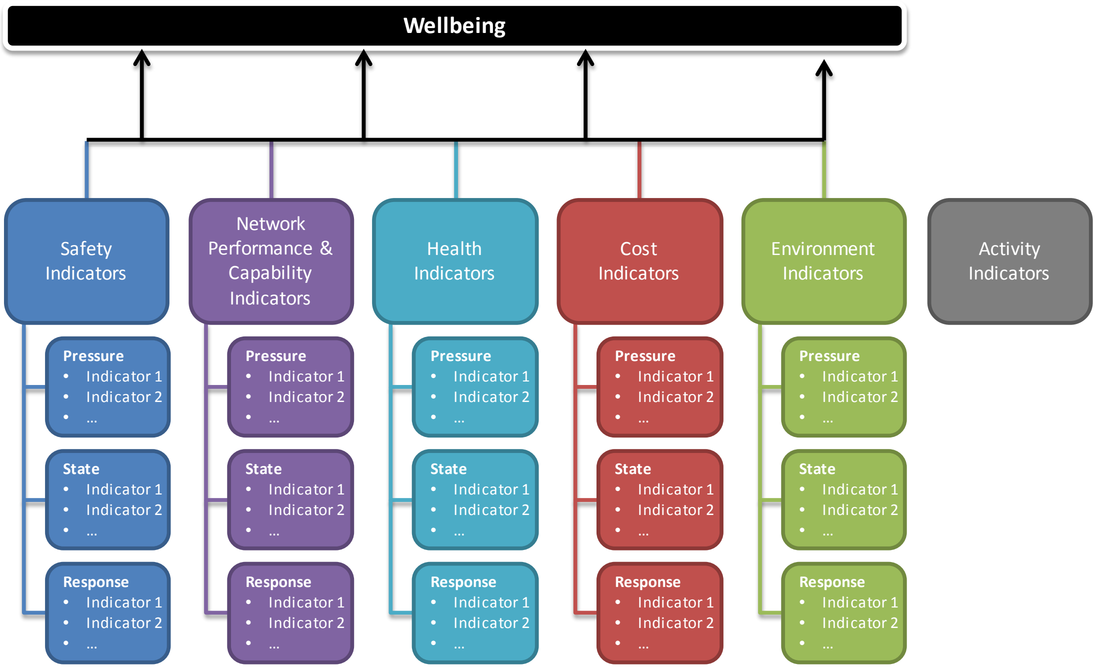
In addition to the wellbeing indicators above, we included a small, separate set of other indicators of aggregate transport activity that are not directly related to wellbeing but that may be useful for planning purposes, tracking broad trends and providing context for policy development. These indicators do not have a direction which is 'better' or 'worse' in terms of wellbeing, but simply measure the aggregate size of the transport task and stock of assets, vehicles, etc. We call these activity indicators.

[11] While some transport users may obtain wellbeing from transport itself (eg motorcycling for pleasure), in our view this will be very small in comparison to the wellbeing generated by the activities that transport facilitates.

3.5.4 Overall framework structure

As previously discussed, the proposed framework is output-oriented and based on the characteristics of transport that affect wellbeing (from figure 3.4), grouped into the five indicator categories listed above. In particular, across these five categories, indicators will be chosen that seek to capture all of the characteristics listed in figure 3.4. As noted above, an important feature of this framework is that there may be wellbeing trade offs across indicator categories but ideally not within categories. Figure 3.6 illustrates the overall structure of the proposed indicator framework.

Figure 3.6 Proposed indicator framework structure



We note that separation of health from environment indicators may result in some repetition of indicators across the framework. This is because many of the relevant pollutants have combined effects on human health and the environment. The most important effects considered under these headings are those associated with air pollution, and we note that the range of pollutants include those that are irritants (to eyes, throat and lungs), leading to worsening of respiratory conditions (health), impacts on air visibility (environment) and potentially interruption of photosynthesis (environment).[12] In addition we note that the air pollution indicators with significant health effects are also included in the core set of national environmental indicators (MfE 2009).

3.5.5 Application of pressure-state-response

To provide additional structure on the indicators within the five wellbeing groups, we also co-opt the OECD PSR framework. In particular, we envisage that within each of the indicator categories, individual indicators will be classified into pressure, state and response sub-categories. This will provide an additional dimension to the indicator framework.

The PSR framework is not strictly hierarchical, but each of the three PSR components relate to different characteristics of the indicator categories. In the transport context:

[12] www.mfe.govt.nz/issues/air/breathe/

- Pressures are underlying *external* forces that affect the demand and supply of transport services, for example population growth, fuel prices, economic activity, etc. Trends in pressures can be used to predict how transport demand and supply will change in future. Pressures can also be useful for formulating appropriate policy responses to changing transport sector conditions.
- State variables measure the current level of condition, activity or output of the transport system. For example, safety state indicators might include crash and fatality rates. While pressure indicators provide a snapshot of the external factors affecting transport, state indicators reflect the *internal* characteristics of the system. In the context of our framework, state indicators measure the current contribution of transport to wellbeing.
- Response variables measure and track policy responses to changes in pressure and state, for example expenditure on transport infrastructure, or fuel taxes. Tracking responses is important for monitoring their effectiveness, and responses can be compared against future changes in state indicators to assess policy outcomes.

However, some overlap of indicators across categories may be unavoidable, particularly for pressure and response indicators, and for health and environment indicators as discussed above. For example, population growth could be considered to be a pressure for safety, network performance, health, environment and cost characteristics of the transport system. In our view this is not a serious problem as long as users of the indicator framework are aware of it and do not mistakenly over-emphasise the repeated indicators.

Over time, data collected in a PSR framework can be used to establish and test relationships between policy choices (ie responses) and state indicators. This is similar to the NZTA's current monitoring of outputs and short and long-term impacts of transport, but with a focus on wellbeing rather than specific government policy targets.

3.5.6 Summary of framework design

The proposed framework therefore has three levels, which provide an increasingly detailed view of transport's contribution to wellbeing. At the highest level is wellbeing. At the intermediate level are the indicator categories identified above. At the lowest level there will be PSR indicators within each of the four indicator categories. It will also be possible to look across all PSR indicators to get an alternative view.

In addition, as a separate component, there will be aggregate indicators of transport activity, such as VKT, road length, number of vehicles, etc. These do not have a direct wellbeing interpretation, but are included in the framework for planning and sizing purposes. For example, the knowledge of the trend in VKT may be useful for forecasting future budgeted transport revenues and costs.

The following features of this framework are important:

- Indicators of wellbeing are clearly distinguished from other indicators that are not directly related to wellbeing.
- The focus on wellbeing means the indicators will be robust to policy changes over time.
- The wellbeing indicator categories are designed so that any trade-offs exist between categories and not within categories.
- To the extent possible we have tried to avoid double-counting indicators (either explicitly or implicitly) within the framework.

3.5.7 Summary of top-level indicator categories

We recommend the following definitions of the proposed top-level categories of indicators:

- Network performance and capability wellbeing indicators: Measures of the transport system's capability and performance in moving people and freight when and where demanded.
- Cost wellbeing indicators: Indicators of the financial cost of using the transport system.[13]
- Safety wellbeing indicators: Measures the extent individuals suffer harm or loss from road and rail transport services. Harm or loss includes both physical injury and property damage due to crashes.[14]
- Health and environment wellbeing indicators: Indicators of the impact of transport activity on the natural environment, where those impacts have direct effects on human health or on wellbeing derived from the environment.
- Activity indicators: Measures associated with the overall scale of New Zealand transport activity but for which changes in the level of the indicator do not directly translate into changes in wellbeing.

To further understand the factors affecting wellbeing in each of the categories, we propose imposing some additional structure on the indicators. This involves determining the components of wellbeing in each category, identifying the immediate causes of these components, and then translating those into observable state and pressure indicators.

For example, the transport wellbeing associated with health and environment is partly determined by mortality and respiratory sickness rates. The immediate causes of this are concentrations of and exposure to particulates, carbon monoxide and nitrogen oxides. Relevant state indicators related to these immediate causes are vehicle emissions and pollutant concentrations in the atmosphere. Relevant pressures are the mix of vehicle types and ages in the fleet, fuel economy levels and engine technology. The next section discusses this in more detail for each of the indicator categories.

3.5.8 Proposed framework versus current NZTA indicators

The high-level indicators currently used by the NZTA were summarised in section 2.1. These focus on measuring specific long-term impacts, monitoring achievement of strategic priorities and giving contextual indicators for output classes. While the existing indicators are useful for measuring specific long-term impacts and strategic priorities, in our view the proposed framework has the following advantages over the existing indicators:

- The framework is based on wellbeing and as such is not specific to current policies. This makes it robust in the long term to policy changes, and also makes the framework useful for guiding policy development.
- The framework is not constrained by currently available data and is able to accommodate data improvements as they occur over time.
- The proposed framework has additional structure that describes how indicators relate to each other and the possible trade-offs between them.
- The indicators in the proposed framework are all based on characteristics of transport that relate to wellbeing, rather than linked to particular policy targets, which are one step removed from wellbeing.

[13] These indicators exclude costs due to externalities (ie environmental and health effects) as those are captured in other indicator categories.

[14] For the purposes of this indicator, harm that is caused by emissions generated by road and rail transport is not included in this indicator as these impacts are assessed within the environmental indicator.

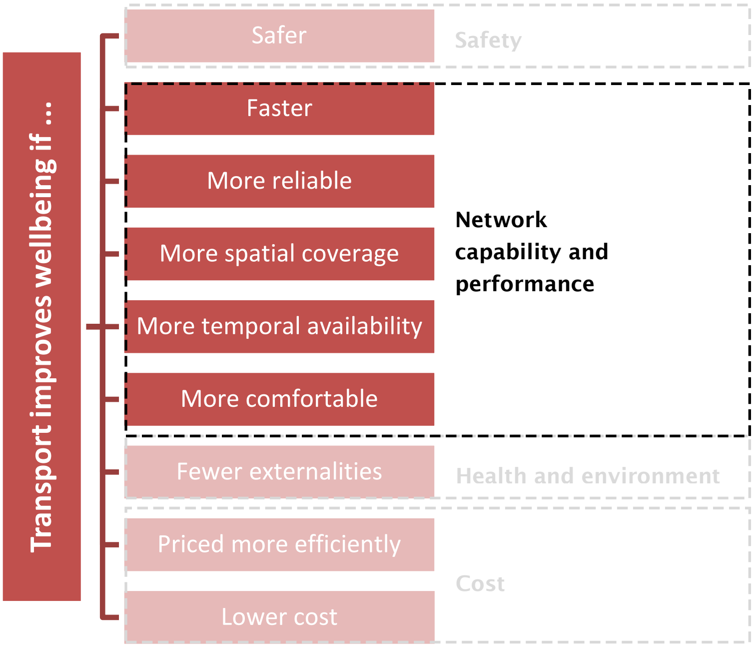
4 Recommended indicators

This section presents the recommended indicators for each of the wellbeing categories above, as well as a set of non-wellbeing related context and activity indicators. For each of the wellbeing indicators we distinguish PSR indicators, as discussed above. We also outline how the indicators could be segmented by transport mode. Ideally, all indicators would be available at a regional level; however, this may not be possible due to data limitations.

4.1 Network performance and capability

These indicators are designed to measure the ability of the road and rail transport system to move people and freight where and when demanded, and are related to the characteristics of the transport system that reflect this (figure 4.1).

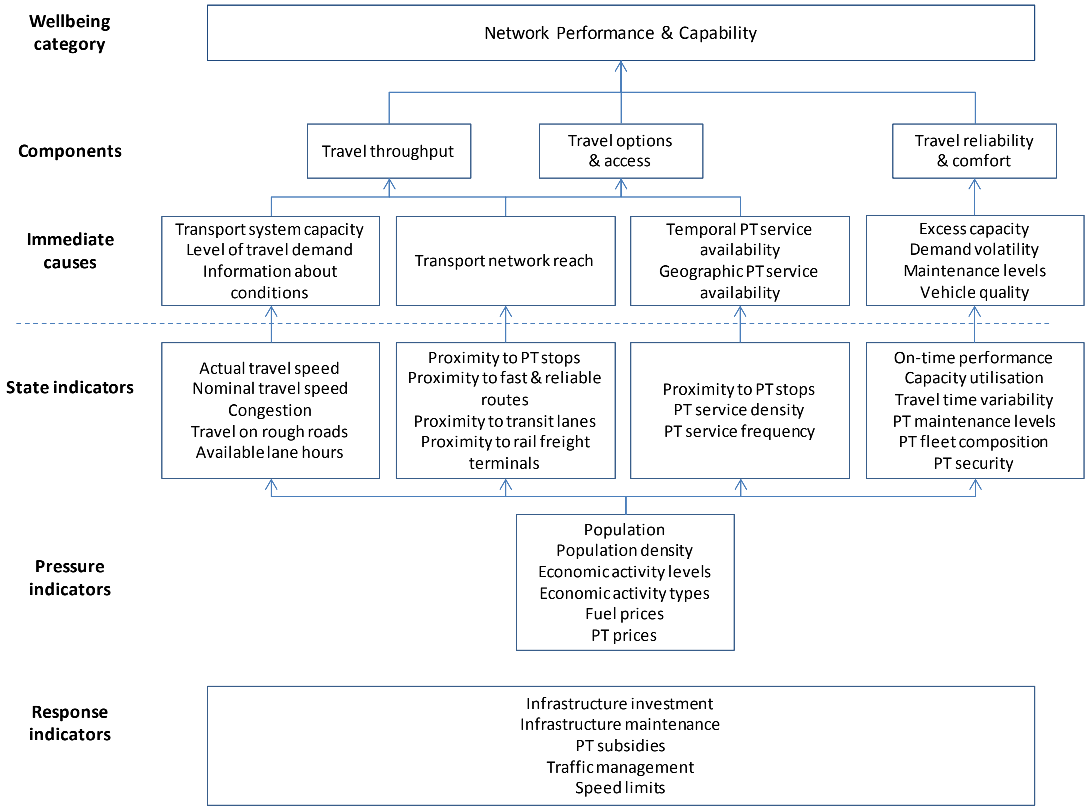
Figure 4.1 Conditions where wellbeing from transport is improved, everything else equal



Source: Covec

Figure 4.2 summarises the proposed framework for measuring this source of wellbeing. In most cases, these indicators are relevant to the transport of both people and freight. For example, travel throughput and travel reliability affect the movement of both people and freight.

Figure 4.2 Network performance and capability framework



The three main components of wellbeing in this category are travel throughput, travel options and access, and travel reliability and comfort.

4.1.1 Travel throughput

Travel throughput measures the ability of the system to move people and freight per unit of time. Moving people and freight is what the transport system does, so throughput is a key measure of performance. This depends on the speed of travel (ie average speeds or travel times), but also on the loads that vehicles carry. For example, the throughput of a congested road can be increased by increasing vehicle loads, such as the use of buses rather than private cars. Thus while in this example travel times may not reduce, throughput has increased in the sense that more *people* are transported during any given time period.

In our view, throughput is a better measure of transport system performance than congestion or travel time-based measures.[15] International indicators, such as those under development by Austroads, are also working towards the incorporation of throughput-based indicators. This is because throughput reflects both travel time and load factors, as explained above. In contrast to congestion measures that focus on the movement of vehicles, throughput focuses on the movement of people and freight, and so is more directly related to wellbeing. Throughput is also better able to capture the full range of effects of transport policy and investments. For example, increasing capacity on a road may not reduce congestion or travel times if it induces more drivers to use the road. However, the road is actually moving more people and freight, and throughput has improved, which is a benefit.

[15] Several members of the NZTA expert group for this project also held this view.

Put another way, reducing congestion is one way to improve the performance of the transport system, but it is not the only way and it may not be the optimal way. A reduction in congestion would be reflected in an improvement in a throughput measure, but throughput can also be improved by increasing vehicle load factors. In contrast to congestion measures, a throughput measure embraces both of these possibilities and allows a broader range of effects to be captured.

Measuring throughput requires knowledge of both vehicle counts (the number of vehicles per unit of time) and load factors, eg the number of people per car or number of passengers per bus, as well as the mix of vehicle types. Where these are not known, existing travel time or congestion measures can be used as a substitute, but we recommend that work be done to develop throughput measures as better indicators of transport network performance. The key informational requirement will be detailed knowledge of vehicle load factors. Higher load factors are a way to improve the productivity of the transport system in moving people and freight without requiring additional road infrastructure to be built.

4.1.2 Travel options and access

Travel options and access refer to the ability of people and goods to travel where they want and when they want to. These depend on the spatial and temporal availability of services, and the design of the transport network. Without good travel options and access, even a well-functioning transport system will be ineffective and its performance will be low.

Options and access are especially relevant for public transport, where the location of stops, the configuration of routes and the frequency of services matter for the viability of public transport as a travel option, and because these features can be changed relatively easily. For private transport and freight, the proximity and ease of access to motorway on-ramps, to high-throughput routes, and to and intermodal connections will be important for the performance of the system.

4.1.3 Travel reliability and comfort

Travel reliability and comfort refer to dimensions of the quality of the travel service in terms of the level of certainty of reaching the destination on time, and the level of comfort of the journey. These relate to the quality of service experienced by transport users while they are actually using the system. This may include both quantitative measures and subjective assessments by transport users. Various measures of reliability and comfort are used internationally, including on-time performance for public transport, travel time reliability, and survey-based measures of comfort and user satisfaction.

There are two dimensions of reliability that can be measured. For scheduled services (eg public transport), *on-time performance* measures the proportion of services that reach their destination within a given window around the scheduled time. The *variance* of travel time is also important. High variance can impose costs and reduce wellbeing.[16] For freight transport, high variance can mean costly ‘buffers’ have to be maintained in the system, eg holding higher stock levels or employing more staff to cope with late deliveries. A lack of predictability of travel times makes resource planning difficult for logistics operators. This will generally require maintaining additional capacity which is necessary to meet performance requirements when travel times are unexpectedly high, but is otherwise idle. These resources could be used for other productive purposes and therefore increased variance of travel time leads to a reduction in wellbeing.

[16] For extensive theoretical and empirical research on this topic, see the proceedings of the International Transport Forum Value of Travel Time Reliability and Cost-Benefit Analysis international meeting, October 2009, available at www.internationaltransportforum.org/Proceedings/reliability/index.html.

These costs can be severe when access to intermodal connections (eg sea freight) is necessary. For private and public transport, high travel time variance can mean missed meetings and appointments, or unproductive waiting time if people travel early to protect against being late.

Reliability and comfort are partly determined by the excess capacity in the system relative to the volatility of travel demand – the greater the excess capacity, the greater the system's ability to cope with volatile demand without causing delays in peak times. Maintenance levels of infrastructure and public transport vehicle maintenance and quality also affect reliability and passenger comfort for public transport.

4.1.4 State indicators

For the reasons discussed above, the following network performance and capability state indicators are recommended.

4.1.4.1 Throughput

Our recommended throughput indicator is: The weighted average number of people moved on a representative sample of key routes during the peak hour, ie the product of vehicle flow counts and average load factor.[17]

This indicator measures throughput directly, ie it counts the amount of people and freight moved per unit of time. Measurement of this indicator requires the following steps:

1. Determine a representative sample of key routes across which to measure throughput. This should include arterial routes and those used by public transport.
2. Measure daily vehicle counts and vehicle load factors on these routes during the peak hour and average over a suitable timeframe, eg a month.
3. Calculate throughput for each route as the product of vehicle counts during the peak hour and vehicle load factors. In this way, throughput will be measured as the number of people moved on the route during the peak hour.
4. Calculate overall throughput as a weighted average across routes, using the throughputs of the routes as the weights.

4.1.4.2 Alternatives to throughput

In our view, throughput is a theoretically desirable performance measure (as explained above); however, in practice it may be difficult to measure. The key difficulty is likely to be the measurement of vehicle load factors. Data on the mean light four-wheeled vehicle occupancy (in terms of people per km) by region is published by the Ministry of Transport.[18] However the data is only updated annually and comes from the New Zealand Household Travel Survey. While this can give an overall picture of vehicle load factors, it may not be sufficiently granular to develop the type of throughput measure described above. Furthermore, the Ministry of Transport measure relates to private vehicles only and does not incorporate information about public transport vehicle loads and freight loads.

Given these difficulties, development of a throughput indicator is likely to require investment of time and resources. We recommend that this work be undertaken; however, in the interim alternative indicators of

[17] Freight tends to move outside of peak hours, making development of freight-based throughput measures more difficult unless monitoring is undertaken throughout the day.

[18] See www.transport.govt.nz/ourwork/TMIF/Pages/TV010.aspx.

travel speed and congestion can be used. In our view, these indicators are inferior to throughput as a measure of network performance, but are measurable using current data and processes.

The following alternative indicators are based on recent work of Austroads (2011c) to develop best practice congestion performance measures. Detailed formulas are contained in Austroads (2011c) for the implementation of these indicators – the formulas are omitted here for brevity but descriptions are given. For all these measures, a sufficiently representative sample of road links needs to be monitored. In all cases, data on vehicle movements (eg speeds) can be obtained from floating car surveys or, preferably, remote road sensors.

Speed and flow productivity: Road link productivity can be measured as the product of average speed and flow. This is similar to throughput except vehicle load factors are not taken into account. A relative productivity can be calculated by dividing the measured product of speed and flow by a product of nominal speed and flow. Across the network, Austroads recommends calculating a weighted average using link lengths as weights. We note that speed and flow productivity is essentially the same as throughput, but lacks the load factor component.

Average travel time: The average time for a nominal 10km journey (or some other representative journey) can be calculated from data on travel speeds and road link flows and lengths. A weighted average of travel speed across road links of different lengths and with different traffic flows can be calculated to estimate overall average travel time per 10km across the measured links. For public transport, this should include transfer times.

Variation from posted speed: This indicator measures the average differential between actual travel speeds and the posted speed limit. For a given road link, this can be calculated by measuring average vehicle speeds during a given time (eg the peak hour) and comparing this to the speed limit. Across the network, Austroads recommends calculating a weighted average over road links using the link lengths as weights.

4.1.4.3 Travel time reliability

As discussed above, travel time reliability relates to the variability of travel time, or in statistical terms the *variance* of travel time. The variance captures the expected range of deviation around the average travel time and is commonly expressed in terms of the *standard deviation*. Austroads recommends normalising this by the average travel time (ie calculating the *coefficient of variation*) because, for example, a 10-minute standard deviation is more significant on a route with average travel time of 15 minutes than a route with average travel time of 60 minutes.

Based on the Austroads recommendation, we recommend both peak and average estimates of travel time reliability.

Travel time reliability (peak): The coefficient of variation of average travel time on a representative sample of key routes during the peak hour.

Travel time reliability (average): The coefficient of variation of average travel time on a representative sample of key routes throughout the day.

4.1.4.4 Network condition

Key measures of network condition that are commonly used internationally relate to the condition of the road surface. As discussed in more detail in appendix A, the next generation Austroads indicators include a pavement condition index, which is generated as a combination of indicators of road surface roughness, cracking, texture, rutting and strength. Road roughness indicators of various types are also used in several other jurisdictions, and the International Roughness Index (IRI) is an accepted international standard for roughness measurement.

In our view the Austroads pavement condition index is too complex for a set of high-level wellbeing measures and we recommend that road surface roughness be used as the overall indicator of road network condition. Roughness relates to characteristics that affect vehicle dynamics, road user costs, ride quality and pavement loads (Austroads 2007) and is therefore an important basic measure of road performance and the quality of the travel experience (Bennet et al 2005).

Roughness can be measured in terms of the IRI. According to Austroads, an IRI of 4.2 or less indicates acceptable travel conditions while an IRI greater than 5.3 indicates less desirable travel conditions (Austroads 2008). This can be calculated as an overall average for the road network, and can be disaggregated for specific geographic locations if required. We therefore recommend a network condition indicator of the percentage of travel on roads classed as smooth (ie an IRI of 4.2 or less).

We note that if the road network is being well maintained, significant changes in the network condition indicator may not be observed over time. At the optimal level of maintenance, 'no change' in this indicator is the desirable observation, rather than an increase or decrease.

4.1.4.5 Network reach

Network reach refers to the geographic extent of the network and some countries have developed measures of this for public transport (see appendix A). Measures are typically based on the density of public transport access points (eg bus stops) relative to the density of population. We recommend the use of the Swiss local availability indicator, which measures the percentage of the population living within 400m of public transport stops where a half-hour frequency service is provided. This can be calculated from geographical information system (GIS) data on population densities overlaid with public transport route maps.

Network reach is also important for freight transport, including access to fast and reliable routes and access to intermodal terminals. This is more difficult to measure directly as the locations of freight-generating activity are dispersed and not necessarily correlated with observable factors such as employment. In our view, this is best measured indirectly for freight, via indicators for throughput and travel time reliability.

4.1.4.6 Service frequency

Frequency is similar to network reach in that it measures the availability of services but in the time dimension rather than spatially. We recommend the use of a population-weighted public transport service frequency based on the same definition as network reach above. In particular the average peak and off-peak service frequency can be calculated for each public transport stop, and then this can be weighted by the population living within 400m of that stop to calculate an overall weighted average for a city or a region.

4.1.4.7 On-time reliability

On-time reliability is important for the quality of public transport services and also for scheduled freight services. Reliability is measured as the proportion of services operating within some defined margin of their scheduled time. Choice of the margin is arbitrary but a standard of five minutes is commonly used. Measuring arrival reliability rather than departure reliability will capture factors that affect on-time departure as well as delays en route. For aggregation purposes, a weighted average across services can be calculated by using patronage as the weighting variable, on the basis that services that are not on time affect more passengers and have a greater impact on wellbeing.

We therefore recommend a reliability indicator for public transport as the proportion of services arriving at their destination within five minutes of their scheduled time. This is consistent with public transport reliability indicators used in other jurisdictions.

In future, data from integrated ticketing systems could be used to develop more detailed measures of *en route* reliability. This would take account of the on-time performance at intermediate stops as well as the final destination.

4.1.4.8 Customer satisfaction

Customer perceptions are another useful indicator of wellbeing for public transport services and are commonly used internationally. The NZTA currently collects data on public transport customer satisfaction from surveys conducted regularly by regional councils. The standardised surveys measure public transport customer perceptions of various aspects of the service they receive. Some of these measures overlap with the indicators outlined above, and in our view it is preferable not to duplicate measures in the wellbeing indicator framework where possible. We therefore recommend that a subset of the customer satisfaction indicators be used, where these capture other subjective aspects of the service quality. This would include the survey measures relating to 'overall service', 'service value for money' and 'vehicle quality/comfort'.

The satisfaction that private road users receive from road use could also be measured by a similar survey. In the absence of a direct measure, we suggest the available highway lane-hours be used as a proxy. In particular, for road user satisfaction, traffic volume-weighted available lane hours relative to total potential lane hours is a useful proxy if a user survey is not undertaken.

4.1.4.9 Public transport subsidy measures

When measuring the effectiveness of public transport subsidies, the NZTA and other agencies place emphasis on the *farebox recovery ratio* (the proportion of total costs paid directly by passengers) and the *number of boardings per dollar of subsidy*. Both these indicators are of interest from a funder's perspective, as increases in these indicators imply that fewer subsidies are required and that subsidies are delivering greater public transport patronage, respectively.

However, these indicators are not appropriate for an indicator framework that seeks to measure the contribution of transport to the wellbeing of New Zealanders as a whole. An increase in the farebox recovery ratio is an improved outcome for funders of public transport, but means that passengers are privately paying more for the service. Whether or not this represents an overall increase in wellbeing is unclear. Similarly, it is not clear whether an increase in the number of boardings per dollar of subsidy results from reduced subsidies, or shifts of demand from other public transport modes, and again the effect on overall wellbeing is unclear. For these reasons, we have excluded these public transport specific indicators from the recommended framework.

4.1.4.10 Headline indicators

Among the state indicators, we consider throughput (or average travel time as an alternative), travel time reliability, and public transport network reach and frequency as headline performance indicators. As discussed above, throughput is a key measure of the performance of the transport system at its primary task, while high travel time reliability benefits private users and freight by reducing the costs of unexpected delays. The reach and frequency of the public transport network are key measures of the effectiveness of the design of the public transport system.

4.1.5 Pressure indicators

Relevant pressures that affect network performance are essentially the drivers of demand for transport services. The greater the demand, the greater the pressure will be on the transport system and network performance and capability will need to improve to prevent service levels from slipping. On this basis, the following high-level pressure indicators are recommended:

Economic activity: A broad measure of national economic activity such as the real GDP growth rate. While other measures of national economic activity are available, such as employment, business growth and investment in capital, in our view GDP provides the best broad measure of activity and is measured on the basis of well-established principles that are comparable across time and across countries. At the regional level, total employment can be measured as a proxy for GDP.[19]

Population: Total estimated population, by region and nationally. This data is available from Statistics New Zealand.

Population density: An aggregate national estimate of population density (ie persons per square km) will provide relatively little information about demand for transport services, as density varies significantly between urban and rural areas. Furthermore, it is only in relatively dense areas where pressure on transport will be the greatest. We therefore recommend urbanisation (the proportion of population living in urban areas) as an indicator.

4.1.6 Response indicators

The main responses to demand for transport services are investment in infrastructure, expenditure on services and expenditure on maintenance. These can all be measured in annual terms, in aggregate for the transport sector, and disaggregated by type of service in some cases (eg expenditure on public transport services or infrastructure). In particular, we recommend three expenditure-related response indicators for network performance and capability:

Infrastructure investment: Total expenditure on new transport infrastructure by central and local authorities.

Service expenditure: Total expenditure on private and public transport services.

Maintenance expenditure: Total expenditure on maintenance of transport infrastructure by central and local authorities.

In our view, speed limits could also be a useful response indicator, under the assumption that higher speed limits correspond to higher network performance, everything else equal. This could be measured as traffic volume-weighted averages across the network.

Another important response is traffic management. A variety of traffic management systems and approaches are used in New Zealand to mitigate the effects of crashes and incidents, and to optimise the flow of traffic across the highway network. We recommend this be measured by the percentage of the road network under active traffic management.

[19] Regional GDP estimates are available from some sources; however, in our view there is significant uncertainty associated with these estimates, making employment (which is directly measured by region) a more reliable indicator of activity.

4.1.7 Summary

Table 4.1 summarises the recommended network performance and capability wellbeing indicators. The table also indicates which modes will be applicable for each indicator. Depending on data availability, the indicators could be segmented by mode in the way illustrated in the table. However, some indicators will not be available or do not make sense for some modes, for example service frequency for road private transport.

Table 4.1 Recommended network performance and capability wellbeing indicators (headline indicators highlighted in bold)

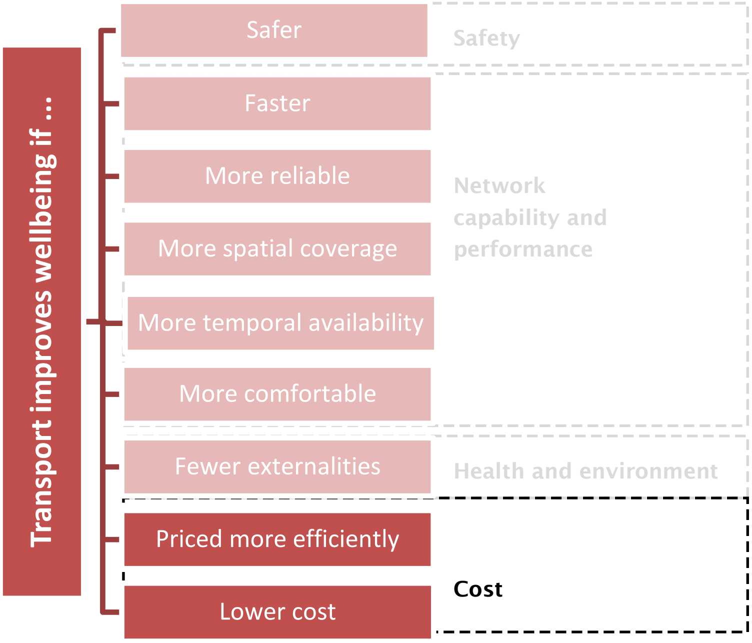
<table>
<tr><th rowspan="3">Indicator</th><th rowspan="3">Description</th><th colspan="5">Mode coverage</th></tr>
<tr><th colspan="3">Road</th><th colspan="2">Rail</th></tr>
<tr><th>Private</th><th>PT</th><th>Freight</th><th>PT</th><th>Freight</th></tr>
<tr><td colspan="7">Pressure indicators</td></tr>
<tr><td>Economic activity: national</td><td>National real GDP growth rate</td><td colspan="5">✓</td></tr>
<tr><td>Economic activity: regional</td><td>Total employment by region</td><td colspan="5">✓</td></tr>
<tr><td>Population</td><td>Total estimated population, nationally and by region</td><td colspan="5">✓</td></tr>
<tr><td>Population density</td><td>Proportion of the population living in urban areas</td><td colspan="5">✓</td></tr>
<tr><td colspan="7">State indicators</td></tr>
<tr><td>Throughput</td><td>Average number of people moved on a representative sample of key routes during the peak hour: the product of vehicle flow counts and average load factor.</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Throughput alternative: average travel time</td><td>Average travel time on a representative sample of journeys during the peak hour. For PT, this could include transfer times.</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Throughput alternative: variation from posted speed</td><td>The difference between average travel speed and the posted speed limit.</td><td colspan="2">✓</td><td colspan="3">✓</td></tr>
<tr><td>Throughput alternative: speed and flow productivity</td><td>The product of average speed and vehicle flow rates for road links.</td><td colspan="2">✓</td><td colspan="3"></td></tr>
<tr><td>Travel time reliability: peak</td><td>Coefficient of variation of average travel time on a representative sample of key routes during the peak hour</td><td colspan="2">✓</td><td colspan="3">✓</td></tr>
<tr><td>Travel time reliability: average</td><td>Coefficient of variation of average travel time on a representative sample of key routes throughout the day</td><td colspan="2">✓</td><td colspan="3">✓</td></tr>
<tr><td>Network condition: road</td><td>Percentage of travel on roads classified as smooth</td><td colspan="2">✓</td><td colspan="2"></td><td></td></tr>
</table>

<table>
<tr><th rowspan="3">Indicator</th><th rowspan="3">Description</th><th colspan="5">Mode coverage</th></tr>
<tr><th colspan="3">Road</th><th colspan="2">Rail</th></tr>
<tr><th>Private</th><th>PT</th><th>Freight</th><th>PT</th><th>Freight</th></tr>
<tr><td>Network reach: PT</td><td>Proportion of population living within 400m of a public transport stop with at least half hour frequency.</td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Service frequency: PT</td><td>Population weighted average public transport frequency in peak and off-peak times.</td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>On-time reliability: PT</td><td>Proportion of services arriving at their destination within five minutes of scheduled time.</td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Customer satisfaction: PT</td><td>Subjective public transport passenger measures of overall service quality value for money, and vehicle quality/comfort.</td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Customer satisfaction: road</td><td>Traffic volume weighted available lane-hours relative to total</td><td colspan="3">✓</td><td colspan="2"></td></tr>
<tr><td colspan="7">Response indicators</td></tr>
<tr><td>Infrastructure investment</td><td>Total expenditure on new transport infrastructure by central and local authorities</td><td colspan="3">✓</td><td colspan="2">✓</td></tr>
<tr><td>Service expenditure</td><td>Total expenditure on private and public transport services</td><td>✓</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Maintenance expenditure</td><td>Total expenditure on maintenance of transport infrastructure by central and local authorities</td><td colspan="3">✓</td><td colspan="2">✓</td></tr>
<tr><td>Speed limits</td><td>Traffic volume weighted averages of speed limits across the road network</td><td colspan="3">✓</td><td colspan="2"></td></tr>
<tr><td>Traffic management</td><td>Percentage of the road network under active traffic management</td><td colspan="3">✓</td><td colspan="2"></td></tr>
</table>

4.2 Cost

Cost indicators reflect the impact that changes to transportation costs have on wellbeing from land transport (figure 4.3). That is, increases in cost impact negatively on wellbeing whereas cost reductions lead to an increase in wellbeing. A reduction in cost while all other indicators remain constant could also be interpreted as an improvement in productivity.

Figure 4.3 Conditions where wellbeing from transport is improved, everything else equal



Source: Covec

The four main cost categories that affect wellbeing are:[20]

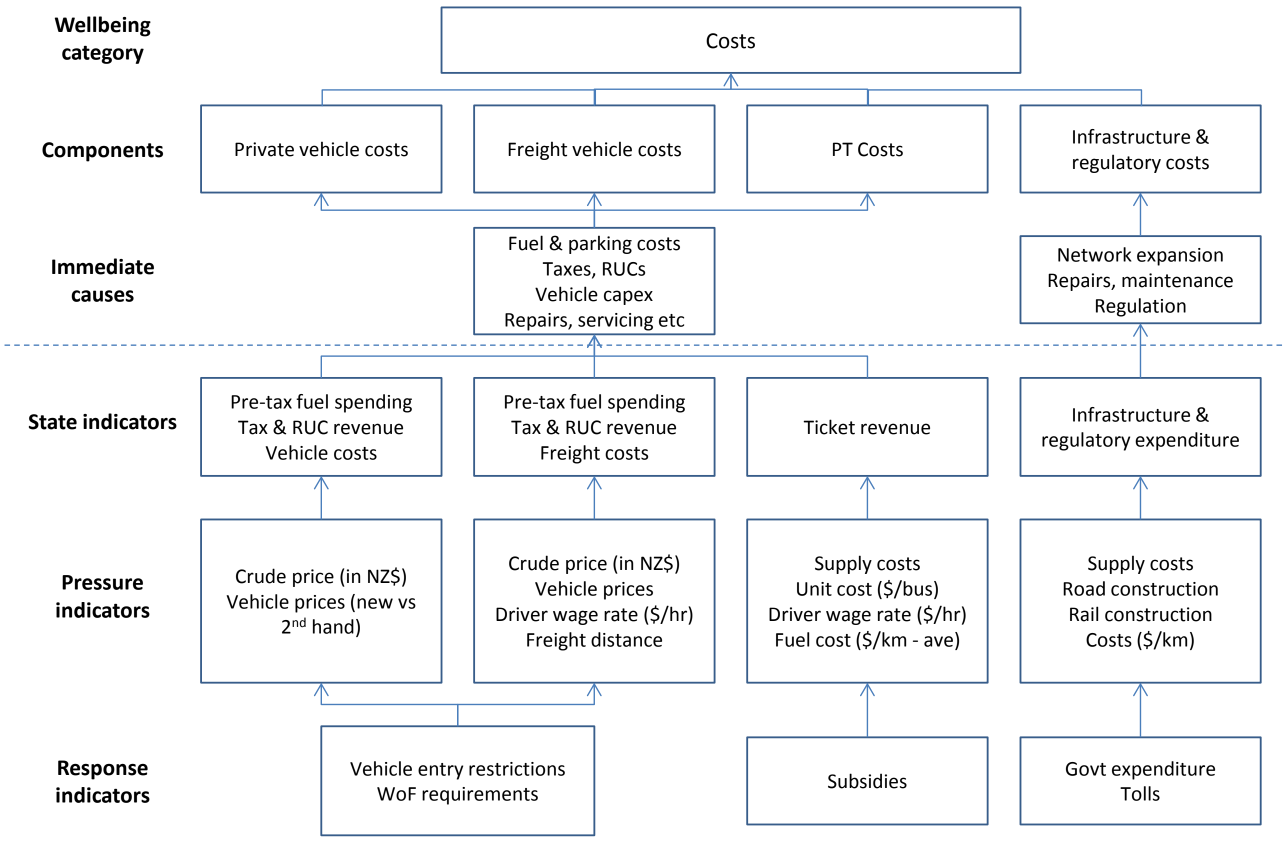
- private vehicle costs
- freight costs
- public transport costs
- infrastructure and regulatory costs.

Transport costs can also be categorised into fixed and variable costs. Fixed costs include the capital cost of vehicles and rolling stock, infrastructure costs and regulatory costs (eg warrant of fitness (WoF) regime). Variable costs include fuel, parking and labour costs (ie driver wages for freight and public transport services).

Figure 4.4 describes the relationships between indicators and cost impacts.

[20] Note other cost types include health and safety costs. These are discussed in the specific health and safety indicator sections.

Figure 4.4 Cost indicator framework



4.2.1 State indicators

Changes to the cost of the transport system can have a substantial impact on the wellbeing of the wider community. Cost reductions can allow users to use more, or better quality, transport services, or enable them to spend more on other non-transport items. Conversely, cost increases may reduce the amount or quality of transport services that users can afford. Consequently, an indicator that incorporates an estimate of the total cost of the entire transport system would be useful.

However, a simple estimate of total transport costs is not a sufficient indicator for the purposes of measuring wellbeing. This is because changes in total costs may be the result of greater transport usage, for example because of population growth. Therefore, an overall cost indicator should be based around the total cost of transport per 'unit' of transport output, ie a measure of average cost. In relation to human transport these units could be person km travelled, which would include both private and public transport.[21] For freight transport costs, the relevant measure would be freight tonne km travelled.

$$\text{Personal transport cost per km} = \frac{\text{Total personal transport costs}}{\text{Total km travelled}}$$

$$\text{Freight transport cost per tonne-km} = \frac{\text{Total freight transport costs}}{\text{Total freight tonne km travelled}}$$

[21] To the extent that future public transport ticketing systems provide greater information regarding public transport usage, estimates of total public transport passenger km travelled are likely to become more robust.

An increase in dollars per person km travelled, or dollars per freight tonne km travelled, indicates the transport system has become more costly. There are several different reasons why the cost of transport may rise, and whether such an increase in cost per km makes users worse off depends on the reason for cost increase:

1. Increased costs may be the result of an increase in the output or performance of the transport system, eg greater network coverage or capacity.
2. Increased costs could be the result of an improvement in the safety or quality of transport services, eg increased purchases of higher quality, safer vehicles.
3. Increased costs may be a result of increases in the price of one or more components of the transport system, eg higher fuel prices, increase vehicle prices, higher driver wages.

Increases in costs because of higher component prices, eg fuel, make transport users unambiguously worse off. This is because the same standard or quantity of transport now costs more. However, increases in costs resulting from either improvements in network performance or from greater safety would not necessarily leave users worse off. This is because the increase in costs may be more than offset by the benefits of improved network performance or safety. Because of these potential trade-offs, it would be necessary to consider changes to cost indicators in light of any changes to network performance and capability indicators and safety indicators as outlined elsewhere in this chapter.

In simple terms, increases (or decreases) in cost only have unambiguous welfare implications if they are not associated with simultaneous changes in other indicators.

Estimating the total cost of transport services would require obtaining information on several aspects of the sector. A measure of total expenditure of freight services could be based on estimates of the total revenue derived by freight companies for both road and rail land transport services.[22] To account for self-supplied freight services by firms such as Fonterra, estimates of private freight expenditures would need to be scaled up and extrapolated into economy-wide figures. Existing NZTA financial modelling of freight activities is likely to be useful in this regard.

In a similar manner to freight expenditure estimates, the total spent on both road and rail public transport services could be determined using total fare revenue figures, although subsidies provided by central or local government would need to be added to private expenditure figures to ensure the actual total cost of these services is estimated.

Estimating the total costs of private travel would be more complex. The total variable costs of private transport would need to be based on estimates of household fuel expenditure and parking charges. Determining total fixed costs would be largely based on estimating the capital cost of the private vehicle fleet, which in turn may require data regarding vehicle purchases and fleet characteristics, eg average age. Estimates of household expenditure on vehicle repair and maintenance would also need to be generated.

The total cost of implementing the various regulatory and legislative requirements applying to land transport would include the costs of operating WoF and vehicle registration regimes. The total direct cost of these regulatory functions would consist of the sum of direct charges levied on users and of any additional government funding.

Figures regarding total transport infrastructure expenditure (on new infrastructure, upgrades, and repairs and maintenance) would provide the data required to establish total infrastructure costs.

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[22] The different cost profiles of different freight types would need to be accounted for in the estimate. For instance, refrigerated freight or hazardous freight is likely to be more expensive than other forms of freight.

Note that to the extent that some regulatory and infrastructure costs are funded from some portion of the taxes levied directly on transport users (eg fuel tax, registration charges, road user charges (RUC)) these amounts should not be double counted across the indicator framework if they have already been included in private, public and freight transport costs.

In summary, our proposed state indicators for cost wellbeing are the total cost of:

- personal transport per km
- freight transport per freight tonne km.

Other jurisdictions commonly collect and publish data concerning private transport costs, such as the cost of owning and operating vehicles, as well as cost information regarding the construction and maintenance of infrastructure, sometimes in the form of cost indices. However, 'per unit' measures such as we have described above do not appear to be published as transport indicators elsewhere. This may be because of the difficulty in accurately calculating such measurements, particularly estimates of the total cost of personal or freight transport. Alternatively, it may be that other jurisdictions have yet to consider the usefulness of such measures from a transport policy perspective.

4.2.1.1 Further segmentation

Cost indicators could be segmented by mode, ie total road-related costs versus rail-related costs. Further segmentation may be possible between private, public and freight transport, depending on the availability of data.

4.2.2 Pressure indicators

There are a number of cost components, both variable and fixed, that influence the overall cost of transport.

With regards to the variable costs of transport, a key pressure indicator is the price of fuel. Because the demand for fuel is relatively inelastic, particularly in the short run, price changes may not lead to substantial changes in usage. However, changes in fuel prices will affect the cost of private, freight and public transport, which will in turn impact on the wellbeing of transport users.

In relation to commercial transport services, ie freight and public transport, another key variable cost indicator is wage rates, predominantly of drivers but also of other transport-related employees.

With regards to fixed costs, a major component is the capital cost of vehicles and rolling stock, which can be influenced by various factors, including the extent to which vehicles are sourced from new or second-hand markets or useful lifespans. This in turn can be affected by entry restrictions on vehicles into the New Zealand market (that affect the new-second hand mix) and WoF requirements (which can reduce the useful life spans of vehicles).

The other major fixed cost component is infrastructure costs. To assess changes in the cost of building or maintaining infrastructure an appropriate indicator should unitise total infrastructure spending by the size of the transport network, ie total km of roading and railway lines. Note that construction costs themselves would need to be capitalised and depreciated over the useful lifespan of the infrastructure.

In summary, our proposed pressure indicators for cost wellbeing are:

- fuel prices
- vehicle prices
- average land transport sector labour costs
- costs of infrastructure construction and maintenance per network km.

Fuel and vehicle price indicators are compiled in a number of jurisdictions and are relatively commonly published indicators. Although labour costs that relate to land transport services are not specifically included in other jurisdictions' transport indicators, this data is likely to be readily available from government departments responsible for publishing statistical information. Indicators regarding the costs of constructing and maintaining infrastructure are published by various jurisdictions. In some cases, indices of construction and maintenance are used whereas in others aggregate spending figures are published. In this regard, the unitisation of these costs on the basis of costs per km of infrastructure is relatively unique.

4.2.2.1 Further segmentation

These indicators may be able to be further segmented by road versus rail. Further segmentation may be possible between private, public and freight transport.

4.2.3 Response indicators

The two main types of policy responses to cost issues that face transport users are for central and local governments to:

1. contribute to these costs via subsidies (or direct provision)
2. impose additional usage costs through taxes, levies or other costs (eg vehicle registration).

Transport subsidies paid by central and local government reduce the effective costs of transport to users, although from a wellbeing perspective this is simply a transfer of wellbeing from one group to another. In relation to infrastructure spending, the government can also provide greater coverage of the transport network than would otherwise exist.

Because central and local governments may wish to maintain the same rate of subsidisation over time, this indicator needs to take account of changes in population, inflation and overall transport usage. This means that an indicator based on the amount of total subsidies should be divided by the total passenger km travelled on subsidised routes. To allow international comparisons, it may also be useful to divide total subsidies by population and real GDP per capita.

The taxes, levies, and other charges that are levied by the government increase the effective cost of transport to users.[23] The impact of these policies can be assessed by evaluating the total amount levied on users, both in relation to personal services and freight services. Because changes in this revenue may relate to changes in total transport use, it is necessary to unitise these figures by total km travelled and total freight tonne km travelled respectively.

Other policy interventions can also have impacts on transport costs, but are typically implemented to achieve other objectives. For instance, tougher vehicle quality standards, whether in relation to imports or WoF requirements, may have the effect of increasing costs to transport users.

In summary, our proposed response indicators for cost wellbeing are:

- total transport subsidies unitised by total passenger km
- total revenue from personal transport-related levies and taxes (eg RUC, fuel tax, registration charges, etc) divided by total km travelled

[23] Note that these costs also include reduced economic efficiency because of the deadweight losses of public funding. That is, the usage patterns of transport users are distorted because of the effect of these taxes and charges, leaving users worse off than they would be in the absence of these taxes and charges.

- total revenue from freight transport-related levies and taxes (eg RUC, fuel tax, registration charges, etc) divided by total freight tonne km.

Information regarding transport subsidies and taxes is published in many jurisdictions although this information is typically provided in aggregate amounts spent. In some jurisdictions these figures are segmented by mode and/or region. However, it does not appear that other jurisdictions have estimated subsidies and taxes on a per 'transport unit' basis (ie per km travelled). This may be because of practical difficulties in obtaining the necessary data or because other jurisdictions may not have considered this level of detail useful.

4.2.3.1 Further segmentation

These indicators may be able to be further segmented by road versus rail. The subsidy indicator may also be further segmented by different regions and routes.

4.2.4 Summary of selected indicators

To ensure the indicator framework is as simple as possible, we have sought to limit the number of specific cost indicators. The specific indicators that we consider would be most useful are outlined in table 4.2 and the ticks indicate how these could potentially be segmented by mode. The two headline indicators are indicated in bold.

Table 4.2 Recommended cost wellbeing indicators

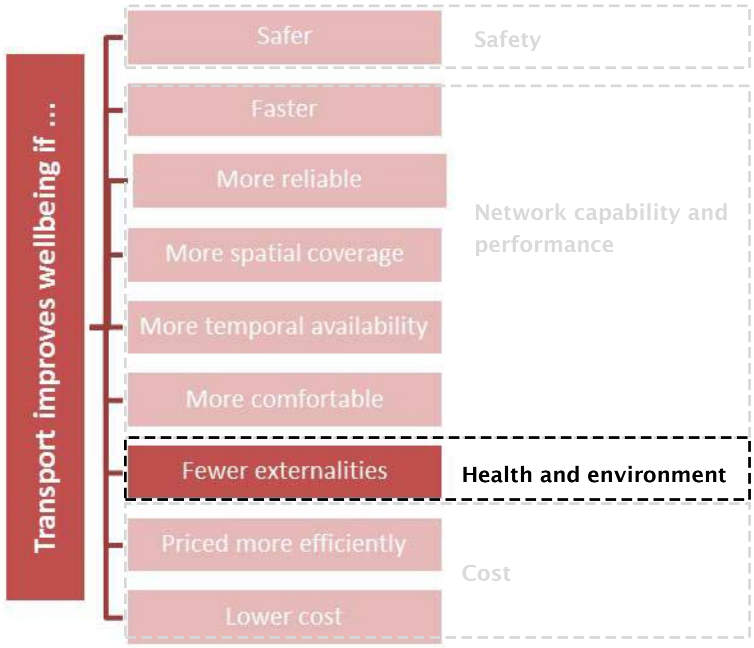
Indicator	Description	Road			Rail	
		Private	PT	Freight	PT	Freight
State indicators						
Cost per person km travelled	**Total fixed and variable costs of personal transport divided by total km travelled**	✓	✓		✓	
Cost per freight tonne km travelled	**Total fixed and variable costs of freight transport divided by total freight tonne and total freight distance travelled**			✓		✓
Pressure indicators						
Fuel costs	Average cost of imported fuel oil per barrel	✓	✓	✓	✓	✓
Transport sector labour costs	Average wage and salary costs for the land transport sector		✓	✓	✓	✓
Vehicle prices	Average value of all transport vehicles imported into New Zealand	✓	✓	✓		
Infrastructure costs	Total infrastructure costs, including construction and maintenance, divided by total network km (construction costs to be capitalised and depreciated over useful lifespan)	✓	✓	✓	✓	✓
Response indicators						
Subsidy per passenger km	Total subsidies divided by total passenger km on subsidised routes		✓		✓	
Taxes, charges per person km	Total govt revenue from personal transport activities divided by total km	✓	✓		✓	

Indicator	Description	Road			Rail	
		Private	PT	Freight	PT	Freight
travelled	travelled					
Taxes, charges per freight tonne km travelled	Total govt revenue from freight transport activities divided by total freight tonne km travelled			✓		✓

4.3 Health

The chief impacts of transport on health are via air emissions and noise, ie externalities (figure 4.5). There are also potential positive health effects from activity and exercise, such as from walking or cycling as transport options.

Figure 4.5 Conditions where wellbeing from transport is improved, everything else equal



Source: Covec

As noted in section 4.4, there are close interactions between environmental effects and those on human health. However, we discuss air emissions with health effects in this section.

4.3.1 Air emissions impacts

The pollutants of potential concern are listed in the summary of the *Health and air pollution in New Zealand* (HAPINZ) study (Fisher et al 2007a):

- Particulates (commonly assessed as PM_{10} or $PM_{2.5}$) – very fine particles that are associated with increased premature mortality, and exacerbate a number of respiratory and cardiac problems.
- Carbon monoxide (CO) – exacerbates heart disease and causes drowsiness and learning difficulties. Is strongly correlated with PM_{10} in cities.

- Nitrogen dioxide (NO_2) – causes breathing problems, and exacerbates asthma and other respiratory problems. It tends to be correlated with PM_{10}.
- Sulphur dioxide (SO_2) – causes sore throat and eyes, and can have an effect on mortality. It is not usually present in hazardous concentrations in New Zealand.
- Ozone (O_3) – causes severe breathing problems in high concentrations. It is not at present a serious problem in New Zealand, with no measured exceedences anywhere.
- Benzene – a component of petrol (along with numerous other hydrocarbons) which can lead to cancer.
- Air toxics – a range of other toxic compounds, including complex organic chemicals, process chemicals and heavy metals. Little is known about many of these.

We note that the NZTA (2011a) has recommended the use of NO_2 as a proxy for motor vehicle pollutants, consistent with WHO recommendations. However, particulates are generally accepted as being the most problematic. The difficulty with particulates as a measure is that small particulates, measured as PM_{10}, have a wide range of sources, including natural (eg sea spray) sources. Very small particles ($PM_{2.5}$) are more definitely the result of human activity. NO_2 is increasingly being recognised as an important pollutant in its own right, including through impacts on human health, and there is a close correlation to particle emission levels (Tham et al 2008; NZTA 2011a).

The approach taken here is to explore indicators of both pollutants. However, we recognise that the NZTA may wish to choose to adopt NO_2 as the key indicator.

4.3.2 Health effects or emissions and concentrations

State indicators can be defined in terms of the resulting health impacts or with respect to the emissions or concentrations of pollutants. A number of recent studies in New Zealand have measured changes in concentrations of the key pollutants, especially particulates, and have estimated the impacts on health. This includes the HAPINZ study (Fisher et al 2007b), the cost-benefit analysis as an input to the national environmental standards on air quality (NZIER 2009) and a recent review and update of HAPINZ for the Auckland region (Kuschel and Mahon 2010). However these effects are not measured directly; rather they use relationships between concentrations and health effects based on factors established in international literature.

This is an emerging field of study and the approach used in New Zealand studies does not appear to be appropriate for measuring the impacts of *changes* in concentrations and is different from that being adopted in US and European policy studies. In particular:

- The underlying relationships between concentrations and chronic mortality are based on studies that have measured differences in death rates and respiratory illness incidence in locations which have had long-term differences in pollution concentrations. Given that the most significant effects are cumulative, these studies can be used only to identify the impacts following a lifetime of living at the changed concentration rather than short-term changes to a lower concentration, which is relevant to policy and a monitoring system.
- The US Environmental Protection Agency (EPA) began to recognise this in policy studies from the early 2000s (eg EPA 2004a) and, in the absence of studies focused on the delay issue, the Advisory Council on Clean Air Compliance Analysis recommended a lagged approach in which 30% of the mortality reductions occur in the first year, 50% equally in years 2 through 5 and the remaining 20% over years 6 through to 20 (EPA 2004b).

- More recently, US studies have addressed the marginal impacts specifically and the results of Laden et al (2006) have been used in particular. This study measured changes in health impacts and mortality following substantial changes in air pollution levels. Their analysis was highly influential on the opinions given in a subsequent study that asked a number of experts their views on the appropriate health benefit values (Industrial Economics 2006; see also EPA 2006; 2011).
- The lagged impact approaches have been adopted in the UK also. The Committee on Medical Effects of Air Pollutants (COMEAP 2010) notes that 'while in principle it might take 40 years for all benefits to be achieved, in practice benefits were likely to occur significantly earlier, with a noteworthy proportion in the first five years'. Building on this, COMEAP decided to use the approach recommended by EPA (see the second bullet point above). COMEAP also considered a range of lag approaches in a separate analysis on alternative lag structures (Walton 2010).

International studies have also noted problems in reporting results in terms of premature deaths. COMEAP (2010), in particular, notes that the immediate benefits of reducing particulate pollution may be fewer deaths in the first year (and different numbers in subsequent years), but this is accompanied by a longer-term benefit of prolonging life or increasing life expectancy by delaying death; the result is a larger and older population. Noting in support the report by the Interdepartmental Group on Costs and Benefits (2007), COMEAP concludes that population total survival time (life years) better reflects the benefits than reductions in premature deaths. One of COMEAP's criticisms of the savings in the number of deaths approach is that these are not sustained; the results only occur until the age distribution of the population adjusts as a result of people living longer. Reductions in pollution levels will still have premature deaths and possibly just as many as before; they will simply be less premature. In fact COMEAP (2010, p17) suggests that 'more deaths will occur annually under lower pollution levels' because of the changes to population structure.[24]

These international developments appear to better explain the impacts of changes in pollution levels than the recent New Zealand studies.[25] Recognising this, and that the approaches being adopted acknowledge the complexity of effects but are making assumptions in the absence of studies that directly address the marginal impacts, it is more appropriate to limit monitoring to changes in concentrations and exposure rather than to estimate health impacts. This is the approach we adopt below.

4.3.3 Particulates

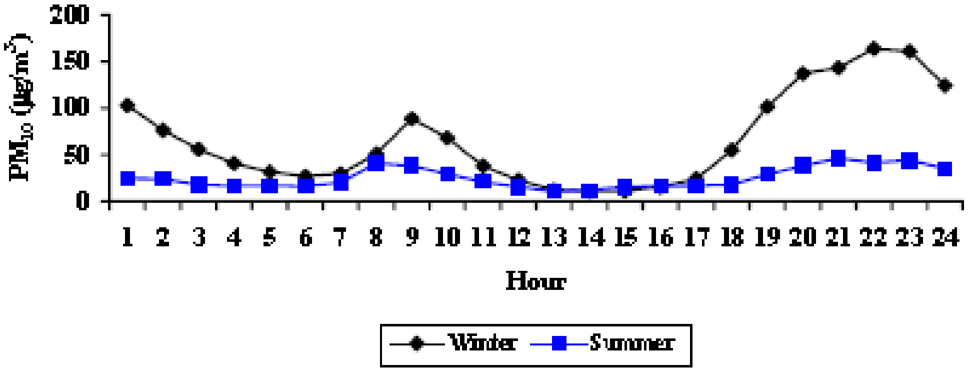
4.3.3.1 State indicators

We start the discussion with state indicators as they determine the others. Building on the analysis above, we suggest that the state indicators for particulates should be based on concentrations of particulates at specific locations, noting that what is important is exposure to these concentrations and that concentrations fall with distance from the emissions, eg away from the road, and change over time. Figure 4.6 shows concentrations over time at one location (St Albans in Christchurch) and illustrates that PM_{10} comes from multiple sources. There is some background level due to factors such as sea spray, small peaks in the morning and evening (summer) that correspond to commuting time and thus high levels of vehicle activity and winter peaks that correspond to use patterns for home heating (particularly wood burners). The HAPINZ study used regression analysis to separate out the sources.

[24] For example, if lower pollution causes people to live longer then the total population alive at any given time will increase, but this may also mean that the annual number of deaths increases, because a larger population means more annual deaths, everything else equal.

[25] The New Zealand studies have tended to discuss premature deaths as though these are discrete individuals rather than reflecting a higher overall death rate as a result of a very large number of shortened lifetimes.

Figure 4.6 Hourly concentrations of PM_{10} in St Albans, Christchurch (1997)



Source: Fisher et al (2007b)

More recently, GNS Science and others have undertaken additional research to separate out the sources of particulates (Ancelet et al 2012). They found contributions associated with vehicles were highest during peak traffic hours but that vehicles also contributed a background level of emissions throughout the day. It suggests that identifying the source of particulate emissions or concentrations is important.

The difficulty of source apportionment is a reason why some have suggested that particulate emissions or concentrations should not be used as a transport indicator. This is a difficult call: particulates are an important pollutant with significant impacts on human health, but tracking emissions or concentrations may give little indication of the contribution of the transport sector. For example, despite measures to limit emissions or exposure from transport through changing fuel specifications or respecifying transport routes, concentrations may rise as a result of increases from other sources.

However, despite the limitations, our preference is for particulates to be included in the indicator system. To the extent that the indicators are a statement of issues of policy importance, removing reference to particulates would not be appropriate. However, it is important to signal also that this indicator would improve over time to the extent that source apportionment can be achieved.

Related to measurements of concentrations and exposure, there are national environmental standards for air quality that include a standard for particulate matter:

> *PM_{10} concentration of 50 $\mu g.m^{-3}$ (24-hour average) will not be exceeded for more than one 24-hour period in a 12-month period*

One approach would be to report the number of exceedances of the standard. However:

- in most New Zealand cities and towns, daily PM_{10} levels are usually well below the standard (and about 25-35 $\mu g/m^3$) (MfE 2011a)
- despite the standard, there is no 'safe' threshold for PM_{10}; adverse health effects are observed at all elevated levels. Thus changes beneath the threshold are important also
- as above, there are many sources of particulates and standards apply to regions as a whole and do not isolate the effects of transport.

There would be challenges in designing an indicator that takes account of exposure, as opposed to simply concentration. This is particularly because the exposed population may be different from that which lives in the proximity of the monitoring site. In addition, not all areas in New Zealand have a monitoring site.

Given this background, there are a number of possible approaches:

- Establishing an agreed network of sites and reporting concentrations in these selected locations. Concentration might be expressed in terms of:
  - annual averages
  - peaks
  - a time-weighted average

  (an example of this approach is given in table 4.3)
- Measuring exposure as concentration times population. This could only be done for the sites with a monitoring station and would be a gross approximation, eg the population of the census area unit (CAU) times the concentration measured at the monitoring site in the CAU.

Table 4.3 PM_{10} statistics (24-hour average) for the 2009 calendar year (PM_{10} µg/m³)

	Wellington central	Lower Hutt	Upper Hutt	Masterton	Tawa	Karori	Wainui-omata
Maximum	31	31	25	55	30	30	41
95th percentile	19	22	20	30	22	19	24
Mean	13	14	11	13	13	11	12
Median	12	13	10	11	12	10	11
Interquartile range	10 to 15	11 to 16	7 to 14	8 to 16	9 to 16	8 to 13	8 to 15
Valid data	100%	97.50%	95.90%	100%	92.10%	99.50%	98.40%

Source: Mitchell (2010)

We understand that NIWA has produced concentration data for each CAU using modelled data based on regression analysis. This is another possibility in the absence of monitoring data. Data from models has the advantage of being more widely available but the disadvantage of being subject to change over time as modelling approaches improve.

Concentration data is likely to be the most simple and transparent. A separate question is then whether to separate out the effects that are due to transport activity from the impacts of home heating and background concentrations. This might be undertaken following approaches used in the HAPINZ study. We note that the revised report is to be released shortly (as of writing in June 2012). If an easily defined methodology can be produced, this would be a useful addition.

Despite the shortcomings of modelled data, the simple exposure indicator would be a useful impact measure because it takes account of factors, such as population movements, that also affect health impacts, eg increasing urban concentration.

The issue of whether reporting is undertaken as PM_{10} or $PM_{2.5}$, is likely to be determined by data availability. Effects appear to be more related to the smaller ($PM_{2.5}$) particles, and these are more certainly anthropogenic, but PM_{10} data is more readily available and over a longer time frame. We suggest that both are collected to the extent possible:

- PM_{10} because the data are more likely to be available for a wide range of locations
- $PM_{2.5}$ because it is a better indicator of damage.

4.3.3.2 Pressure indicators

Pressure indicators measure changes in the factors that result in changes to particulate concentrations. These issues were addressed by the HAPINZ study (Fisher et al 2007b) and include, in particular:

- Vehicle fuels – sulphur dioxide (SO_2) forms an aerosol that functions as a small particulate. Thus sulphur concentrations in fuels are a major indicator of expected small particulate concentrations, although the effect is more pronounced in diesel than petrol. However, levels of sulphur are now extremely low—diesel manufactured in New Zealand has less than 5ppm of sulphur and is classified as 'zero sulphur' diesel.
- Petrol or diesel engines – the relationship between engine technology and emission rates is complex, with petrol vehicles emitting more very small particles (nano-particles) than diesel engines but, overall, petrol vehicles emit less than diesels 'for all particle parameters (including mass and number) tested' (Fisher et al 2007b, p115).
- Remote-sensing tests have found higher average emissions of particulates measured as opacity. However, particulate traps can make a significant difference to emission rates.

Sulphur content of diesel would appear to be a worthwhile pressure indicator, but the very low levels now found in fuel means that it is unlikely to provide useful information as a trend from now on. Engine technology (diesel versus petrol) looks to be useful, but the relationship is complex and it is not clear which direction of change is best for particulates.

Other factors include the age of the vehicle, so that, all other things being equal, a newer vehicle fleet would be expected to have lower emissions.

VKT is a potential indicator of pressure for air pollution. However, the effects are related to exposure so that it matters where the VKT occur; this differs from CO_2 emissions for which the location does not matter. Thus total VKT is not included in our list of suggested indicators.

4.3.3.3 Response indicators

Response indicators could include:

- National concentration standards for particulates and/or number of exceedances. However, standards are set for entire airsheds and transport is not the dominant contributor in any location in New Zealand. This is unlikely to be a useful focus for indicators.
- Fuel sulphur content regulations. However, fuel sulphur is effectively zero at this stage so is not expected to change over time.

4.3.4 Nitrogen dioxide (NO_2)

4.3.4.1 State indicators

As with particulates, we suggest that concentrations at key monitoring sites are used as the main state indicator. We also suggest that an indicator based on modelled concentrations and population (per CAU), would be a useful indicator of exposure.

4.3.4.2 Pressure indicators

NO_2 emissions vary with a wide range of factors including fuel type, engine technology and the combustion conditions, as affected by cold-start versus hot-running conditions and the speed of the vehicle (see for example European Environment Agency 2009). A more generic set of factors links emissions to the vehicle technology alone, ie Euro 1, 2, 3 4 etc. Classifying vehicles in this way would provide a simpler approach.

4.3.4.3 Response indicators

Response indicators could include:

- emission standards, plus exceedances
- import standards for new and used vehicles.

4.3.5 Noise

There is no comprehensive data set on noise from transport in New Zealand but a number of studies have looked at the impacts of road surface on noise levels (Dravitzki et al 2006; Dravitzki and Kvatch 2007). Table 4.4 shows a table of differences in which the performance of different road surfaces is shown relative to 10mm asphaltic concrete (AC-10).

Table 4.4 Road surface corrections, relative to AC-10 (dBA)

Surface category	Cars	Trucks
Asphalt – dense graded	0.0	-2.0 – 0.0
Open graded porous asphalt	-2.0 – +3.5	-4.0 – -1.0
Capeseal	0.0 – +3.5	-1.0 – +1.0
Stone mastic asphalt	+1.5	-1.5
Slurry seal	+1.0	-1.0
Macadam	+3.0	0.0
Chipseal	+3.0 – +6.0	-2.0 – 1.0
Two-coat seals	+5.0 – +6.0	+1.0

Source: Dravitzki and Kvatch (2007)

Some studies have predicted noise levels based on a range of factors including traffic volume and speed, road gradient and road surface (URS 2012). This approach has been used to set priorities for action to reduce noise levels. This work is still in development and is not available comprehensively across New Zealand.

In the absence of noise data, it is not possible to develop a *state* indicator, but the length of road under different types of seal could be used as a *pressure* indicator. Noise will have greater impact where there are more people, ie in urban rather than rural areas. The indicator might usefully be limited to urban areas.

4.3.6 Walking and cycling

The Ministry of Transport notes that walking and cycling are accessible forms of exercise for improving cardio-vascular fitness, reducing the risk of heart disease and controlling obesity (MoT and Brunton Grant Consulting 2008). It notes recent research from Australia that conservatively estimated cycling for recreation and commuting saves over A$220 million per year in health costs (Bauman et al 2008).

These issues will be best addressed through a *state* indicator of the proportion of trips taken via walking and cycling.

4.3.7 Summary

Table 4.5 summarises the recommended indicators for the health wellbeing category. We note the difficulties of attribution of particulate emissions and concentrations to transport sources, but also the potential importance of transport to total emissions. This means that we believe it is useful to include an indicator relating to particulates but recognise the difficulties of identifying something that will provide meaningful data. We suggest that particulates are included in the indicator system, particularly to the extent that the system is some kind of statement of issues of policy importance, but that the approach is improved over time as more information is available relating to source apportionment.

Table 4.5 Recommended health wellbeing indicators

Category	Indicator
Air quality Pressure	Average age of the vehicle fleet
State	Concentration of $PM_{10}/PM_{2.5}$ at key monitoring sites Concentration of NO_2 at key monitoring sites Average exposure to $PM_{10}/PM_{2.5}$ (concentration in CAU × CAU population)/total population Average exposure to NO_2 (concentration in CAU × CAU population)/total population Proportion of trips taken using walking or cycling
Response	Vehicle import standards
Noise Pressure	Kilometres of roads categorised by surface category (possibly limited to urban areas)

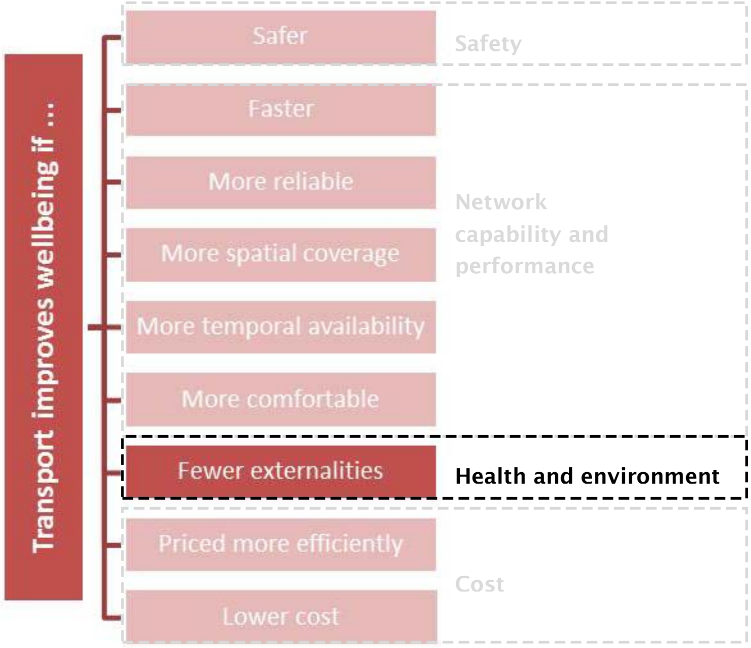
4.4 Environment

The environmental impacts of road transport include those that arise from:

- emissions to air of greenhouse gases and local air pollutants
- road runoff
- biodiversity and community cohesion.

As with health effects, these can be characterised as externalities (figure 4.6).

Figure 4.6 Conditions where wellbeing from transport is improved, everything else equal



Source*:* Covec

There are close interactions between environmental effects and those on human health. In particular, emissions to air have impacts on human health, particularly respiratory problems resulting from small particulates. These same emissions can also result in visual impacts (visible smog) and, in other countries but reportedly not in New Zealand, have resulted in acid rain. We separate our discussion of these issues by including the local air pollutants under health indicators and limiting the discussion of air emissions with environmental effects to greenhouse gases.

4.4.1 Greenhouse gas emissions

Greenhouse gas emissions from transport in New Zealand are not a major cause of environmental problems for New Zealand. Greenhouse gases are long lived and mix thoroughly in the atmosphere so the impacts are shared with all other countries. The impacts of climate change that New Zealand may face, including impacts on the transport system, are the result of atmospheric concentrations that result very largely from the emissions of other countries. New Zealand will simply take these impacts (as modified by any adaptation measures taken). These characteristics are the reason there is an international agreement to tackle climate change rather than it being tackled via unilateral action. The consequences of this agreement are that emissions from New Zealand are better characterised as an economic rather than an environmental impact. New Zealand faces a cost either in the form of the cost of internationally tradable emission units or the costs of lost reputation, but it faces little direct impact as a consequence of its own emissions. The introduction of the emissions trading scheme (ETS) and the inclusion of transport fuels within this effectively internalises the cost in transport fuel prices.

Despite these qualifications, we discuss greenhouse gas emissions as an environment indicator and we examine their treatment under a pressure state response framework (see table 4.6).

Table 4.6 Greenhouse gas emissions indicators

	Potential indicator
Pressure	Emissions intensity of the fleet VKT by fleet category
State	CO_2 emissions
Response	Internalisation of costs via the ETS

The state indicator, ie the main issue that results in impacts on wellbeing, is the level of emissions. As noted above, it is transport sector emissions rather than the damage or change in atmospheric concentrations attributable to emissions from New Zealand transport that most directly affect the wellbeing of New Zealanders. We define this as the chief indicator.

4.4.1.1 Pressure indicators

The pressure indicators, ie the causes of emissions, are based on:

- the emissions intensity of the fleet, which can be measured as an average and by vehicle category
- the amount of travel (VKT) per vehicle category.

Emissions from a vehicle are the product of two key factors: the characteristics of the vehicle that determine its emissions intensity and the usage of the vehicle. Driver behaviour is also a major contributing factor to emission rates, so that variation in behaviour can be a more important contributory factor than the theoretical emissions intensity of the vehicle based on its engine technology. However, it is not easily measured. We concentrate on the factors that influence emissions intensity.

CO_2 emissions intensity

The emissions intensity of the fleet can be assessed in terms of the average emissions intensity of the whole fleet, the change in emissions intensity and by the factors that determine emissions intensity.

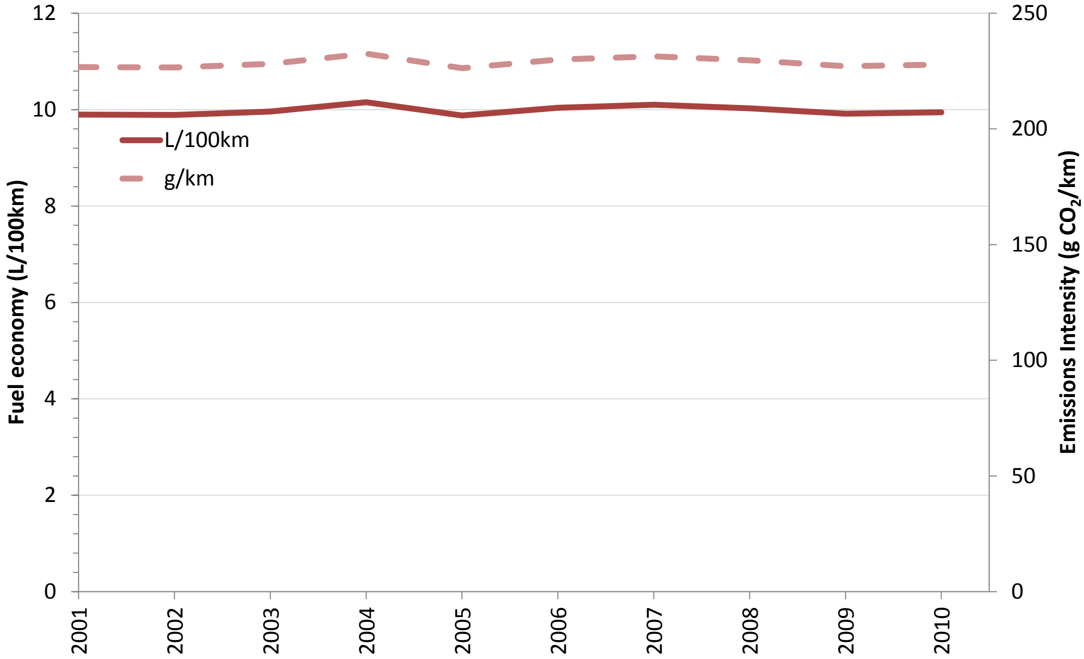
Data on the average emissions intensity of the fleet is shown for the light petrol fleet in figure 4.7. This is estimated using a percentage (98.2%) of the petrol fuel consumption and dividing by an estimate of the VKT by the petrol fleet. Doing the same analysis for diesel vehicles is much more difficult because of the problems of separating transport uses from other uses, such as for diesel generators or boats.

Figure 4.7 suggests there is little change in CO_2 intensity of the light petrol fleet over time, but this masks some of the detail. At the same time, the emissions intensity of vehicles entering the fleet is improving (figure 4.8), but the impact is diluted as the average age of the fleet is increasing because of fewer new entrant vehicles and fewer vehicles exiting the fleet (figure 4.9).

To capture what is happening in a comprehensive way would be to track the fleet in terms of the number of vehicles in different classes of emissions intensity (or fuel economy) over time. However, data is available for a relatively small proportion of the total fleet. In addition, we note that classifying the fleet in this way is useful largely if it can be correlated with data on activity (measured as VKT). However, the VKT data (as discussed below) can be classified by categories associated with a vehicle’s number plate. This is chiefly its engine size, plus propulsion and age.

Given these limitations, the more general data in figure 4.7 is likely to be the best overall indicator of the emissions intensity of the fleet.

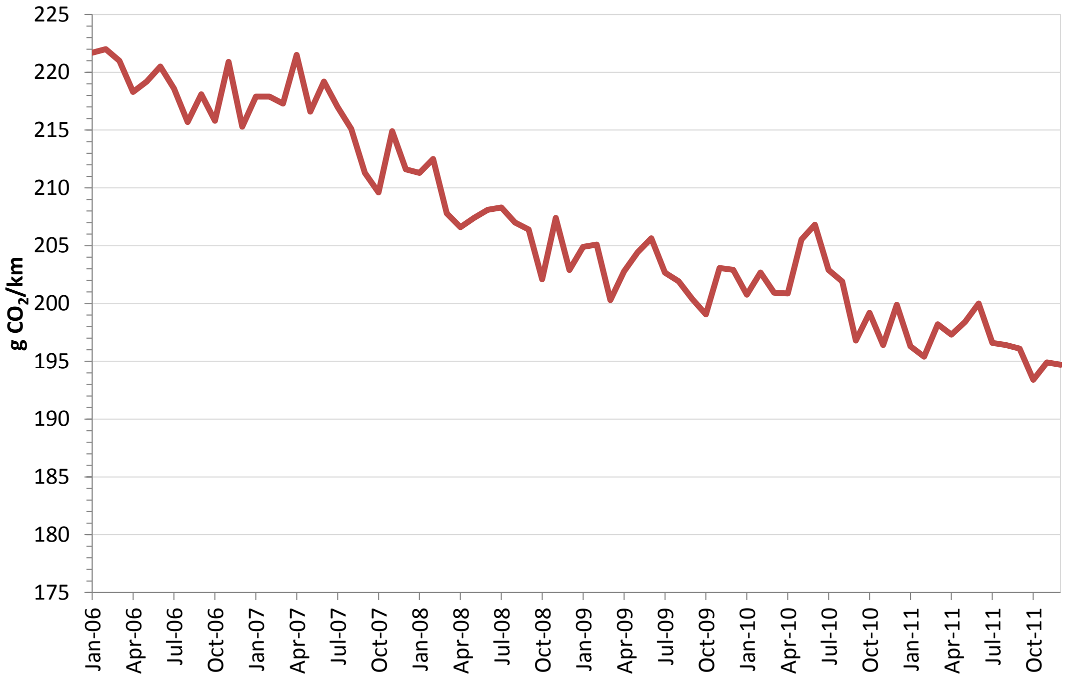
Figure 4.7 Average fuel economy and emissions intensity of light petrol fleet



Note: Estimated from 92.82% of petrol sales divided by total VKT

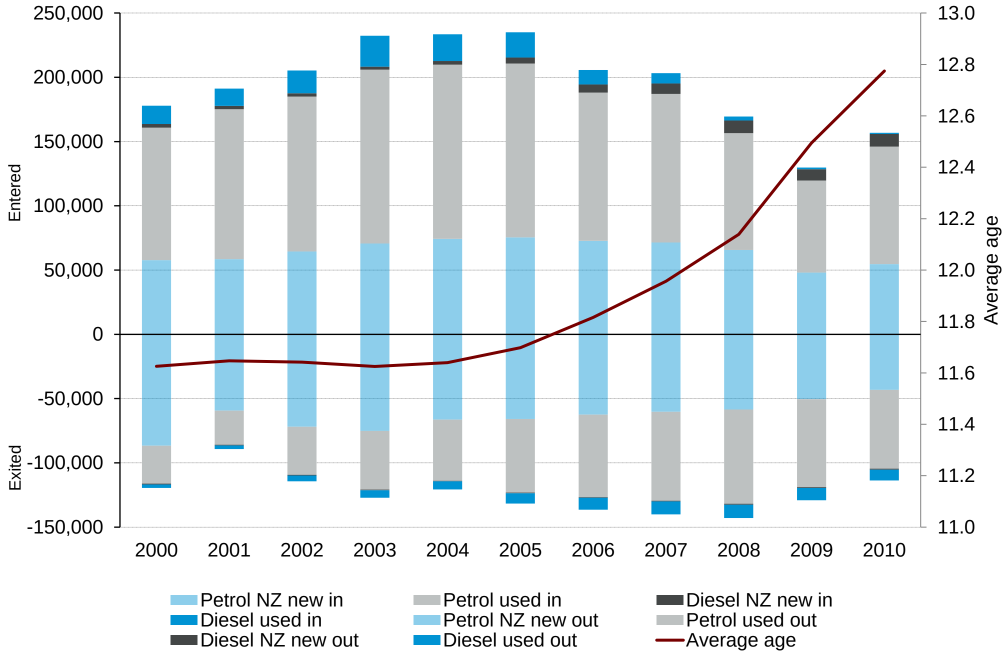
Source: MoT (2011a)

Figure 4.8 Average emissions intensity of new vehicles entering the fleet



Source: MoT TMIF

Figure 4.9 Light passenger fleet entry and exit



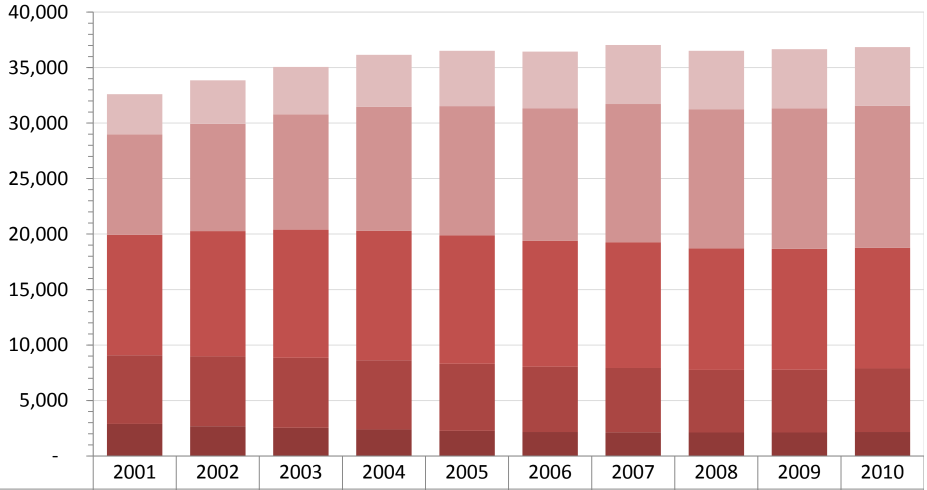
Source: MoT (2011a)

Monitoring numbers of specific vehicle types might be used as a secondary indicator. For example, measurements might be made of the number of electric vehicles or hybrids. However, this risks focusing on one possible solution to CO_2 emissions, whereas policy makers have adopted a policy approach (the ETS) which is indifferent to specific solutions; measuring emissions intensity captures changes that could result from more use of electric vehicles, shifts towards smaller vehicles and modal shifts.

Vehicle kilometres travelled

As noted above, VKT is a useful data set if it can be collected for categories that can also be used to define fuel economy. The data in figure 4.10 is collected from odometer readings when vehicles are tested for WoFs.

Figure 4.10 Kilometres travelled by light vehicles



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Light 3000+	3,611	3,915	4,276	4,687	4,977	5,106	5,315	5,285	5,336	5,284
Light < 3000	9,055	9,672	10,382	11,172	11,658	11,954	12,459	12,508	12,656	12,802
Light < 2000	10,858	11,282	11,557	11,666	11,564	11,349	11,337	10,969	10,906	10,881
Light < 1600	6,198	6,303	6,308	6,229	6,056	5,880	5,787	5,641	5,658	5,727
Light < 1350	2,881	2,679	2,540	2,398	2,258	2,161	2,136	2,110	2,114	2,153

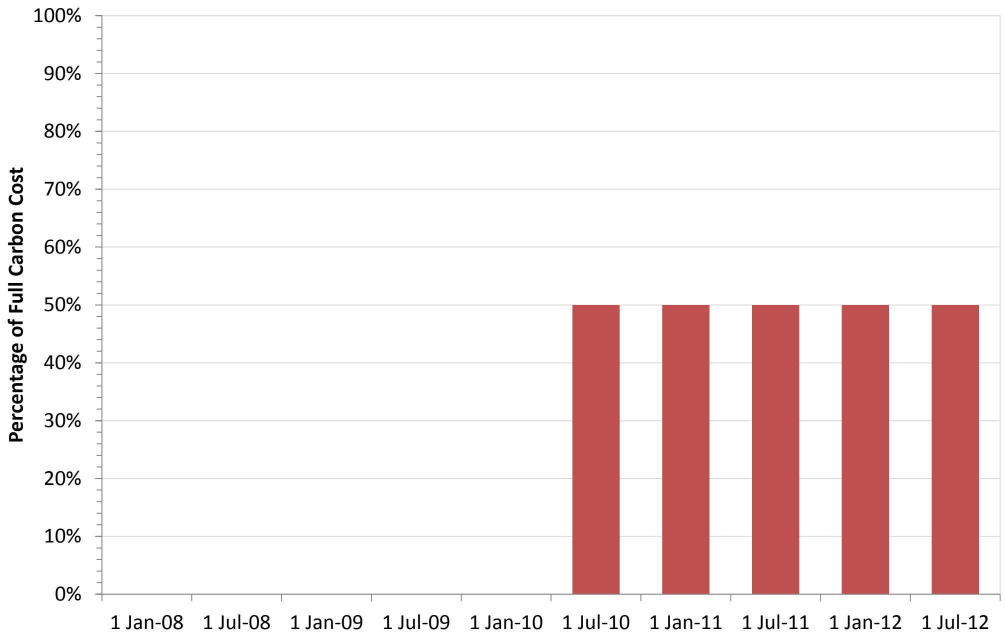
Source: MoT (2011a)

4.4.1.2 Response indicators

Response indicators might include measures to improve the fleet's emissions intensity, or to improve driver behaviour, including through speed limits. However, we have limited the proposed indicators to the extent to which the transport fleet faces the same price per unit of emissions as New Zealand as a country.

The chief indicator of policy pressure on vehicles is the extent to which they are facing the full international price of emissions. However, although this might be possible currently (mid-2012), it may be more problematic in the future following the end of the first commitment period under the Kyoto Protocol. The way in which any future international commitment will function is highly uncertain. Nevertheless, this appears to be a reasonable approach.

Figure 4.11 Percentage of international carbon price paid by road users



4.4.2 Road runoff

There are many processes by which contaminants from transport enter the environment, including emissions to air that are precipitated out into aquatic environments and compounds that are deposited to roads from tyres and are subsequently washed into waterways (Moncrieff and Kennedy 2004). Road runoff contains contaminants derived from vehicles that include heavy metals and hydrocarbons; they can adversely affect the ecology of receiving environments and/or the human uses or values associated with them (Gardiner and Armstrong 2007). The impacts are highly localised as receiving environments differ widely in their inherent sensitivity and their risk from road runoff depends on a variety of factors apart from traffic levels.

Reed et al (2008) monitored a number of sites, noting among other things, that there were significant other sources of metal concentrations in sediments (that required investigating) and that road runoff appeared to be a fairly minor contributor to polycyclic aromatic hydrocarbon concentrations.

Moores et al (2010) suggest that the major contaminants of concern are copper and zinc; they note that emissions occur more as a result of traffic behaviour than traffic volumes, with high emissions from roads with greater rates of brake and tyre wear, rather than on roads with relatively free movement of traffic. However, levels of contaminants in the environment also depend on rainfall.

Gardiner and Armstrong (2007) developed a model to measure impacts. In the model, pollutant loads were derived from traffic flow, speed and congestion, vehicle type and pollutant emission rates (ie brake, tyre and road surface wear, oil leakage and exhaust emissions). They also classified receiving environments in terms of sensitivity. The model was subsequently tested against actual levels of contamination in case study sites; they found that the model was successful in identifying areas at risk.

The analysis to date in New Zealand provides some capability for predicting road runoff, but the monitored levels of contaminants would not be able to identify the source of the contaminants and there is no systematic monitoring of all potential at-risk sites for actual levels of contamination. Existing research for the NZTA suggests that the environmental impacts of state highway runoff are not strong and consistent in most cases (Shaver and Suren 2011).

It is likely that no relevant state indicators can be developed for road runoff. If available, indicators of road congestion and/or free movement of traffic might be used to provide some indication of risk of contamination. However, these are not currently available and the link to runoff is somewhat tangential; therefore we do not recommend pursuing congestion measures as a primary indicator.

4.4.3 Impacts on biodiversity and community cohesion

The total area covered by roads would be one indicator of habitat displacement, although a more important impact might be via habitat severance where a road cuts through and divides a habitat. Data is available on road length, by different road types and this could be converted to area with some simple assumptions about width. However, the area changes by very little in percentage terms over time and the aggregate number is very small as a percentage of the land area of the country. Area taken up by roads does not appear to be a useful environmental indicator. Habitat severance will be even less easily measured.

4.4.4 Summary

Table 4.7 summarises the recommended indicators for environmental wellbeing.

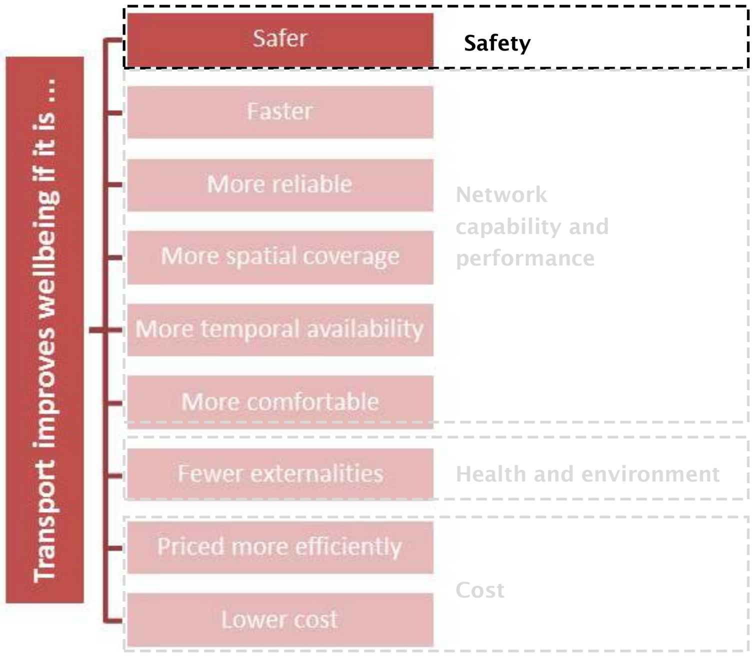
Table 4.7 Recommended environmental wellbeing indicators

Category	Indicator
Greenhouse gas emissions	
Pressure	Average fuel economy of fleet – fuel consumption/VKT (separately for petrol and diesel)
	VKT
State	CO_2 emissions by road vehicles
Response	Degree of internalisation of CO_2 price – proportion of transport fuel facing the emissions price
Road runoff	
Pressure	Congested roads (km) (noting difficulties explained above, ie this is not a priority indicator)

4.5 Safety

Safety indicators measure the safety outcomes that have an impact on wellbeing from land transport (figure 4.12). That is, bad safety outcomes impact negatively on wellbeing whereas safety improvements lead to an increase in wellbeing.

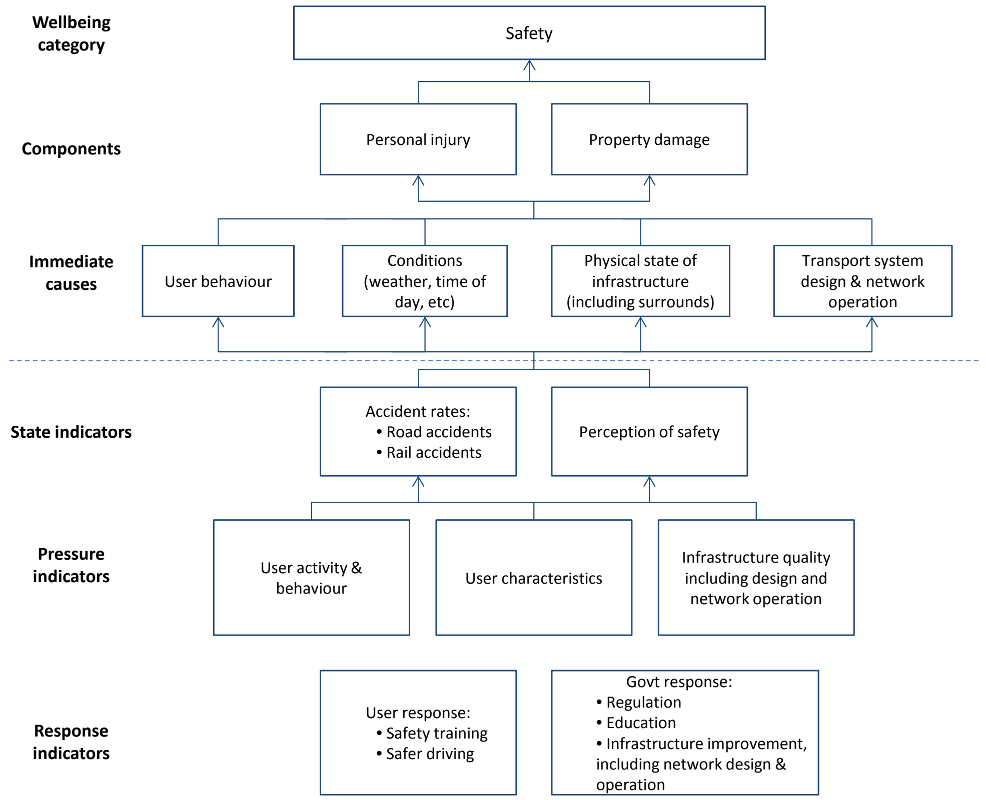
Figure 4.12 Conditions where wellbeing from transport is improved, everything else equal



Source: Covec

Figure 4.13 describes the relationships between the indicators and safety outcomes. In this figure we have categorised possible indicators using the OECD's PSR framework. NZTA's Safe Systems approach is incorporated into the selection of specific indicators, as is outlined in the following sections.

Figure 4.13 Safety indicator framework



4.5.1 State indicators

Safety wellbeing incorporates two components:

- physical injuries, including deaths
- property damage.

Consequently, any indicator(s) that seeks to identify the current level of safety outcomes should ideally account for these types of harm. Although the amount of harm or number of incidents provides useful information regarding safety outcomes, and may be particularly useful for public purposes, the level of these outcomes can be affected by factors not directly caused by the transport system itself. For instance, increased transport usage from population growth can have an impact of safety outcomes although there has been no change in the risk to users of safety incidents. As a result, useful indicators of safety outcomes should be based predominantly on the rate of safety incidents rather than merely raw totals.

Consequently, a useful approach would be to unitise measures of total harm by some appropriate denominator, such as total km travelled or total population. A potential indicator could be:

$$\text{Overall safety} = \frac{\text{Total harm}}{\text{Total km travelled}}$$

Indicators that reflect the overall state of safety outcomes in land transport can potentially use two different approaches for measuring total harm. One is to adopt a ‘social cost' approach in which the harm, losses and costs arising from all injuries, including deaths, are converted into dollar values. This approach has the advantage of being able to combine the different types of harm into one overall figure. The resulting measure of total social cost estimates the value that society as whole loses from crashes that result in personal injuries and property damage. These losses arise from:

- decreased wellbeing to injured parties
- decreased wellbeing to friends and family of fatalities
- costs of health care and emergency services
- costs of repair, replacement or loss of property.

Estimates of the loss of wellbeing from injuries, including deaths, are typically generated using willingness to pay approaches. There are three different methods that can be used to estimate willingness to pay: stated preference, revealed preference and willingness to accept. Internationally, most of the literature uses either stated preference or revealed preference methods. Stated preference methods typically require surveys that ask people directly how much they would be prepared to pay to reduce the risk of certain injuries, eg death. These survey results are then scaled up to provide estimates of the willingness to pay of society as a whole. Revealed preference methods involve studying relevant buying behaviour, for example the purchase of safety-related products or the level of wage premium that is required to compensate for increased risk.

Another method for valuing the loss of life is the human capital approach. This approach is based on estimates of the present value of individuals' current and future economic output. This approach is an incomplete method of valuing loss because it focuses only on lost productivity. That is, this method does not directly account for the loss incurred by friends and family in the event of a fatality or the reduced quality of life (eg pain and suffering) of an injured party.

These different approaches were assessed in a study undertaken by the ACC (Wren and Barrell (2010). This study recommended that evaluations of the cost of injuries should use a standardised approach based on willingness to pay. This study also concluded that the value of statistical life used to value the loss of life from fatal transport crashes should be re-evaluated and updated. The current estimate is based on a value of preventable fatality survey undertaken in 1991 which is adjusted for inflation. Additionally, this study, along with another by Access Economics (2008), suggests there is considerable international variation in the assessment of total social cost of injuries.

However, a disadvantage of this approach is that it does not provide detailed information regarding the different harm types that may be of more interest to policy makers, eg deaths and serious injuries as opposed to minor injuries and vehicle damage. Furthermore, valuing different types of harm in dollar terms can be difficult and controversial, and this process is an extra analytical burden. An appropriate alternative approach may instead be to use raw numbers of those incidents that are of specific interest, eg deaths and serious injuries.

Once an appropriate measure(s) of total harm has been determined, this figure should be divided by an appropriate denominator to provide a more accurate indication of the level of safety. This would ensure that the indicator provides a more accurate reflection of the risk faced by a user on either a per user or per usage basis.[26]

A potentially useful denominator would be the total kilometres travelled by all transport users. Dividing the measure(s) of harm by total kilometres travelled would provide a unitised indicator of current safety levels based on the actual usage of the transport system.

Consequently, our proposed state indicators for safety wellbeing are:

- the rate of deaths
- the rate of all serious injuries (including deaths)
- the rate of total social cost of safety incidents.

Many jurisdictions produce large numbers of safety indicators based on deaths and other injuries and in this regard these indicators are broadly consistent with international practice. However relatively few jurisdictions use indicators based on the rate of transport usage (ie total person km travelled) although Australia is one example. More common are injury rates based on population. As discussed above, injury rates based on actual usage provide a better indication of risk faced by transport users, as transport usage does not necessarily change proportionally with changes in population.

4.5.1.1 Other potential state indicators

If the measures of total km travelled are not sufficiently robust then another possibly useful denominator is total population. The rate of incidents, or the amount of social cost, can be measured per capita. As well as comparisons across time, a population-based indicator would also be more useful for international benchmarking as there may be inconsistency across international estimates of total km travelled.

Despite the analytical advantages of unitised safety indicators, some safety indicators based on raw data may be useful for publication purposes if there is a concern that rate-based indicators could generate confusion among the public about whether there are targeted (ie acceptable) levels of safety incidents. As a result we have included the total number of deaths and serious injuries as an indicator that could be used for public documents or other such publications.

[26] For instance, if the number of serious safety incidents remained unchanged while the population and overall transport usage increased, using total harm figures would suggest there was no improvement in safety, whereas the rate of incidents has fallen and safety levels have in fact improved.

As well as using the cost and/or number of safety incidents, other state indicators could be based on the perceptions of the safety of transport users. These would be obtained via periodic user surveys. Appropriately framed surveys could indicate the extent to which some transport users consider that safety has improved.

4.5.1.2 Further segmentation

The total social cost of safety incidents could be further broken down into injury costs (comprising of both the value of physical harm and lost income) and property damage costs.

As well as total incident numbers or costs, the range of safety data currently collected means that it is possible to segment the overall safety indicator by a number of different variables (MoT 2011b), including:

- vehicle or road user types (eg heavy, light, motorcycle, cyclist, pedestrian)
- driver characteristics (eg age – such as 15 to 25 year olds, gender, alcohol and drug use, restraint use)
- crash characteristics (eg intersection, level crossing, head-on)
- prevailing conditions (eg weather – dry or wet, time of day)
- crash causes (eg distraction).

Further segmentation could include public transport passenger injuries and crashes. Additionally, rail-related safety incidents can also be separated out. These typically involve the road network at level crossings or pedestrians on railway tracks but may also include carriage derailment and personal injury as well as rail sector employee incidents.

4.5.2 Pressure indicators

Pressure indicators seek to measure the factors that influence safety outcomes. That is, these indicators should reflect the factors that are explanatory variables for state indicators. Many of these factors are outlined in the NZTA's Safe System approach to road safety, such as roads and roadsides, vehicles, road use and speeds.[27] Consistent with this approach, we have identified the following specific indicator groups:

- the behaviour, actions and characteristics of transport users
- vehicle characteristics
- the design and physical condition of transport infrastructure, including the surrounding roadsides and speed environment, and the operation of transport networks.

There are a number of possible pressure indicators which relate to driver behaviour (ie road use) and driver characteristics. Possible driver behaviour indicators currently measured include excessive speed, alcohol use and safety belt use. User perceptions of risk also have the potential to provide some useful information if these perceptions cause users to be more cautious and/or acquire safer vehicles. Given the relative prevalence of certain behaviours among certain groups, driver characteristics may be a useful indicator and could be assessed using any available data regarding driver demographics such as age and gender.

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[27] A discussion of these factors is included in *Safer journeys: New Zealand's road safety strategy 2010–2020* (MoT 2010). Note that, unlike the safe systems approach, the categorisation of pressure indicators used in this report does not include a separate category for speed. This is because speed-related factors are separated into two separate indicator groups that both influence vehicle speeds. These are the behaviour of road users and design features of transport infrastructure, including speed limits and broader speed environment.

The physical attributes of the vehicle fleet also have a bearing on safety outcomes. For instance, older vehicles tend to have fewer safety features.[28] Additionally, motorcycles are disproportionately over-represented in safety incidents and are associated with higher risk. Vehicle characteristics could be assessed using information regarding vehicle safety ratings based on data held on the car registration database. Other indicators could also be potentially useful as a proxy for more detailed safety information, such as the average age of the fleet. The number of motorcycles per capita may be useful for incorporating the influence of motorcycle usage on safety outcomes.

Similarly, the proportion of walking and cycling trips made by transport users would also be a useful indicator because it provides information regarding the possible exposure to risk of pedestrians and cyclists. The higher the proportion of these trips that are made, the greater exposure these transport users have to harmful incidents.

Another important pressure indicator relates to the transport infrastructure itself. The physical condition of infrastructure can be an important factor in safety outcomes. Aside from more straightforward physical attributes, such as age or materials, another key factor is system design. Given that human error, as opposed to deliberate unsafe driving, is a contributing factor to many crashes, the design of roading infrastructure has a large bearing on safety outcomes. Specifically, safety outcomes may be worse to the extent that transport infrastructure does not effectively accommodate the fact that drivers will inadvertently commit errors and that some level of on-going human error by users is not able to be eliminated.

One example is the ‘speed environment’ in a given stretch of road. This is an important factor but is difficult to measure as it includes not only speed limits but can also include road design features that may encourage safer speeds. Although it does not account for all of the relevant design aspects, a potentially useful indicator in relation to highways is the Star Rating measure of roads as determined as part of KiwiRAP.[29] In particular, the average safety rating of the highway network may be of use. Star Ratings are derived from a Road Protection Score and are calculated for every 100m of road. Risk Mapping is also carried out using previous crash records.

The other main component of the roading network is local roads. A specific indicator regarding the safety-related design features of local roads, such as safety ratings for intersections, would be useful, however such information is not widely available. In the absence of this information, a measure of total traffic on local roads could potentially be of use as a pressure indicator. Although this measure does not take account of all of the relevant road and roadside design features this information could be useful as a measure of exposure, particularly to pedestrians and cyclists.

Specific safety-related rail network infrastructure information may be particularly useful. One indicator that would provide an insight into the safety level of rail infrastructure is a measure of the number of controlled railway (level) crossings. Crashes are less likely to occur at railway crossings that are controlled, whether by barrier arms, signals or stop signs. Because the absolute number of controlled crossings does not provide sufficiently detailed information regarding changes in the level of safety, a more useful indicator would the proportion of total railway crossings that are controlled. By using a proportion rather than an absolute number, any changes in the number of railway crossings would be taken into accounted, eg because of new roads. Measures of the quality and operation of rail infrastructure and rolling stock may also be useful safety indicators.

Other factors that are external to the transport system itself also affect safety outcomes. These can include prevailing conditions, eg weather, time of day, etc. Although there is substantial crash data

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[28] This assumes all other variables are held constant.

[29] See: KiwiRAP: New Zealand Road Assessment Programme 2010.

regarding conditions such as weather, time of day, visibility, etc, this is in relation to safety outcomes. Additionally, these factors are outside of the control of policy makers. As a result, measures of these conditions are not included as pressure indicators.

Consequently, our proposed pressure indicators for safety wellbeing are:

- vehicle characteristics – safety ratings, number of motorcycles per capita
- user characteristics – age (such as the proportion of transport users that are 15 to 25 years old, or over 65), pedestrians and cyclists
- user behaviour – speed, substance use
- infrastructure and transport system design characteristics – highway network safety ratings.

Various jurisdictions compile indicators that concerning a number of the aspects outlined above although these types of pressure indicators are in general much less common than state (ie incident) measures. For instance, at least one other jurisdiction (Australia) produces a detailed road surface indicator while many other jurisdictions do not. Some jurisdictions (eg Ireland) and organisations (eg the European Transport Safety Council) measure some aspects of user behaviour, such as seatbelt usage and average speed, but not other aspects, such as substance use. The European Transport Safety Council also measures the penetration rate of new cars and their respective safety ratings.

4.5.3 Response indicators

In the context of land transport safety, response indicators primarily consider how various agencies (ie relevant central and local government authorities) utilise the various policy tools at their disposal in attempting to improve overall safety wellbeing. These tools include regulatory or legislative interventions and direct expenditure on safety promotion measures.

The response to existing safety levels could be assessed using information regarding four main categories:

- education and safety awareness, eg advertising campaigns
- safety improvements to infrastructure, including surrounding environments, and to transport system design and operation, eg road straightening, installation of median barriers or barriers at rail crossings, removal of roadside obstacles, change of driving rules, changes to intersection layouts, etc
- enforcement of rules, eg policing strategies, speed cameras
- regulation, eg speed limits, vehicle safety standards.

In relation to education and infrastructural improvements, broad indicators for these responses could consist of the total amount spent on these measures. To adequately account for population or GDP changes, these expenditures should be evaluated on a per capita or percentage of GDP per capita basis.

However, in relation to infrastructural improvements, a complicating factor is that safer transport infrastructure is not simply a function of greater expenditure. An important consideration is the design of roads, and roadsides, that not only takes account of physical safety considerations (eg median barriers, road surfaces) but also road use considerations (eg road design can influence driver behaviour, such as speed). Given the importance of roading design, an ideal indicator framework would include for this variable. However, at present little information on these attributes is collected and compiled in a standardised manner. This is an area that NZTA may wish to consider further in the future.

Indicators for regulatory and enforcement responses could measure the number of new regulatory and enforcement initiatives that are implemented, however it is not the case that any individual regulation would necessarily improve safety. Because it is not possible to determine the effectiveness of any given regulation without first undertaking an in-depth analysis of that regulation, it is not possible to generate a simple, quantitative response indicator that relates to the government's regulatory responses. In the absence of such a quantitative regulatory indicator, an expenditure-based response indicator appears to be the only useful quantitative measure, albeit an incomplete and imperfect one.[30]

Consequently, our proposed response indicators for safety wellbeing are:

- per capita expenditure on education and safety awareness
- per capita expenditure on safety improvements to infrastructure
- per capita expenditure on enforcing safety rules.

Although many jurisdictions provide statistics regarding spending on infrastructure, few if any appear to provide data specifically concerning safety-related spending, much less per capita-based data.

4.5.3.1 Further segmentation

Measures of safety response could be further segmented by mode, ie road versus rail.

4.5.3.2 Other potential indicators

Regarding possible user behaviour responses, information regarding safety activities could be useful, eg the number of individuals taking driver education courses.

4.5.4 Summary

To ensure that the indicator framework is as simple as possible, we have sought to limit the number of specific safety indicators to as few as possible. The specific indicators that we consider would be most useful are outlined in table 4.8. The headline indicators that are likely to be of particular interest are in bold.

Table 4.8 Summary of recommended safety wellbeing indicators

Indicator	Description	Road			Rail	
		Private	PT	Freight	PT	Freight
State indicators						
Rate of deaths	**Number of deaths divided by sum of total km travelled (ie the sum of PKT and public transport passenger km travelled).**	✓	✓	✓	✓	✓
Rate of serious injuries and deaths	**Number of serious injuries and deaths divided by total km travelled.**	✓	✓	✓	✓	✓
Rate of total social cost of incidents	**Total social cost of all safety incidents divided by total km travelled.**	✓	✓	✓	✓	✓
Number of deaths and serious injuries	Total number of land transport-related deaths and serious injuries	✓	✓	✓	✓	✓

[30] Note also that as the wider community becomes more aware of certain safety issues over time, the amount of education required to maintain a certain level of safety outcomes may fall.

Indicator	Description	Road			Rail	
		Private	PT	Freight	PT	Freight
Pressure indicators						
Vehicle characteristics: safety ratings	Average safety rating of all vehicles	✓				
Vehicle characteristics: motorcycles	The total number of registered motorcycles	✓				
User characteristics: age	Percentage of total drivers aged between 15 and 25.	✓				
User characteristics: pedestrians and cyclists	Proportion of trips made by pedestrians and cyclists.	✓				
User characteristics: risk drivers	Percentage of total drivers caught driving while disqualified, unlicensed, fleeing or racing.	✓				
User behaviour: speed	Percentage of vehicles exceeding speed limit on open and urban roads	✓	✓	✓		
User behaviour: substance use	Percentage of drivers using alcohol or drugs	✓				
Highway network safety rating	Average star rating of highway network weighted by traffic volume	✓	✓	✓		
Railway crossings	Proportion of total railway crossings that are controlled.				✓	✓
Response indicators						
Highway education	Total expenditure on safety education and awareness campaigns	✓	✓	✓	✓	✓
Infrastructural improvement	Total expenditure on infrastructural safety improvements	✓	✓	✓	✓	✓
Enforcement	Additional resources ($) used to enforce safety-related rules.	✓	✓	✓	✓	✓

4.6 Activity indicators

As discussed above, a set of context and activity indicators can be distinguished from wellbeing indicators. These reflect the overall level of transport activity, but do not have a direct relationship to wellbeing.[31] For example, VKT measures aggregate transport activity but there is no sense in which higher

[31] However, some activity indicators may correspond to pressure indicators for the wellbeing categories.

(or lower) VKT corresponds to greater wellbeing. For this reason we recommend that activity indicators be clearly distinguished from wellbeing indicators.

However, such indicators may still be useful for planning and monitoring purposes. For example, aggregate needs for transport infrastructure investment and maintenance will depend in part on the total volume of transport activity.

Total activity measures are also useful for calculating productivity measures, for example economic value added per unit of transport activity. We are not currently aware of publicly available transport or freight productivity data for New Zealand; however, activity measures would be a useful component of productivity indicators, as the denominator in productivity ratio calculations.

We therefore recommend including a set of high-level activity indicators alongside the wellbeing indicators.

A set of activity indicators are included in the 'transport volume' component of the TMIF, and we recommend a subset of these as aggregate activity indicators. This subset is consistent with total activity measures used in other countries and is designed to capture the total amount of transport activity across private transport, freight and public transport modes:

- total VKT, annually, estimated from WoF/CoF odometer readings
- total person kilometres travelled, annually, estimated from the New Zealand Household Travel Survey
- total tonne-kilometres travelled, annually, estimated from weigh-in-motion data and WoF/CoF odometer readings
- total public transport boardings and passenger km, annually, summarised by region and by mode, reported by regional authorities to the NZTA
- total vehicle fleet numbers, average annual, by vehicle type and by region, from the motor vehicle register.

4.7 Aggregation of indicators

The wellbeing indicators in the previous section are grouped into four categories. There is a question of whether the indicators in each category should be aggregated to provide an overall indicator for the category, and if so, how this should be done. Such aggregation would achieve a multi-level indicator framework with 'headline' and 'detail' indicators in each category, which could be desirable.

Aggregation of some indicators in this manner is envisaged by the Austroads Next Generation Indicators project (Austroads 2011a). For example, Austroads proposes five different indicators of road pavement condition, which are then aggregated to calculate a single overall pavement condition indicator.

There are two challenges of aggregating indicators in this way:

- *Scaling:* Different indicators will have different numerical scales and different units of measurement. Failing to correct for this will result in composite indicators mostly reflecting the individual indicators that happen to take on large numerical values, overstating the importance of these.
- *Weighting:* In calculating the aggregate indicator, some individual indicators may be more important than others, and the weights used in the aggregation need to reflect this.

There is no easy way to overcome these challenges. In the pavement condition example, Austroads recommends the use of a non-linear 'transfer function' to transform the numerical values of individual indicators so that they are on similar scales. However the use of such functions requires making some arbitrary assumptions about the type and form of transfer function used. The composite indicator will reflect these assumptions to some extent, and it is difficult to make this adjustment process transparent to the user of the indicator. It is also difficult to justify the assumptions used for the transfer function, particularly when a diverse range of indicators are being combined.

The second weighting issue is equally vexed. There is little, if any, empirical evidence on which to base weighting of indicators. Austroads recommends some unequal weights based on expert judgement, but such assumptions may be controversial and lack transparency. Using an equal weighting is a natural alternative; however, this is just as arbitrary as any other choice of weights.

Overall, in our view, the problems associated with the scaling and weighting necessary to create composite indicators are complex and not easy to overcome. Any scaling and weighting method used will necessarily have some arbitrary components and will be difficult to explain to users of the indicators. This will introduce a ‘black box’ element into the indicators that may result in a lack of trust and acceptance of the validity of the outputs.

Therefore, we recommend that individual indicators in each of the four categories are not aggregated to produce composite indicators. Rather, each indicator should be presented alongside all others, and users can form their own judgements about the importance of each. Additional detail can be provided by segmenting the individual indicators by region and by transport mode if possible, but we do not recommend further aggregation of the indicators within categories.

Instead of aggregation, to provide some additional structure to the indicators, we have recommended a subset of ‘headline’ state indicators in each category where there are a significant number of state indicators. These headline indicators are, in our view, the most important indicators in each category, with additional indicators providing extra detail if required. For presentation, the headline indicators could be presented initially, with the option to drill down into detailed indicators if required. We also recommend that state, pressure and response indicators be clearly separated, with the state indicators having priority, as these directly capture the contribution of land transport to wellbeing.

5 Indicator implementation and data assessment

In this section we describe how the recommended indicators could be populated and review the data that is available to the NZTA to populate the indicators recommended in chapter 4. For this purpose we have reviewed data currently held by the NZTA as well as data available from external sources such as Statistics New Zealand and the Ministry of Transport (including the TMIF).

5.1 High-level issues

Some data-related issues that cut across the implementation of indicators in all categories are discussed briefly below.

5.1.1 Public transport data issues

We have identified some other practical data and implementation issues in our research for this project, in relation to public transport. The NZTA's collection of public transport service data relies on annual information entered manually by regional council staff in the *Transport Investment Online* system. This process is somewhat error prone and does not lend itself to the provision of high-quality, timely public transport data. We understand that a process is underway to improve public transport data collection and we support the development of improved systems. Until the public transport data collection process is improved, public transport indicators may need to be caveated in regards to their accuracy.

5.1.2 Improvements in data over time

We expect that the coverage and quality of the indicators will improve over time as better data becomes available. For example, the implementation of integrated ticketing is expected to greatly improve the data relating to public transport activity. Similarly, improvements in remote sensing and measurement technologies to measure vehicle movements is expected improve the quality of network performance measures. While the basic set of indicators will not change, we expect the quality of data and the number of indicators that can be populated will increase over time. We note below some specific indicators for which we expect this to occur in the short-to-medium term.

5.1.3 Regionalisation of indicators

Where possible, indicators should be collected at the regional level as well as the national level. However, we understand that in some cases the quality of regional data is relatively low, and relevant data does not exist in some cases. We therefore expect that the indicators will primarily be national in nature, at least initially. At the regional level, data for each indicator will need to be carefully checked to ensure it is reliable and consistent with definitions used in other regions.

5.2 Network performance and capability

The recommended network performance and capability indicators are summarised in table 4.1 (chapter 4).

5.2.1 Pressure indicators

5.2.1.1 Economic activity: national

The national real GDP growth rate is published quarterly by Statistics New Zealand (also the Reserve Bank).[32] We recommend the use of the seasonally adjusted time series which adjusts for typical peaks in the December quarter and troughs in the March quarter. Actual GDP data is published with a lag of approximately six months, therefore we also recommend including some short-term forecasts. The forecasts published by the Reserve Bank are generally considered to be reliable.[33]

5.2.1.2 Economic activity: regional

Total employment estimates by region are published quarterly by Statistics New Zealand as part of the linked employer-employee database (LEED).[34]

5.2.1.3 Population

Statistics New Zealand publishes annual national and subnational (regional) estimates of the New Zealand resident population.[35]

5.2.1.4 Population density

Statistics New Zealand classifies CAUs into urban and rural categories, and from this the proportion of the population estimated to be living in urban areas can be calculated.[36]

5.2.2 State Indicators

5.2.2.1 Throughput

As described in table 4.1, throughput on a route is the product of vehicle flow counts and load factors, ie the number of vehicles travelling the route in a given amount of time, multiplied by the average number of passengers per vehicle. Freight throughput could also be calculated for freight vehicles by using the freight load in tonnes or freight volumes in cubic metres.[37]

Throughput cannot be calculated accurately with currently available data. Vehicle flow counts are available at certain points on the state highway network and on some local roads, but load factor data is inadequate. Average national load factors for private vehicles are published every year as part of the TMIF.[38] However, this data is highly aggregated and infrequent. In our view, a useful throughput indicator needs to be based on local data (for each route) updated annually. This would need to be obtained by survey methods for private vehicles. For public transport, good data on load factors will be available from integrated ticketing systems being rolled out in the coming years.

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[32] See www.stats.govt.nz/browse_for_stats/economic_indicators/GDP.aspx

[33] The forecasts are contained in the Reserve Bank's quarterly Monetary Policy Statement, see www.rbnz.govt.nz/monpol/statements/index.html

[34] See http://wdmzpub01.stats.govt.nz/wds/TableViewer/tableView.aspx?ReportName=LEED/1-way/Table%205:%20LEED%20Measures%20by%20Region

[35] See www.stats.govt.nz/browse_for_stats/population/estimates_and_projections.aspx

[36] See www.stats.govt.nz/browse_for_stats/people_and_communities/Geographic-areas.aspx

[37] The ideal measure from a wellbeing perspective would be freight value in dollars, however it is unlikely that such data would be available.

[38] See www.transport.govt.nz/ourwork/TMIF/Pages/TV010.aspx.

Freight loads would also need to be obtained by a survey of freight operators. The only currently available data on loads is provided by weigh-in-motion surveys; however, this includes the weight of the vehicle, and determination of the amount of freight carried is not possible with reasonable accuracy. Therefore, development of freight throughput indicators will require additional work and the cooperation of the freight sector to provide load information.

5.2.2.2 Throughput alternative: average travel time

Data on average travel time for selected routes is currently available to the NZTA from the floating car surveys conducted by Beca (2012). This data largely relates to travel times for private vehicles and freight, although bus travel times may be correlated, where priority lanes are not used. With integrated ticketing, better data will be available about public transport travel times. We recommend that a set of representative public transport journeys be established and the average times for travel on these journeys (including connections if required) be monitored.

5.2.2.3 Throughput alternative: variation from posted speed

Variation from posted speed can also be calculated from the floating car survey data, and will apply to private vehicles and freight. In respect of public transport, we understand that improved global positioning system (GPS)-based data is becoming available and this could be used to calculate variation from posted speed for public transport vehicles.

5.2.2.4 Throughput alternative: speed and flow productivity

This measure can be calculated by combining average speed data from the floating car surveys with vehicle flow data for selected roads where these two measures are available. However, the overlap between these data sets is incomplete and it appears that productivity can only be calculated for a small set of routes. As with the other measures above, in our view it is better to take a route-based approach to this measure rather than a road-based approach, since the vast majority of trips involve the use of multiple roads. Where calculation of this indicator is possible, it will apply to both private vehicles and freight.

5.2.2.5 Travel time reliability: peak and average

Data on travel times for selected routes are available to the NZTA from the floating car surveys, and travel time reliability (eg the coefficient of variation) can be calculated from this data, for private vehicles and freight. For public transport we recommend investigation of the calculation of similar measures from vehicle GPS data and/or integrated ticketing data.

5.2.2.6 Network condition

The NZTA already collects annual data on the percentage of travel on the road network that is classified as smooth (percentage of rutting < 20mm). However we understand that the quality of this data varies, with high-quality data available for state highways, and lower quality data available for local roads. Until data for local roads improves, we recommend that appropriate caveats be attached to this indicator.

5.2.2.7 Network reach: public transport

Data on the percentage of population living with 400m of a public transport stop is not currently available but could be calculated using GIS software. It would be necessary to overlay a map of public transport stops with census data on population counts at the meshblock level. The population living within a 400m radius of each public transport stop can then be calculated by intersecting these circles with meshblocks. Assuming a uniform spatial distribution within each meshblock, the population within the 400m radius can be estimated.

Population counts at the meshblock level are only provided every five years as part of the census. To generate estimates for intermediate years, it will be necessary to apply Statistics New Zealand population growth estimates at the CAU level to each meshblock within each CAU. Alternatively, the spatial distribution of population could be assumed to be unchanged between each census.

5.2.2.8 Service frequency: public transport

Details of public transport timetables can be combined with the network reach data described above to calculate this indicator. For example, the number of services at each public transport stop in peak times can be calculated. This can then be weighted by the population estimated to be served by that stop (using the method described above) to calculate an overall population-weighted service frequency.

5.2.2.9 On-time reliability: public transport

We understand that on-time reliability for public transport services is currently reported by operators to local councils and to the NZTA. However, in the case of bus services we understand this is based on driver-reported data and measures departure reliability rather than arrival reliability. We recommend that this indicator be based on GPS data from vehicles, as such data becomes available.

5.2.2.10 Customer satisfaction: public transport

Annual customer satisfaction surveys are currently carried out of public transport users and the results are available to the NZTA. As indicated in table 4.1, we recommend that the 'overall service value for money' and 'vehicle quality/comfort' measures of these surveys be used as indicators.[39] However, results from the public transport surveys are not available for all regions in all years, and this may limit the usefulness of these indicators unless the survey frequency is improved.

5.2.2.11 Customer satisfaction: road

The NZTA currently collects data on available lane-hours across the state highway network. We understand that this is not currently weighted by traffic volumes, but traffic volume data is also available to carry out this weighting.

5.2.3 Response indicators

5.2.3.1 Expenditure measures

Total annual investment in transport infrastructure, and expenditure on public transport services and maintenance expenditure by the NZTA and local authorities is available to the NZTA in the *Transport Investment Online* system, and is aggregated in the NZTA and NLTF annual reports.

5.2.3.2 Speed limits

Traffic volume weighted speed limits can be calculated by weighting speed limits for each road section by the estimated VKT.

5.2.3.3 Traffic management

Active traffic management refers to the system of electronic signs and sensors deployed on some state highways. The percentage of the network subject to these systems can be estimated from data on the location of traffic management assets and infrastructure and the effective extent of the controls.

[39] Other measures of the surveys are incorporated in objective indicators and it is not necessary to duplicate these by also including survey results in the indicator framework.

5.2.4 Summary of network performance and capability data

Table 5.1 Summary of network performance and capability indicators and data

Indicator	Data assessment
Pressure indicators	
Economic activity: national	Available from Statistics New Zealand (actual data) and the Reserve Bank (short-term forecasts).
Economic activity: regional	Available from Statistics New Zealand in the linked employer-employee database (LEED).
Population	National and subnational estimates are available from Statistics New Zealand.
Population density	Can be calculated from Statistics New Zealand data using classification of CAUs into urban and rural.
State indicators	
Throughput	Cannot be calculated accurately due to lack of sufficient load data – additional work needed to estimate private vehicle and freight loads.
Throughput alternative: average travel time	Can be calculated for selected routes from floating car data; integrated ticketing will provide good data for calculating public transport travel times.
Throughput alternative: variation from posted speed	Can be calculated for selected routes from floating car data; new GPS data for public transport vehicles will provide good data for calculating public transport speeds.
Throughput alternative: speed and flow productivity	Can be calculated for a small set of routes using floating car data.
Travel time reliability: peak	Can be calculated from floating car data; vehicle GPS and/or integrated ticketing will provide good data for calculating public transport travel times.
Travel time reliability: average	
Network condition: road	Already collected by the NZTA; however, data quality varies significantly at the regional level and for local roads versus state highways.
Network reach: public transport	Not currently available but could be calculated using GIS data on public transport networks and census data.
Service frequency: public transport	Not currently available but could be calculated using public transport timetables combined with the data used to calculate the network reach indicator.
On-time reliability: public transport	Currently provided by regional authorities to the NZTA; however, the quality of operator-reported data for bus services is questionable. When GPS data is available, the quality of this indicator will improve significantly.
Customer satisfaction: public transport	Currently available in the annual public transport customer surveys carried out by regional authorities and reported to the NZTA.
Customer satisfaction: road	Available lane-hours are collected by the NZTA, and could be weighted using traffic volumes data.
Response indicators	
Infrastructure investment	Available to the NZTA in the *Transport Investment Online* system, and aggregated in NLTF annual reports.
Service expenditure	
Maintenance expenditure	
Speed limits	Can be calculated by weighting speed limits for each road section by estimated VKT.
Traffic management	Can be estimated from data on the location of active traffic management assets and the effective extent of these controls.

5.3 Cost

The recommended cost indicators are summarised in section 4.2.

5.3.1 Pressure indicators

5.3.1.1 Fuel prices

The Ministry of Economic Development produces a weekly oil price monitoring report.[40]

5.3.1.2 Transport sector labour costs

Statistics New Zealand compiles a range of labour cost data, some of which includes transport-specific information. One such source is the LEED, which includes quarterly data regarding mean, median and total earnings of employees in the road transport sector. These figures are further broken down by new hires versus continuing jobs. Additional data regarding total employment, jobs created when businesses start up or expand, jobs destroyed when businesses contract or shut down, and worker turnover is also provided for the road transport sector.

Another source of data is the New Zealand Income Survey, which has provided annual data from 2009. This includes wage and salary earnings for machinery operators and drivers, broken down by average, and median, hourly and weekly earnings as well as the total number of jobs. The same data is also available for the transport, postal and warehousing sector.

Statistics New Zealand also compiles producer price and labour cost indices. The Producer Price Index includes quarterly data regarding input prices for road transport, and for road freight specifically, from 1994. The Labour Cost Index contains quarterly data regarding salary and wage rates, non-wage labour costs and total labour costs for the machinery operators and drivers occupational group, and for the transport and storage sector, from 1992.

5.3.1.3 Vehicle prices

Statistics New Zealand produces data regarding the value of all imports, including vehicles. It also produces imported overseas trade indices, which measure the change in volume of imports, including vehicles. Vehicle-related imports are categorised into rail sector and non-rail sector. This information may provide scope to establish indices for vehicle prices.

Alternatively, the NZTA could undertake periodic surveys to estimate vehicle prices for the purposes of establishing a price index. Auctions (such as the online TradeMe) may be a useful source of such data.

5.3.1.4 Infrastructure costs

The NZTA produces annual total spending on infrastructure and maintenance, as included in their annual reports. Additionally, the NZTA has data regarding the whole-of-life costs of new infrastructure as these figures are included in funding applications. Similarly, the expected remaining useful lifespan of much of the road network and the expected future maintenance costs should be known to the NZTA, although this data may be somewhat limited and variable in quality. For investments that have had post-implementation reviews carried out, the data should be of a higher quality.

Data on investments by the NZTA and local government is available in *Transport Investment Online*.

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[40] See: www.med.govt.nz/sectors-industries/energy/liquid-fuel-market/weekly-oil-price-monitoring.

5.3.2 State indicators

5.3.2.1 Cost per person km travelled

Person km travelled have been estimated in the New Zealand Household Travel Survey conducted annually by the Ministry of Transport. In the absence of further household travel surveys, there does not appear to be another method for obtaining useful estimates of this figure. Consequently, the NZTA may wish to undertake further survey, or alternatively, use VKT estimates for private vehicles as a proxy.

Total cost estimates would need to be generated using data from various sources. These would include household travel expenditure data, parking, vehicle and fuel costs and usage from Statistics NZ, and regulatory and infrastructure cost data held by the NZTA.

5.3.2.2 Cost per freight tonne km travelled

Data concerning vehicle freight tonne km travelled is currently collected during the calculation of RUC. This is used to estimate the growth in freight tonne km as reported in the TMIF by the Ministry of Transport.[41] However, this will change in August 2012 with the move to levy RUC on gross vehicle mass (or maximum allowable mass if lower).

Alternatively, weight and motion sensor data may be useful for generating total freight tonnage estimates. Otherwise, freight data could be collected via specific survey of freight vehicles.

Some freight transport cost data is held by Statistics NZ, although this would not cover the entire sector as some firms ‘self-supply’ freight services. As outlined in section 4.2.1, the NZTA has undertaken financial modelling of the road freight transport sector. This may be useful for generating estimates of total freight costs for the road transport sector. We also understand NZ Rail has undertaken similar modelling regarding the costs of rail transport services. However, if these models are either not suitable or not available for use, it may be necessary for the NZTA to undertake original cost modelling to generate the relevant cost estimates.

5.3.3 Response indicators

5.3.3.1 Subsidy per passenger km travelled

The NZTA compiles data regarding the total public funding provided by both itself and local authorities towards subsidising public transport.

Data on total public transport passenger km is provided by regional authorities, estimated on the basis of patronage and average distance. In future, integrated ticketing systems can be used to improve the accuracy of this data.

5.3.3.2 Taxes and charges per person kilometre travelled

Data regarding total fuel excise revenue is compiled by the Ministry of Transport. Vehicle registration data is held by the NZTA and could be used to determine the total amount of registration charges levied on non-freight vehicles.

[41] www.transport.govt.nz/ourwork/TMIF/Pages/FT004.aspx.

5.3.3.3 Taxes and charges per freight tonne km travelled

Data regarding total RUC revenue is compiled by the Ministry of Transport. Vehicle registration data is held by the NZTA and could be used to determine the total amount of registration charges levied from freight vehicles.

5.3.4 Summary of cost data

In general, a reasonable amount of cost-specific data is currently compiled, particularly in relation to specific aspects of the land transport sector, eg fuel and vehicle prices, indices of construction-related cost, etc. However, some aspects of the selected indicators would present challenges for the NZTA.

As outlined above, estimating either costs or subsidies on a per km basis, whether for personal transport or freight, would present some difficulties. Chiefly, establishing accurate estimates of total km travelled could prove demanding. In respect of public transport, proposed new ticketing technologies may provide an opportunity for much greater collection of individual travel data.

In relation to costs per freight tonne per km, estimates of both total freight costs and total freight transported may also be difficult to generate, particularly as the new RUC regime provides less detailed freight-specific information. This provides a challenge to collecting sufficiently accurate freight transport data.

Table 5.2 Summary of cost indicator data assessment

Indicator	Data assessment
Pressure indicators	
Fuel prices	The Ministry of Economic Development (now the Ministry of Business Innovation and Employment) publishes relevant data.
Transport sector labour costs	Statistics NZ publishes relevant data.
Vehicle prices	Statistics NZ publishes some relevant data. The NZTA could complement with additional survey.
Infrastructure costs	The NZTA has relevant information.
State indicators	
Cost per person km travelled	The NZTA, Statistics NZ and Ministry of Transport have approximate data regarding various costs and km travelled. NZTA would need to calculate and refine cost and km travelled estimates
Cost per freight tonne travelled	The Ministry of Transport has approximate data regarding freight VKT and vehicle freight capacities. Statistics NZ has some data on revenue of freight businesses. The NZTA has a financial model of road freight services and NZ Rail has a rail cost model. These could provide useful basis for cost estimates. If models are unsuitable or inaccessible, the NZTA may need to undertake further analysis to generate useful estimates.
Response indicators	
Subsidy per passenger km travelled	The NZTA has subsidy data and limited travel data. The Ministry of Transport has passenger travel estimates.
Taxes and charges per person km travelled	The Ministry of Transport and the NZTA have revenue data. Km travelled data as for ‘cost per person km travelled’ above.
Taxes and charges per freight tonne km travelled	The Ministry of Transport and the NZTA have revenue data. Freight tonne km travelled as for ‘cost per freight tonne km’ above.

5.4 Health

In chapter 4 we noted that the chief impacts of transport on health are via air emissions and noise. We discuss key indicators for these effects below. The indicators and data sources are summarised in table 5.2.

5.4.1 Pressure indicators

The NZTA has recommended that NO_2 is used as a proxy for motor vehicle pollutants. However, particulates are the major pollutant of concern. We included indicators relating to both below.

Emission rates vary with vehicle age so average age is a useful indicator of expected emissions. The average age of the fleet is available from fleet data maintained by the Ministry of Transport.[42]

Noise is a result of the interaction of vehicles with the road. The main potential pressure indicator relates to road surface. Noise pressure indicators based on kilometres of road classified by material is available from NZTA data.

5.4.2 State indicators

Concentrations of NO_2 are measured via an ambient air quality monitoring network as described in NZTA (2011a). This data has been used to develop predictive models of concentrations in all CAUs in work undertaken for the NZTA by NIWA. The data can be combined with population data at the CAU level available from Statistics NZ to develop an exposure measure.

Concentrations of particulates at the CAU level have been estimated for the HAPINZ study. However, the study limited the number used and focused on more densely populated areas. A regression model was constructed building on research in Christchurch. It appears that, at this stage, the particulate data is not as readily available or as accurate as the NO_2 data.

The TMIF put together by the Ministry of Transport provides data on the proportion of total trips by residents of urban areas that are made by walking and cycling.

5.4.3 Response indicators

Suggested response indicators are the policy and regulatory measures, such as vehicle import standards relating to emissions, taken to address the different pollutants.

Table 5.3 Data sources for recommended health wellbeing indicators

Category	Indicator
Pressure	
Average age of the vehicle fleet	Ministry of Transport maintains this data.
Noise: km of (urban) roads categorised by surface category	Road assessment and maintenance management (RAMM) database.
State	
Concentration of NO_2 at key monitoring sites	Currently measured via air quality monitoring network described in NZTA (2011a). Predictive model used to extend to all CAUs.
Concentration of $PM_{10}/PM_{2.5}$ at key monitoring sites[1]	Limited data available currently, but as with NO_2, it may be possible to combine data with predictive (regression) model.
Average exposure to NO_2	Sum of concentration in CAU × CAU population for all CAUs/total

[42] See: www.transport.govt.nz/research/newzealandvehiclefleetstatistics/

Category	Indicator
	New Zealand population Concentration data modelled (see above); CAU and total population from Statistics NZ.
Average exposure to PM_{10}/$PM_{2.5}$	Requires PM concentration data (see above). Population data as for NO_2.
Response	
Vehicle import standards	Emission rules set out in Land Transport Rule: Vehicle Exhaust Emissions 2007 (and amendments) administered by the NZTA.

(1) Apportionment of this to transport and other sources should be undertaken to the extent possible.

5.5 Environment

Environmental impacts of transport include emissions to air of greenhouse gases and local air pollutants, road runoff and the impacts on biodiversity and community cohesion. Emissions to air of local air pollutants are included under health indicators; we limit the indicators here to greenhouse gas emissions. Road runoff is a problem in some specific locations, but is not widespread; for this reason we have not included national indicators of this issue. Impacts on biodiversity likewise are highly localised and there is no clear national indicator.

5.5.1 Pressure indicators

Pressure indicators focus on the factors that determine the CO_2 emissions from vehicles; this is chiefly the fuel economy of the fleet.

The average fuel economy of the petrol fleet can be estimated from total fuel consumption divided by VKT. This data is maintained by the Ministry of Transport in its vehicle fleet statistics.[43]

The same data for diesel vehicles is less easily obtained because diesel consumption is less easily allocated to transport use. Some estimate of the diesel use by transport is made by the Ministry of Economic Development (MED) for the Energy Data File and this could be used to establish an estimate of diesel vehicle fuel intensity over time.

VKT data is maintained by the Ministry of Transport in the vehicle fleet statistics.

5.5.2 State indicators

Data on CO_2 emissions from transport is recorded by the Ministry of Transport using data on fuel consumption and emission factors.

5.5.3 Response

The degree of internalisation of CO_2 price (the proportion of transport fuel facing the emissions price) is readily estimated from the latest policy position. It is shown in figure 4.11.

[43] See: www.transport.govt.nz/research/newzealandvehiclefleetstatistics/

Table 5.4 Recommended environmental wellbeing indicators

Category	Indicator
Pressure	
Average fuel economy of fleet – fuel	Consumption/VKT (separately for petrol and diesel).
VKT	Available from the NZTA.
State	
CO_2 emissions by road vehicles	Estimated by the Ministry of Transport, but diesel emissions requires estimation.
Response	
Degree of internalisation of CO_2 price	Proportion of transport fuel facing the emissions price – information available from MfE.

5.6 Safety

The recommended network performance and capability indicators are summarised in section 4.5.

5.6.1 Pressure indicators

5.6.1.1 Vehicle characteristics – safety ratings

Vehicle safety rating data is not currently available in the motor vehicle registry for most vehicles, although the collection of this data could become more extensive over time. In the absence of an established collection mechanism, it may be possible to use the existing vehicle registry and publicly available vehicle safety rating information (eg from manufacturers) to compile the relevant data.

5.6.1.2 Vehicle characteristics – motorcycles

The NZTA possess data regarding the total number of registered motorcycles in its vehicle registry.

5.6.1.3 User characteristics - age

The NZTA collects age data for all licensed drivers. However, because the NZTA does not have records of whether licensed drivers continue to reside in New Zealand, this data may not provide an entirely accurate representation of driver demographics. Consequently, it may be necessary to adjust licensed driver figures using other demographic data, eg Statistics NZ population data.

5.6.1.4 User characteristics – pedestrians and cyclists

As noted under the health indicators, the TMIF put together by the Ministry of Transport provides data on the proportion of total trips by residents of urban areas that are made by walking and cycling.[44] The New Zealand average is 20% but this varies across urban areas (eg Wellington 27%, Hamilton 14%).

5.6.1.5 User characteristics – at risk drivers

Data concerning inappropriate driver behaviour, eg driving while disqualified, dangerous driving, etc is likely to be captured by the New Zealand Police.

[44] www.transport.govt.nz/ourwork/TMIF/Pages/TP005.aspx.

5.6.1.6 User behaviour – substance use

Alcohol use is estimated in the New Zealand Household Travel Survey reported annually by the Ministry of Transport. This survey could be expanded to obtain information about the use of other substances in the transport sector.

Additionally, data regarding violation of existing drink-driving and drug-driving laws is publicly available from Statistics New Zealand.[45]

5.6.1.7 Highway network safety rating

Safety rating information provided by the KiwiRAP Road Assessment Programme was published in 2010. The Star Ratings cover 89% of the state highway network (ie over 10,000km). Risk maps established by KiwiRAP cover 100% of the network and are based on data from 2002 to 2006. Both of these data sets could potentially be updated on a regular basis if required.

5.6.2 State indicators

5.6.2.1 Rate of deaths and serious injuries

Fatality and serious injury data is currently compiled by the Ministry of Transport using its Crash Analysis System.

As discussed above, it may be possible to estimate total kilometres travelled, using estimated total person and total freight km. However, if generating sufficiently robust estimates is not possible, VKT may provide a reasonable alternative.

5.6.2.2 Rate of total social cost of incidents

Estimates of the total social cost of land transport crashes are generated on an annual basis by the Ministry of Transport.[46] Much of this is based on information estimated and compiled by the ACC.

5.6.2.3 Number of deaths and serious injuries

Fatality and serious injury data is currently compiled by the Ministry of Transport using its Crash Analysis System.

5.6.3 Response indicators

5.6.3.1 Highway education

NZTA holds information regarding the expenditure on road safety campaigns. For instance, spending on advertising campaigns in the current year is estimated at $12 million.[47]

5.6.3.2 Infrastructural improvement

Currently there is no robust breakdown of total infrastructure spending into that which relates to upgrading or replacing existing capacity and that which relates to safety improvements. Determining the amount that should be apportioned to safety improvements would require further analysis. Any such analysis could involve estimating the expected (or observed) safety benefits of a specific infrastructural

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[45] www.stats.govt.nz/tools_and_services/tools/tablebuilder/criminal-conviction.aspx.

[46] www.transport.govt.nz/ourwork/TMIF/Pages/SS009.aspx.

[47] www.nzta.govt.nz/about/advertising/campaign/faq.html.

investment and allocate this portion of the investment as a safety response. We understand that the required data may be available in the NZTA's PROMAN project management database.

5.6.3.3 Enforcement

Information regarding the funding for enforcement activities is provided in New Zealand Police annual reports. The expenditure on the Road Safety Programme for the year ended 30 June 2011 totalled $294 million.[48]

5.6.4 Overall assessment

There is a wide range of detailed safety data currently collected and compiled. This provides the NZTA with a high degree of information regarding safety outcomes and means that most indicators could be established using existing data.

However, several safety indicators would require some additional information and/or compilation or calculation. For instance, although vehicle safety ratings are publicly available, data regarding the entire fleet has not been compiled and analysed. Establishing such a measure would require collation and additional analysis. Regarding the rate of injuries, and injury costs, ensuring these indicators were accurate would require establishing new estimates of total person km travelled. Alternatively, less robust estimates could be generated using existing VKT figures.

Table 5.5 Data assessment for recommended safety indicators

Indicator	Data assessment
Pressure indicators	
Vehicle characteristics – safety ratings	Individual vehicle ratings are publicly available, but fleet-wide data has not been compiled.
Vehicle characteristics – motorcycles	The NZTA holds motorcycle data.
User characteristics – age	NZTA holds this data.
User characteristics – pedestrians and cyclists	The Ministry of Transport compiles relevant data.
User characteristics – at risk drivers	NZ Police hold relevant data.
User behaviour – substance use	The Ministry of Transport obtains survey data.
Highway network safety rating	KiwiRAP road assessments published. Updates could be carried out by the NZTA if required.
State indicators	
Rate (and number) of deaths and serious injuries	The Ministry of Transport compiles transport injury data. No current estimate of total person km travelled.
Rate of total social cost of injuries	The Ministry of Transport estimates total social cost of transport injuries. No current estimate of total person km travelled.
Response indicators	
Highway education	The NZTA holds relevant data.
Infrastructural improvement	Information not currently compiled.
Enforcement	Cost information provided by NZ Police.

[48] See www.police.govt.nz/sites/default/files/resources/annual/new-zealand-police-annual-report-11.pdf, page 68.

5.7 Activity indicators

All activity indicators recommended in section 4.6 are available from the TMIF and/or the data underlying the TMIF. One caveat is that VKT data from odometer readings does not give locational information, as it is unknown where the VKT occurred. VKT can be estimated on a regional basis from road traffic volume monitoring data; however, this only covers a small sample of roads in any given year and total VKT estimates per region are subject to some uncertainty.

6 International benchmarking opportunities

As discussed in section 2.4 and reviewed in detail in appendix A, there is considerable variance in the types and usage of land transport indicators in other countries. In any international benchmarking exercise it is crucial that the measures being benchmarked are consistent across countries, otherwise the benchmarks are meaningless. The variation in international approaches and availability of data therefore limits the extent of international benchmarking that is possible.

Sensible benchmarking also requires construction of a comparison set of a reasonable size. Benchmarking New Zealand indicators against those from one or two other countries is not very informative, as in a statistical sense the uncertainty associated with any benchmarks is high. In general, the larger the size of the benchmarking set, the more confident we can be in making conclusions about New Zealand's performance relative to other countries in the set.

Therefore, to assess the opportunities for international benchmarking, we have assessed the extent to which comparable indicators are available for other countries, based on the survey of international practice in appendix A. We have searched for indicators that are defined on a comparable basis across countries and are publicly available or can be readily calculated from publicly available data. To maintain consistency with our proposed indicator framework, we only consider indicators that are related to those we have recommended in the previous sections.

Many of the indicators published on a consistent basis across other countries are activity-related indicators, such as VKT and public transport patronage. As we have discussed above, such indicators are not useful for measuring the contribution of land transport to wellbeing, as it is not possible to determine whether an increase or a decrease of VKT is associated with an increase in wellbeing.

For the same reason, in our view, international benchmarking against activity indicators is not helpful for policymaking. If, for example, such benchmarking revealed that New Zealand's VKT was increasing relatively slowly compared with other countries, it would not lead to any helpful recommendations for policy development or for policy evaluation. In the same way that an increase in VKT in New Zealand, for example, cannot be interpreted as increasing or decreasing wellbeing, the comparison of land transport activity levels in New Zealand with other countries says nothing about New Zealand's or other countries' land transport contribution to wellbeing. Therefore, we consider only non-activity indicators in this benchmarking assessment.

We are also of the opinion that only 'state' indicators are relevant for international benchmarking. Different countries will face different pressures and will adopt different responses, but no value judgement can be attached to these, as the circumstances of each country are different. In contrast, the state indicators are intended to capture the contribution of land transport to wellbeing, and it is therefore meaningful to benchmark these across countries.

For example, if throughput is higher in New Zealand than in other countries, it could be said that the performance of the New Zealand transport system is better than in other countries. This observation supports the conclusion that the contribution of New Zealand's transport system to wellbeing is higher than in other countries, everything else equal.

Among the wellbeing state indicators that we have recommended above, environmental and safety indicators are the most widely published and are generally consistent across countries. Based on our review of international practice (see appendix A), it would be possible to benchmark the contribution of land transport to environmental wellbeing of New Zealand against Australia, Canada, the UK, Ireland, the

EU, Switzerland, Norway and the USA. It would also be possible to benchmark safety against all countries in appendix A.

Benchmarking of network performance and capability is more difficult, as consistent measures of throughput, congestion, travel speeds, travel time reliability and public transport network reach and frequency are not published by most countries. A key difficulty with these indicators is that alternative definitions can be employed and there is no standard international approach.

For example, throughput, congestion and travel time reliability measures depend on the definition of a journey, and the routes and times of day that are used to collect the data. Unless these factors are standardised, it is not valid to compare these measures across countries. In any case, many countries do not appear to publish such measures.

The best opportunity for benchmarking network performance and capability is against the Australian states, using the next generation Austroads indicators. While this is a relatively small set of jurisdictions, it would be possible to benchmark average travel time, travel time reliability and road productivity against the Australian states, if the Austroads methodologies were adopted in New Zealand. In our view, considerable effort has been put into the Austroads next generation indicators to make them robust and empirically valid

Finally, cost is very difficult to compare across countries due to the different scale of transport activities in each country (meaning that total costs cannot be compared) and the complexity of funding for transport investment. Ideally, benchmarks of cost per person-km and tonne-km could be calculated using data on fuel prices and infrastructure costs. While fuel price data is relatively easy to obtain, transport infrastructure funding is complex and considerable effort would need to be expended to ensure that comparable measures were obtained for different countries. Therefore, in our view, the difficulty in constructing comparable cost benchmarks is too great relative to the value of such benchmarks.

7 Decision-making support assessment

In this section we discuss how the recommended framework and indicators can support land transport decision making and policy analysis in New Zealand.

The current administrative structure for land transport separates policy making and implementation decisions between the central government, local government and the NZTA. We expect that the proposed framework will be able to support decision making at all levels.

The indicators will be useful to the central government in the formulation of policy directions, assessment of the effects of policy and assessment of the overall implementation of policy directives by the NZTA. The NZTA will be able to use the indicators to assess overall achievement of strategic priorities and desired long-term impacts. Local government will be able to use the indicators to monitor national trends, and to assess policies and strategies at the local level to the extent that local data is available.

The foundation of the indicator framework is the contribution of land transport to the wellbeing of New Zealanders. Development of the framework was also guided by a desire for simplicity and a preference for a relatively small number of indicators. These features mean that the framework will be most useful for high-level strategic planning, the formulation of transport policy, and evaluation of policies and strategies.

The framework is not expected to be very useful for detailed evaluation of individual transport projects or small-to-medium scale investments, because the indicators are generally high level, and it may not be possible to distinguish the impacts of smaller projects or investments in the high-level data. The proposed framework may, however, be useful for evaluating the effects of very large transformational projects or programmes that are expected to have a significant impact on the land transport system as a whole, such as the Roads of National Significance programme. At the regional or local level, the usefulness of indicators will depend crucially on the quality of data that is available.

In our view, using wellbeing as a foundation for this framework gives it a significant advantage in terms of decision-making support, as it is largely independent of the policies of the government of the day. Wellbeing is a fundamental concept, and the enhancement of wellbeing is a general objective of all governments, although different governments may have different views about how best to achieve this.

In particular, in the development of this framework, we identified that trade-offs might exist between characteristics of the land transport system that relate to its contribution to wellbeing. For example, improvements in safety (which increases wellbeing) may increase transport costs (which reduces wellbeing). Different governments may make different choices regarding these trade-offs and will set transport policy accordingly. The proposed framework can accommodate this as the trade-offs are recognised in the design of the framework. Over time, the indicator framework will therefore serve to record and measure the effects of different policy directions on wellbeing. In our view, an indicator framework that is robust to changes in policy direction will be very useful for decision making over the long term.

A further practical consideration is that many of the recommended indicators are only available at quarterly or annual frequencies, which may not be frequent enough for operational and tactical decision making.

The PSR structure is expected to provide useful guidance for different types of decision making:

- Pressure indicators reflect changes in the external environment and can be used to predict short-to medium-term changes in demand for land transport, the costs of providing transport services, and external factors that affect safety and environmental outcomes.
- Changes in state indicators over time can be used to understand the effects of pressures and responses on transport outcomes.
- A record of responses can be constructed, which can be compared with changes in pressure and state indicators, to assess the impacts of these responses.

We expect that the indicator framework will become increasingly useful over time, as a time series of each indicator is built up and trends can be determined. In addition, some indicators are expected to benefit from improvements in data collection technology over time, such as the public transport activity data that will be available from integrated ticketing systems. While we have designed the underlying indicator framework to be robust to changes in the external environment, there are opportunities to improve individual indicators within this framework, and such improvements should be undertaken continuously, as the opportunity arises.

8 Main findings and recommendations

In this section we summarise what we consider to be the key findings and recommendations of our research.

8.1 Opportunities and challenges

The following are the key opportunities and challenges that we have identified for design and implementation of a land transport indicator framework in New Zealand:

- Existing indicators used and published by the NZTA focus on measuring desired long-term impacts and achievement of strategic priorities. While suited for this purpose, these indicators are tied to current policies and objectives (which may change over time) and there is a lack of an overall structure. This means it is difficult to understand relationships and trade-offs among indicators. Similarly, the Ministry of Transport's TMIF indicators lack a clear link to wellbeing in many cases, and interpretation of the direction of improvement is not always possible. There is a clear opportunity for improvement in the design and use of indicators in New Zealand.
- This report outlines a wellbeing-based framework that provides a robust foundation for developing indicators. Overall, this framework is based on the characteristics of the transport system that are related to wellbeing of New Zealanders, and seeks to measure changes in these characteristics and the impact on wellbeing. The advantages of a wellbeing-based framework are that it provides a logically consistent way of selecting and organising indicators, and is generally robust to changes in transport policy over time.
- There is a lack of a single international best practice in transport indicator frameworks: different countries use different approaches to suit their own needs. This makes international benchmarking difficult, except for safety and environmental indicators, where international standards are established. This also suggests that a New Zealand indicator framework should not be constrained by what has been done overseas and there is an opportunity to design a framework that best fits the needs of decision makers in New Zealand.
- A key challenge in designing a new framework is to shift thinking away from vehicle-centric transport indicators and to focus on the efficiency of the land transport system at moving *people* and *freight* rather than vehicles. For example, developing measures of transport throughput rather than congestion.
- Another challenge relates to availability of data, and there are some data gaps around measures of transport network performance, environmental effects, and cost measures. Additional work, including improved and expanded data collection processes will be required to fully address these issues.
- Currently available transport indicator data in New Zealand varies significantly in quality. A particular concern is the quality of data available at the local or regional level, which varies in quality across regions, and is generally of a lower quality than data available for the state highway network. We also understand that data definitions sometimes differ across regions, and these must be standardised in order to create useful regional indicators. Initially, it may only be possible to report some indicators at the national level.
- Close cooperation with regional authorities will be required to address these data quality issues. Improvement is most likely to occur if regional authorities understand the reasons for providing good quality data, and if the provision of data benefits them directly, rather than simply being a compliance exercise.

- Integrated ticketing is expected to greatly improve data available for public transport indicators, particularly measures of passenger throughput, on-time reliability, cost and network efficiency.
- The concept of wellbeing-based frameworks can be applied more generally to other sectors beyond transport, and there are opportunities for the NZTA's framework development to be a model for similar work by other government departments.

The following sections expand on some of these points in more detail and summarise the transport indicator framework that we have developed in this report.

8.2 Limitations of existing indicators used by the NZTA

The existing high-level indicators collected and published by the NZTA were summarised in section 2.1. These indicators focus on measuring the NZTA's desired long-term impacts and achievement of its strategic priorities. While generally suited for those specific purposes, in our view the existing indicators suffer from:

- being closely tied to current policies and objectives, which may change over time, necessitating changes to the indicators and consequent lack of consistency and difficulty with tracking long-term trends
- a lack of overall framework or structure (aside from reflecting current policy objectives), which makes it difficult to understand relationships and trade-offs among the indicators
- their selection being driven largely by data availability rather than having an overarching framework to measure the contribution of transport
- a relatively large number of indicators, with no consistent way to summarise or prioritise information
- a lack of links between external trends (pressures) and measurement of the current state of the transport system
- not making best use of all available data.

The TMIF has relatively broad coverage, but it lacks clear links to wellbeing. As such, it is most useful for describing the state of the transport sector. However, for many indicators it is not clear whether an increase or a decrease corresponds to an increase in welfare, and interpretation of the indicators may be difficult.

Therefore, there are opportunities to improve land transport indicators in New Zealand, including the actual indicators reported and the framework within which these indicators are presented and analysed.

8.3 International best practice and benchmarking

We first looked to international practice to understand approaches to transport indicators used in other countries and how these might be applied in New Zealand. Our research revealed:

- There is a lack of a single 'best practice' and there is a wide variety of approaches across countries, reflecting different needs and data availability.
- There are some indicators that are in common use internationally, particularly in the measurement of safety and environmental outcomes, but this does not extend to all indicators that are necessary to benchmark the overall impact of transport on wellbeing.

Given these findings, in our view it is better to develop an indicator framework that best suits the needs of users in New Zealand, rather than trying to adopt what other countries have used. In particular, New Zealand transport indicators should not be constrained by the requirements for international benchmarking or some notion of international best practice, as there is so much variety across countries. Rather, indicators should be chosen based on their suitability for the local context, and local data availability, with international benchmarking a secondary objective if feasible.

In addition, regional benchmarking within New Zealand may be useful if high-quality consistent data is available across regions. However, current data quality is uneven across regions and across local roads versus state highways. Care must also be taken not to create incentives for distorting the indicators to show artificial improvements.

8.4 Designing a robust indicator framework

Given the lack of international best practice, the best foundation for a robust land transport indicator framework is to base the framework on measuring the contribution of land transport to the wellbeing of New Zealanders. Wellbeing is the central concept of welfare economics, and the principles of welfare economics provide a disciplined and logically consistent basis for developing an indicator framework.

8.4.1 Foundations

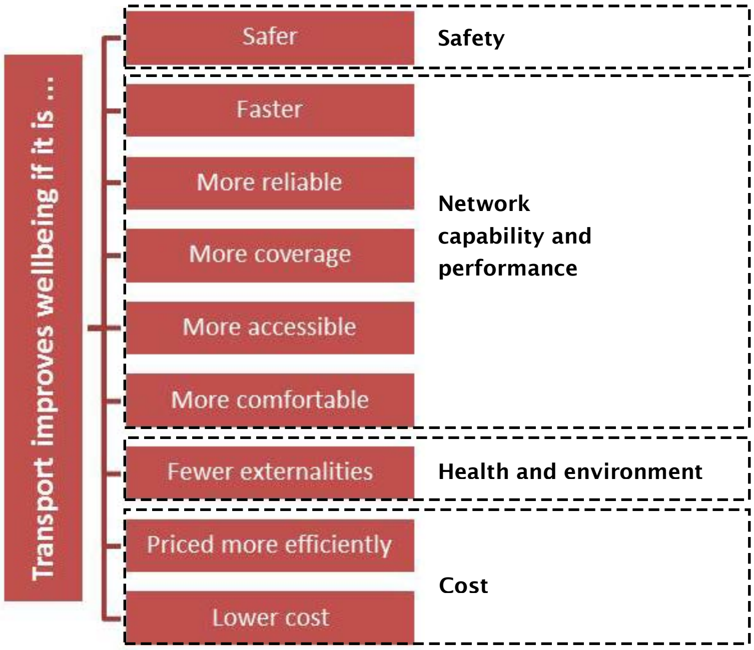
The starting point of the recommended framework is viewing transport as an input into the generation of wellbeing, rather than generating wellbeing directly. This reflects transport's role as a technology that enables human interaction, trade and other activities, while at the same time imposing costs on society. Therefore, transport can be said to improve wellbeing if it better facilitates these activities and/or imposes lower costs. In simple terms, wellbeing improves if the transport system performs better at moving people and freight.

This leads to categories of indicators based on observable characteristics of the transport system that are relevant to wellbeing, ie:

- *Network performance and capability*: Measures of the transport system's capability and performance in moving people and freight when and where demanded.
- *Safety*: Measures of the extent that individuals suffer physical injury and property damage from transport services.
- *Health and environmental effects*: Indicators of the impact of transport activity on the natural environment, where those impacts have direct effects on human health or on wellbeing derived from the environment.
- *Cost*: Indicators of the financial cost to users of the transport system.

These characteristics are summarised in figure 8.1.

Figure 8.1 Conditions where wellbeing from transport is improved, everything else equal



This division of indicators into categories recognises the possibility that trade-offs will exist across indicator categories. For example, an improvement in safety may come at the expense of network performance, everything else equal. However, we have selected indicators so that trade-offs exist across categories but not *within* categories, where possible.[49] For example, an improvement in any indicator in the safety category reflects an improvement in safety and is unlikely to imply a worsening of any other indicator in the safety category.

The key features of an indicator framework based on wellbeing are that it:

- is designed to measure the contribution to wellbeing of the transport system as a whole, moving away from vehicle-centric indicators towards indicators focused on the movement of *people* and *freight*
- allows clear interpretation of an increase or decrease in an indicator as an improvement in wellbeing
- facilitates identification of wellbeing trade-offs among indicators and classification of indicators into groups based on these trade-offs
- clearly distinguishes activity indicators (such as VKT) with no direct link to wellbeing from indicators for which an increase or decrease can be interpreted in terms of the impact on wellbeing
- is robust to changes in government policy over time.

We also recommend that the wellbeing indicator framework be overlaid with the OECD's PSR framework. The use of this framework provides an additional layer of structure on the indicators, and clearly separates indicators into external forces (pressures), information on the current state of the transport system and data on policy responses over time. This separation allows the tracking of external trends and potentially the evaluation of the impacts of responses or policies over time.

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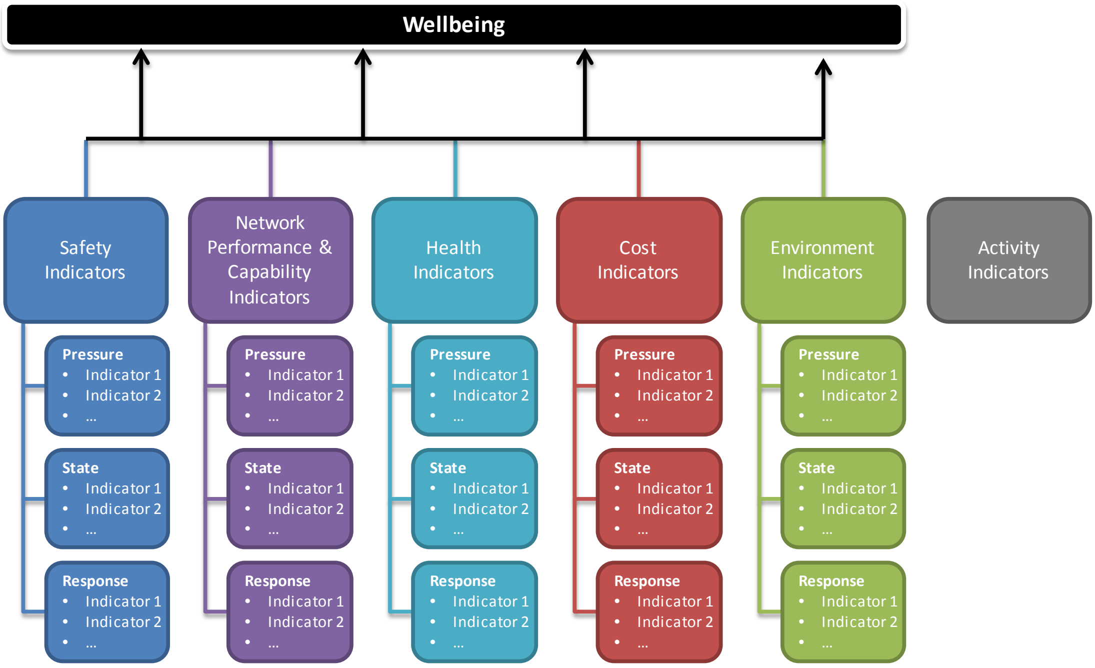
[49] Additionally, there may be trade-offs between transport modes. For example, if network capacity is constrained, improving public transport performance may be traded off against private vehicle performance. These additional trade-offs are too complex to capture in our framework but should be borne in mind when doing detailed analysis of indicators.

In particular, in order to evaluate the effects of policies it will be necessary to monitor changes in state indicators, while also controlling for changes in external pressures that may also influence state indicators. The separation of indicators implicit in the use of a PSR framework should greatly aid policy evaluation and analysis.

Figure 8.2 summarises the high-level structure of the proposed wellbeing indicators framework. The indicators relating to wellbeing are divided into five categories, where trade-offs may exist across these categories but not within each category. Each category is further segmented by applying the PSR framework. In addition to the wellbeing indicators, a set of activity indicators provides context but does not directly relate to wellbeing.

Figure 8.2 Proposed indicator framework structure



In addition to wellbeing indicators in these categories, we also recommend a small set of *activity* indicators that will be useful for understanding how the quantum of transport activity is changing over time, largely for planning purposes. These indicators have no particular relationship to wellbeing, but may still be useful for monitoring broad trends in the transport sector:

- total VKT annually
- total person km travelled annually
- total tonne km travelled annually
- total public transport boardings and passenger km, by region and by mode
- total number of vehicles in the fleet, by vehicle type and by region.

8.4.2 Criteria for indicator selection

Within the framework outlined above, we have recommended a number of particular indicators under each category. Based on the literature on the design of indicator frameworks, we identified the following considerations for indicator selection in design in general:

- *Policy relevance*: Indicators must be relevant to actual policy levers available to transport policymakers, but reasonably robust to changes in policy directions over time.
- *Wellbeing:* Indicators must have a connection to the wellbeing of New Zealanders as this is the basis of the framework.
- *International best practice*: Where possible, indicators should be consistent with international best practice and be suitable for international benchmarking.
- *Data availability and quality*: The actual data that is available and its quality are practical considerations in the selection of indicators, but this assessment must also be forward looking and indicators should be flexible enough to accommodate opportunities for data improvement over time.
- *Comparability*: Where possible, indicators should be comparable across jurisdictions, across time and across sectors to facilitate benchmarking.
- *Simplicity and transparency*: Indicators should not be unnecessarily complex and their calculation should be transparent.
- *Cost effectiveness*: The cost of any necessary data collection or manipulation to generate indicators should be balanced against their usefulness.

8.5 Recommended wellbeing indicators

The particular wellbeing indicators that we recommend in each category are summarised in chapter 4 and issues relating to the implementation of each are summarised in chapter 5. Table 8.1 summarises the recommended indicators in each category. The ‘headline’ state indicators in each category are highlighted in bold.

Table 8.1 Summary of recommended indicators, with headline state indicators in bold

Category	Pressure indicators	State indicators	Response indicators
Network performance and capability	• Real GDP growth rate (national); employment (by region) • Total estimated population • Proportion of population living in urban areas	• **Throughput, or average travel time**, or variation from posted speed, or speed and flow productivity • **Peak and average coefficient of variation of travel time** • Percentage of travel on smooth roads • **Proportion of population living within 400m of a public transport stop with at least half-hour frequency** • *Population weighted average of public transport frequency* • Proportion of public transport services arriving at their destination within five minutes of schedule • Survey measures of public transport users' view of service quality, value for money and vehicle quality/comfort • Traffic volume weighted available lane-hours relative to total	• Total expenditure on new transport infrastructure by central and local authorities • Total expenditure on private and public transport services • Total expenditure on maintenance of transport infrastructure by central and local authorities • Traffic volume weighted averages of speed limits • Percentage of the road network under active traffic management
Cost	• Average cost of imported fuel oil per barrel • Average wage and salary costs of the land transport sector • Average value of all transport vehicles imported into New Zealand • Total land transport infrastructure costs, divided by total network km	• **Total fixed and variable costs of personal transport divided by total km travelled** • **Total fixed and variable costs of freight transport divided by total freight tonne and total freight distance travelled**	• Total subsidies divided by total passenger km on subsidised routes • Total government revenue from personal transport activities divided by total km travelled • Total government revenue from freight transport activities divided by total freight tonne km travelled
Health	• Sulphur content of diesel • Average age of the vehicle fleet • Kilometres of roads categories by surface type	• **Concentration of PM_{10}/$PM_{2.5}$ at key monitoring sites** • **Concentration of NO_2 at key monitoring sites** • **Average exposure to PM_{10}/$PM_{2.5}$** • **Average exposure to NO_2**	• National standards for PM and NO_2 concentrations • Exceedances of national standards • Regulated S content of diesel • Vehicle import standards

Category	Pressure indicators	State indicators	Response indicators
Environment	• Average fuel economy of fleet • VKT	• **CO_2 emissions by road vehicles**	• Proportion of transport fuel facing the emissions price
Safety	• Average safety rating of all vehicles • Total number of registered motorcycles • Percentage of total drivers aged 15–25 • Proportion of trips made by pedestrians & cyclists • Percentage of total drivers caught driving while disqualified, unlicensed, fleeing or racing • Percentage of vehicles exceeding speed limit on open and urban roads • Percentage of drivers using alcohol or drugs • Average star rating of highway network weighted by traffic volume • Proportion of total railway crossings that are controlled	• **Number of deaths divided by sum of total km travelled (ie sum of private and public transport passenger km)** • **Number of serious injuries and deaths divided by total km travelled** • **Total social cost of all safety incidents divided by total km travelled**	• Total expenditure on safety education and awareness campaigns • Total expenditure on infrastructural safety improvements • Additional resources ($) used to enforce safety-related rules

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Appendix A: Survey of international practice

This appendix reviews the indicators and performance monitoring frameworks used in other countries and by international organisations in relation to road and rail transport activity, in addition to those that were reviewed in section 3.4. We focus on indicators that are publicly available and published at the national level.

We concentrate on *transport specific* indicators. In addition, most countries publish generic indicators such as population counts, GDP and environmental indicators that are relevant for transport but are not transport specific. In such cases, we report '*None*' in the tables below to indicate that we did not identify any transport-specific indicators, but this does not mean that no indicators are published at all.

We classify indicators used in other countries as follows:

Pressure: Drivers of demand for transport services, eg population, economic activity, prices, costs, etc.

State: Indicators of the current state of the transport system, with the following subcategories:

- *Activity:* Measures of the volume of aggregate transport activity of a particular type, eg VKT, passenger km, tonne km, etc.
- *Energy and environmental:* Measures of environmental effects and energy used, eg emissions, noise, fuel efficiency, etc.
- *Safety:* Measures of safety-related outcomes or transport system characteristics, eg crash rates, fatality rates, serious injury rates, etc.
- *Social:* Measures of social effects of transport, including connectivity, accessibility, public transport frequency, etc.
- *Performance:* Measures of transport system performance, eg congestion delay, travel times, public transport on-time performance, etc.
- *Condition:* Measures of the physical condition of transport infrastructure, eg road surface quality, quality of public transport facilities, etc.
- *Inventory:* Measures of the nature and extent of the transport network and vehicles, eg road length, rail length, fleet composition, number of bridges, etc.

Response: Measures of effort to tackle problems and invest in or maintain the transport system, eg fuel taxes, infrastructure investment, maintenance expenditure, etc.

A1 Australia

Road and rail transport indicators in Australia are published by the Bureau of Infrastructure, Transport and Regional Economics (BITRE), Austroads, and the Australian Transport Safety Board (ATSB). Individual state-level road authorities also collect and publish indicators for asset management and planning purposes within their jurisdictions. We also summarise a detailed set of recommendations for transport indicators made by the Curtin–Monash Accident Research Centre (Hughes et al 2011).

A1.1 BITRE

The BITRE publishes road and rail activity indicators, and safety indicators on its website.[50] The current BITRE indicators are summarised in table A.1 (BITRE 2011).

Table A.1 Summary of indicators currently published by the BITRE

Type	Indicator	Segmentation(s)
Pressure	Road construction and maintenance price and cost index	Territory
	Private vehicle ownership and operating cost index	
	Average retail petrol prices	Capital city
State: activity	Total freight tonne km	Mode, territory, bulk/non-bulk, vehicle type
	Total interstate freight	Mode, state of origin
	Total intrastate freight	Mode, state of origin
	Total passenger km	Mode, capital city
	Primary travel to work transport mode	Territory
	Total VKT	Vehicle type, territory, capital city
State: energy and environmental	Total transport petroleum fuel sales	Fuel type
	Direct greenhouse gas emissions	Mode
	Road transport direct greenhouse gas emissions	Vehicle type
State: safety	Number of fatalities and fatality accidents	Mode, territory
	Fatality rate and injury rate per 100,000 population	Mode, territory
	Fatality rate and injury rate per billion passenger km	Mode, territory
	Number of rail fatalities	Territory
	Rail fatality rate	Territory
	Number of rail casualties	
State: social	*None*	
State: performance	*None*	
State: condition	*None*	
State: inventory	Total road length	Road type, territory
	Stock of registered motor vehicles	Vehicle type, territory
Response	Value of transport engineering construction work	Mode, public/private, territory

Source: BITRE (2011)

A1.2 Austroads – current indicators

For the past 10 years, Austroads has published a set of transport measures for Australian states and New Zealand, for road transport only (Austroads 2011a). These indicators allow benchmarking across the members and over time. Each indicator includes the following data and metadata:

[50] See http://bitre.gov.au/info.aspx?NodeId=5

- basic statistical information for the current year
- time series information
- national averages
- general notes and considerations that apply to the indicator
- specific factors or qualifications that must be taken into account when interpreting an indicator for an individual jurisdiction
- descriptions of the methodology used for the indicator.

The Austroads indicators have evolved over time. The initial set of 14 indicators established in 1993 gradually expanded to 72, which made the indicator set more costly to maintain (Austroads 2011a). A review was conducted in 2004 and resulted in a reduction of the number of indicators and modifications of some. The set of performance indicators currently collected and published by Austroads is summarised in table A.2. Most of the current Austroads indicators relate to safety, road performance and road condition.

Table A.2 Road transport indicators currently published by Austroads

Type	Indicator	Segmentation(s)
Pressure	*None*	
State: activity	*None*	
State: energy and environmental	*None*	
State: safety	Serious casualty crashes per 100,000 population	Member
	Serious casualty crashes per 100m VKT	Member
	Fatalities per 100,000 population	Member
	Fatalities per 100m VKT	Member
	Persons hospitalised per 100,000 population	Member
	Persons hospitalised per 100m VKT	Member
	$m cost of serious casualty crashes per 100,000 pop	Member
	$m cost of serious casualty crashes per 100m VKT	Member
State: social	*None*	
State: performance	Urban actual travel speed	Time of day, member
	Urban nominal travel speed (posted speed limit)	Member
	Urban congestion: Difference between actual and nominal travel time (min/km)	Time of day, member
	Urban variability of travel time	Time of day, member
	Lane occupancy rate (persons/lane/hour)	Time of day, member
	Car occupancy rate (persons/car)	Time of day, member
State: condition	Proportion of travel undertaken each year on roads with a roughness level condition of less than 4.2 IRI	Road type, member
	Proportion of travel undertaken each year on roads with a roughness level condition of less than 5.33 IRI	Road type, member
State: inventory	*None*	
Response	Return on road construction expenditure (benefit-cost ratio)	BCR ranges, member

Source: http://algin.net/austroads/site/Index.asp?id=5

A1.3 Austroads – next generation indicators

The structure of the Austroads next generation indicators was described in section 3.4.1. The following are some additional details for each of the indicator categories.

A1.3.1 Pavement condition

Austroads proposed that a pavement condition index be calculated for each of a set of (as yet undefined) road types. The road network within each type would be broken up into a number of distance segments, and roughness, rutting, cracking, texture and deflection measures calculated for each segment. Using a transfer function to put each of these measures on a common scale, the pavement condition index for each road type is calculated as a weighted sum of the five condition measures, with weights 0.33, 0.11, 0.33, 0.22 and 0.22 respectively.

The overall pavement condition network performance indicator (NPI) can then be calculated as a weighted sum of the condition indices for each road type, with the weights in this sum determined by the proportion of total road length of that road type in the whole network.

A1.3.2 Environmental

The environmental NPI proposed by Austroads is an unweighted sum of air quality, fuel consumption and noise indices. These are calculated at the level of the network as a whole and are defined as follows:

- *Air quality:* the ratio of the road system contribution to greenhouse gas emissions in CO_2 equivalent to the total transport system contribution to greenhouse gas emissions in CO_2 equivalent.
- *Fuel consumption:* the ratio of the weighted average nominal fuel consumption of all new light vehicle types on the road network to a reference fuel consumption value of 10L/100 km.
- *Noise:* the ratio of urban road network weighted average traffic noise to a reference noise level of 50dB(A) Leq 24hr.

A1.3.3 Safety

The safety index proposed by Austroads is based on road characteristics and conditions rather than safety-related outcomes (eg crashes or fatality rates). Austroads propose that a 'NetRISK methodology (Affum and Goudens 2008) be applied to road segments within the network, and then a safety NPI can be calculated as the weighted sum of the NetRISK scores, where the weights are the lengths of road in the network.

The NetRISK methodology computes a road safety risk measure for a road segment based on a number of physical characteristics of the road, including (Austroads 2011b):

- *Road geometry:* horizontal alignment, lane width, shoulder width, delineation, parking, etc
- *Surface condition:* skid resistance, weather, rutting, roughness
- *Intersections:* turn provision, sight distance, pedestrian provision
- *Roadside condition:* road user/vehicle risk.

A1.3.4 Efficiency

Austroads proposed a number of indicators of travel efficiency:

- *Travel time per 10km:* the average time to travel a standard distance of 10km on weekdays.
- *Variation from posted speed:* the difference between average speed and the signposted speed (speed limit).

- *Reliability:* the variability of travel time for a typical trip, calculated from the ratio of the standard deviation of travel time to the average travel time.
- *Productivity:* the productivity of the roads in moving vehicles, calculated from the product of vehicle speeds and flow rates.

A1.4 ATSB

The ATSB collects and publishes data relating to rail safety in Australia.[51] This includes frequency counts segmented by state of the following types of rail incidents:[52]

- derailments
- collisions
- level crossing occurrences
- signal passed at danger occurrences
- loading irregularities
- track and civil infrastructure irregularities
- deaths
- serious injuries.

The frequency counts are also published after being normalised by (per state):

- train km
- freight train km
- passenger train km
- total track km.

A1.5 Individual state-level road authorities

Each individual state-level road authority in Australia is a member of Austroads. This section summarises the road transport indicators published by at least one state-level authority that are *not* the same as or very similar to those published by Austroads. The state-level authorities typically use these indicators for performance measurement, asset management and planning purposes.

Table A.3 Other indicators used by state-level road agencies in Australia

Type	Indicator	Segmentation(s)
Pressure		
State: activity	Traffic volumes	Location, road type, time of day
State: energy and environmental	Number of fauna-sensitive road design installations	
	Kilometres of noise barriers installed	

[51] The ATSB also publishes aviation and marine safety statistics, which are outside the scope of this project. Road safety statistics in Australia are published by the BITRE, as discussed above.

[52] See www.atsb.gov.au/rail/rail-statistics.aspx

Type	Indicator	Segmentation(s)
	Number of environmental incidents	Incident level, incident type
State: safety	Licence suspensions and cancellations	Licence type
State: social	Mobility parking permits	Permit class, age group, postcode
	Safety camera detected offences	
State: performance		
State: condition	Pavement durability	Road type
	Ride quality	Road type
	Remaining pavement life or seal age	
	Community satisfaction with road maintenance	
	Availability of traffic signals/road lighting/ emergency phones	
State: inventory	Total number of vehicle registrations	Vehicle type, usage, year, manufacturer, colour, age, postcode, motive power, axle configuration, etc
	New vehicle registrations	Buyer type, vehicle type, make, colour, fuel type, postcode
	Transfer of vehicles	Vehicle type, transfer type
	Licenced drivers	Licence type, age group, postcode, gender, replacements, issues, conditions
Response	Investment expenditure	Road type
	Maintenance expenditure	Road type
	Number of road and bridge projects completed	
	Expenditure on safety infrastructure and initiatives	
	Expenditure on noise wall installation	

A2 Canada

The majority of transport indicators are published by Transport Canada, with some additional indicators published by other agencies.

A2.1 Transport Canada

Transport Canada is the federal department responsible for promoting a safe, secure, efficient and environmentally responsible transportation system in Canada. It compiles a large number of annual transport indicators, including road and rail indicators (Transport Canada 2010). Some of the most relevant are outlined in table A.4.

Table A.4 Summary of road and rail indicators currently published by Transport Canada

Type	Indicator	Segmentation(s)
Pressure	Fuel prices	Fuel type
	Price	Price index changes
	Cost structure (variable vs capital costs)	Public carriers/larger transport industries
State: activity	Total transport revenue	Mode, domestic vs tourist (incl vehicle rental), commercial/ personal, trucking co type, us service type, exports, region
	Domestic trips	Mode, same day/overnight, trip purpose
	Transport employment	Mode, function, region
	Average earnings in sector	Mode, region
	Transport spend as % of GDP	Mode, commercial/ personal, government spend, investment
	Freight tonne km	Mode
	Railway revenue tonne km	Route type, year
	Rail freight tonnes	Mode, year, cargo type
	Rail imports and exports	Port of clearance/ destination, year
	Rail passenger and passenger-km	Year, commuter/regional
	Vehicle travel km	Vehicle type, region, origin/ destination, usage
	Urban transit passenger and vehicle km	Year
	Intercity bus passenger	Year
State: energy and environmental	Greenhouse gas emissions	Mode, vehicle type
	Air pollution emissions	Pollutant, year
	Energy use	Mode, fuel type, region,
State: safety	Accidents: fatalities/injuries	Mode, region, commercial/personal, road user type, vehicle type
	Accident rates	Mode, region
	Accidents: safety belt rates	Region
	Accidents: alcohol prevalence	Level, year
	Accidents: dangerous goods	Year
State: social	*None*	
State: performance	Financial performance	Mode
	Trucking: bankruptcies	Region, year
	Urban transit systems indicators: price, cost, cost-recovery, loss	Region
	Productivity/efficiency indicators (lab, fuel, capital)	Mode
State: condition	*See below*	
State: inventory	Railways	Ownership, km, region

Type	Indicator	Segmentation(s)
	Roading: km	Road type, region
	Vehicles	Vehicle type, region, age
	Urban transit fleet	Vehicle type
Response	Government expenditure and revenue	Department, provincial/ federal, operating/capital/ infrastructure, mode

Transport Canada also monitors particular information regarding urban transportation.[53] This monitoring considers: outputs (actions taken), outcomes (the results of actions) and external conditions (the circumstances of actions). Additionally, it undertakes studies of specific transport issues on an occasional basis, eg child restraint usage.[54]

Regarding the condition of the road network, the responsibility for maintaining and developing much of this infrastructure lies with the respective provincial and territorial governments. Consequently, road network conditions indicators are compiled with varying methods across the various provinces (TAC 2006).

A2.2 Transportation Association of Canada

The Transportation Association of Canada (TAC) is made up of a range of industry stakeholders including government departments, municipalities, academic institutions, private sector engineering and consulting firms, trade associations and other corporate members. As part of its urban transportation monitoring activities, the TAC undertakes the Urban Transportation Indicators Survey (TAC 2010). This initiative seeks to compare the progress of urban regions within Canada in achieving the TAC's 'New Vision for Urban Transportation', which involves the contribution of urban transport to improve the efficiency, environmental health and quality of life in Canadian cities.

The TAC has also been involved in instituting studies regarding other issues. One such issue is measuring the performance of roads, including the condition of road infrastructure (Hass et al 2009). This study reviewed international road performance measures as well as the varying approaches used across Canada (Hass et al 2009, in particular tables 2, 3, 4 and 7).

A2.3 Human Resources and Skills Development Department

The Human Resources and Skills Development Department is a federal department of the Government of Canada. It has a responsibility for addressing issues that affect the wellbeing of citizens in Canada. According to its mission statement, it is responsible for assisting citizens 'in making choices that help them live productive and rewarding lives, and to improve Canadians' quality of life'. It has identified that transport has an important role in the daily lives of many Canadians both socially and economically. It also has an impact on human health and the environment. In this context it has considered a number of transport indicators and how they have changed over time, including: vehicle ownership by vehicle type; distance travelled; commuting mode used; energy use by vehicle type; and on-road freight.[55]

[53] www.tc.gc.ca/eng/programs/environment-utsp-monitoringsustainabletransp-966.htm

[54] www.tc.gc.ca/eng/roadsafety/resources-researchstats-child-restraint-survey-2010-1207.htm

[55] www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=67

A2.4 Other departments and organisations

Air quality indicators are not part of the specific transport indicators and are compiled separately by Environment Canada. These measurements are used in a range of initiatives, including the Air Quality Health Index, the Canadian Environmental Sustainability Indicators and the Chemical Management Plan.[56]

A3 UK

The Department of Transport publishes a large volume of transport-related indicators in its annual Transport Statistics Great Britain publications. Some of these statistics are outlined in table A.4 (DfT 2010).

Table A.4 Road and rail transport indicators published by the UK Department for Transport

Type	Indicator	Segmentation(s)
Pressure	Motoring costs: price indices	Mode, transport component
	Petrol prices and duties	Fuel type
	Bus: fares index	Year, region
	Forecast traffic and vehicles	Vehicle type, decade
	Road construction tender price index	Year
State: activity	Passenger transport	Mode
	Public transport: passenger journeys	Mode
	Average distance travelled per person	Mode
	Trips per person per year	Mode, purpose
	London commuters: morning peak	Mode
	Commuting time	Mode, area
	Household transport spend	Mode
	Transport-related employment	Mode, occupation, gender
	Freight transport	Mode, commodity, year, vehicle size
	Rail: passenger travel	National/London Underground
	National railways: total revenue	Year, fare type
	Rail km	Passenger, timetabled, year, fare type
	National railways: stations open	Year, track type, passenger/freight
	London Underground: passenger trips	Year, fare type
	London Underground: passenger km	Year
	London Underground: revenue	Year, fare type
	London Underground: loaded train km	Year
	London Underground: revenue per journey	Year
	Light rail: passenger trips	Year, region
	Light rail: passenger km	Year

[56] www.ec.gc.ca/air-sc-r/default.asp?lang=En&n=C87142DF-1

Type	Indicator	Segmentation(s)
	Light rail: revenue	Fare type, year
	Bus: passenger trips	Year, region
	Bus: VKT	Year, region, service type
	Bus: operating revenue	Year, region
	Road traffic: VKT	Vehicle type, quarter, road type
	Vehicle excise duty	Vehicle type
	Traffic volumes	Road type, vehicle type, year
	Freight	Mode
State: energy and environmental	Petroleum use	Mode, fuel type
	Energy use	Mode, energy source
	Average new vehicle fuel consumption	Vehicle type
	GHG emissions	Mode
	CO_2 emissions	Mode
	Air pollutant emissions	Mode, pollutant
	Average vehicle emissions: urban conditions	Year
State: safety	Road accidents	Year, road user type, injury, road type, day/ time of day, alcohol use
	Motor vehicle offences	Offence type, year
	Rail accidents	Accident type, passenger casualties, casualty type, signal misses, year
	Passenger casualty rate	Mode
State: social	*See below*	
State: performance	Traffic speed	Road type (speed limit), vehicle type
	Average vehicle delay: slowest journeys on strategic road network	Road type, year
	National railway: performance measure (on-time %)	Region
	London commuter rail: passenger in excess of capacity	AM peak/PM peak
State: condition	Highway Condition Index	Road type, rural/ urban, region, year, local government type
	Road Condition Index	Road type, rural/ urban, region
	Road maintenance required: percentage of total	Region, road type, year
	Skidding resistance	Road type, local government type, year
	Surface condition of trunk roads	Year
State: inventory	Rail: length of track	Year
	Rail: rolling stock average age	Operator type, year
	London Underground: carriages	Year
	London Underground: route km	Year

Type	Indicator	Segmentation(s)
	Light rail: carriages	Year
	Light rail: stations	Year
	Light rail: route km	Year, region
	Bus: vehicle stock	Year, vehicle type
	Road length	Year, region
	Vehicles	Licence type, size, engine size, body type, axle configuration, ownership rate, annual mileage, region, year
	Vehicle licence holders	Age, gender
Response	Public investment	Central/local government, mode
	New road construction	Year, starts/ completions
	Public funding: bus services	Central/local government, year, subsidy type
	Public funding: roading	Road type, region
	Maintenance expenditure, $	Structural/routine, road type, road length, year

Other data compiled by the Department for Transport, in conjunction with the Office for National Statistics and the National Centre for Social Research, includes attitudes to a number of transport-related issues as well as experiences with different forms of transport.[57] These surveys relate to various aspects including:

- congestion, eg how serious a problem do people consider congestion to be
- pollution, eg how serious a problem do people consider exhaust fumes, how concerned are people with damage to the countryside from building roads
- climate change, eg how concerned are people about the effect of transport on climate change
- transport usage and availability by mode, eg how often do people travel on different modes of transport
- vehicle ownership, eg how many vehicles of different types do people own
- transport costs, taxes and congestion charges, eg do people consider that driving on busy roads should cost more
- possible investment in transport infrastructure, eg do people consider that more should be spent on transport infrastructure
- road safety, eg do people consider that speed limits should be reduced and punishment for drink-driving increased.

The department has either outlined or compiled several indicators that may be useful in the course of investigating various social issues. Some indicators have been considered in the course of establishing ‘accessibility planning’ guidelines for local councils. Some of the indicators considered useful include:

[57] www.dft.gov.uk/statistics?post_type=release&series=public-attitudes

- the percentage of primary pupils within 15 and 30 minutes of a primary school, and secondary pupils within 20 and 40 minutes of a secondary school, by public transport
- the percentage of 16–19 year olds within 30 and 60 minutes of a further education establishment by public transport
- the percentage of working age people receiving the 'jobseekers' allowance who are within 20 and 40 minutes of work by public transport
- the percentage of households without a car who are within 30 and 60 minutes of a hospital, and within 15 and 30 minutes of a GP, by public transport
- the percentage of households without a car who are within 15 and 30 minutes of a major centre by public transport.

A3.1 Office of National Statistics

A number of commuting-related statistics are collected by the Office of National Statistics as part of its annual Labour Force Survey. These include:

- usual method of travel to work, categorised by mode (including whether driver or passenger if by car), region of residence and region of workplace
- commuting time, categorised by mode, region of residence and region of workplace.

A4 Ireland

Transport–related indicators are compiled by several agencies and organisations in Ireland, including the Central Statistics Office and the Road Safety Authority.

A4.1 Central Statistics Office

The largest collection of transport-related indicators in Ireland is held by the Central Statistics Office (table A.5).

Table A.5 Road and rail transport indicators published by Ireland's Central Statistics Office

Type	Indicator	Segmentation(s)
Pressure	*None*	
State: activity	Average km travelled	Vehicle type (private/goods), vehicle weight, region, year
	Rail passenger journeys	Journey type, year
	Rail freight: tonnes and tonne km	Commodity type, year
	Rail traffic: km	Year
	Rail revenue	Passengers/freight, year
	Road freight	Freight type, journey type, vehicle type, vehicle age, axle configuration, vehicle weight, vehicle capacity, business owner, freight origin, year
State: energy and environmental	*None*	
State: safety	*None*	

Type	Indicator	Segmentation(s)
State: social	*None*	
State: performance	*None*	
State: condition	*None*	
State: Inventory	Vehicle numbers	Vehicle type, fuel type, engine capacity, weight, CO_2 emission band, age, make, licence date, year/month
	Licensed drivers	Licence type
Response		

A4.2 Department of Transport, Tourism and Sport

In Ireland, the Department of Transport, Tourism and Sport compiles a small range of transport indicators, most of which appear to be based on data sourced from the Central Statistics Office. Additionally, the department periodically undertakes studies on specific transport issues, eg the condition of non-national roads.[58]

A4.3 Road Safety Authority

The Road Safety Authority (RSA) collects data and information regarding road safety incidents. Much of this is available in published reports and/or on the Authority's website (RSA 2010). Available data includes:

- collision statistics – these are published annually and include collision data categorised by a number of variables such as:
  - injury/fatality characteristics
  - time and date
  - weather conditions
  - road surface
  - casualty and driver characteristics, eg age, gender, road user type
  - safety belt usage
  - vehicle type
  - location
- penalty point statistics – categorised by offence type, date, points incurred, points per driver and driver licence type
- safety belt usage surveys.

A4.4 Railway Safety Commission

The Railway Safety Commission compiles safety statistics in relation to both by national railways and urban light rail in Ireland (RSC 2009). Its most recent statistical publication provides data regarding:

[58] www.transport.ie/viewitem.asp?id=13004&lang=ENG&loc=397

- National Railways (Iarnrod Eirann) incidents categorised by a number of variables including:
  - injury type – fatal or non-fatal
  - incident type – operations and track maintenance activity, collision type, signs passed at danger, derailment
  - location – onboard, level crossing, etc
  - passenger or employee injured.
- light rail (LUAS) incidents, categorised by a number of variables including:
  - road traffic accidents and pedestrian contact
  - derailments
  - emergency brake applications.
- industrial railways (Bord Na Mona).

The trends in Irish rail safety incidents are compared with European averages by determining incident rates based on kilometres travelled and total track kilometres.

A4.5 National Roads Authority

The National Roads Authority has a wide range of publications regarding various road issues in Ireland, including evaluations and assessments of specific road developments, and design and engineering matters. Of more relevance is that it also publishes annual statistics regarding national routes (NRA 2010). These statistics include total route lengths broken down by characteristics such as road type and county.

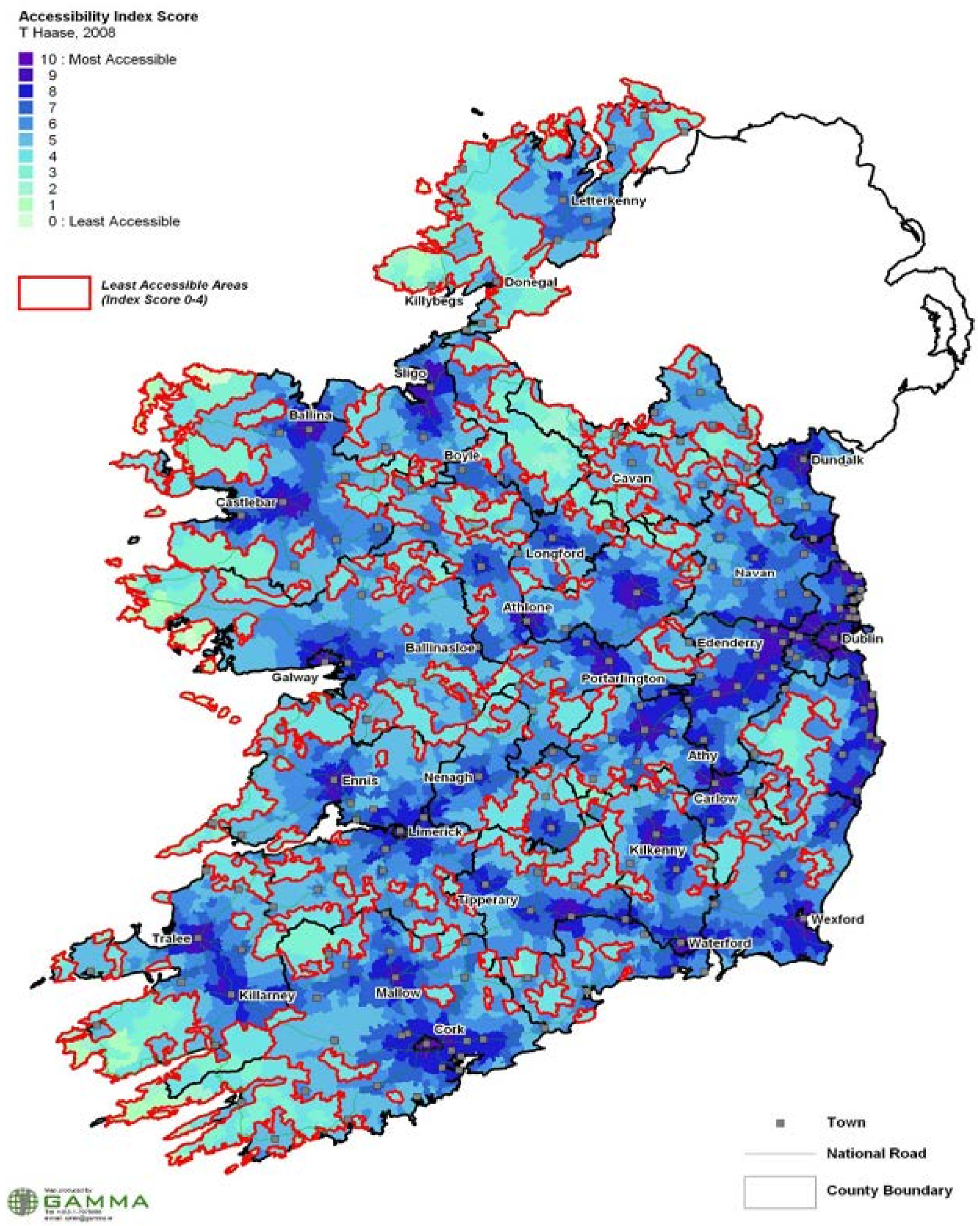
A4.6 Other departments and organisations

The Automobile Association of Ireland provides an on-going petrol price index which monitors monthly price changes across the main different petrol types.

The Environmental Protection Agency compiles data regarding air quality and transport sector emissions. It publishes a limited amount of data regarding the total greenhouse gas emissions from the transport sector, broken down by mode.

Information regarding transport deprivation has been published by Pobal (2009), an agency that works on behalf of the government to support communities and local agencies in achieving social inclusion, reconciliation and equality. Specifically, Pobal commissioned a study to identify a method measuring transport access across Ireland broken down into local areas. The system gives a rating to each area based on distance from services and access to public transport. The resulting rating, or Accessibility Index, indicates the degree to which services and activities can be reached from particular locations. The index ranges from 0 (most inaccessible) to 10 (most accessible).

Figure A.1 Illustration of transport accessibility in Ireland (from Pobal 2009)



Accessibility indices can be mapped to graphically highlight the least accessible areas at county, regional and national levels. The least accessible areas can also be graphically overlaid on an economic deprivation map to indicate areas where transport deprivation and economic disadvantage coincide (Pobal 2009, p11, map 3).

A5 European Union

Some pan-Europe road and rail transport indicators are published by Eurostat and the European Transport Safety Council. These indicators are calculated and reported on a consistent and comparable basis across all EU countries.

A5.1 Eurostat

Eurostat is the statistical office of the European Union, and publishes statistics at a European level that enable comparisons between countries and regions. Table A.6 summarises the indicators published by Eurostat relating to road and rail transport.

Table A.6 Road and rail transport indicators for the European Union published by Eurostat

Type	Indicator	Segmentation(s)
Pressure	Average annual indices for transport prices	Mode, country, cost type
State: activity	Road traffic volumes (VKT)	Country, mode
	Rail transport of passengers (passenger-km)	Country
	Goods transported	Mode, country, unit
	Modal split of passenger transport (% in total inland passenger-km)	Mode, country
	Modal split of freight transport (% in total inland freight tonne-km)	Mode, country
	Index of the ratio of volume of passenger transport relative to GDP	Country
	Index of the ratio of volume of freight transport relative to GDP	Country
State: energy and environmental	Energy consumption of transport	Mode, country
	Greenhouse gas emissions from transport	Country
	Average CO_2 emissions per km from new passenger cars	Country
	Emissions of nitrogen oxides from transport	Country
	Emissions of particulate matter from transport	Country
State: safety	Number of fatalities in road accidents	Country
	Fatality rate per 1m inhabitants	Country, province
State: social	*None*	
State: performance	*None*	
State: condition	Renewal rate of passenger cars	Country, year of first registration
	Renewal rate of lorries and road tractors	Country, year of first registration
State: inventory	Total motorway length	Country
	Total length of railway lines	Country
	Number of passenger cars	Country, fuel type
	Number of passenger cars per 1000 inhabitants	Country
	Number of lorries and road tractors per 1000 inhabitants	Country
Response	Investment in transport infrastructure	Mode, country (not yet available)

Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

A5.2 European Transport Safety Council

The European Transport Safety Council (ETSC) is an independent, not-for-profit organisation dedicated to reducing the number of transport deaths and injuries in Europe. The ETSC has established a Road Safety Performance Index (PIN) to encourage member countries to enhance road safety (ETSC 2011). Since 2006, the following road safety indicators have been published in the PIN reports:

- percentage change in the numbers of people killed on the road
- proportion of car occupants using safety belts
- percentage of fatalities resulting from crashes involving at least one driver impaired by alcohol
- mean speed and level of compliance in free-flowing traffic (ie the proportion of vehicles exceeding the posted limit) on different road types
- number of powered two-wheeler rider deaths per billion km ridden
- number of deaths on motorways per billion km driven by vehicles on motorways
- number of road deaths per 100,000 inhabitants aged 65 years and older
- penetration rates of new cars sold; the star rating for occupant protection, pedestrian protection and child occupant protection and safety belt remainders based on European New Car Assessment Programme
- number of road deaths per million inhabitants aged under 15
- percentage reduction over time in the number of people killed on the roads per 100,000 residents in capital cities
- percentage change in the number of serious injuries on the roads compared with the percentage change in the number of deaths on the roads
- percentage change in the number of deaths among pedestrians, cyclists and motorcycle riders
- percentage change in road deaths on rural roads (a road other than a motorway outside urban area boundaries)

A6 Switzerland

Road transport indicators in Switzerland at the national level are published by the Swiss Federal Statistics Office. We have also reviewed the public transport indicator framework used by the Office of Public Transport in Bern.

A6.1 Federal Statistics Office

The Swiss Federal Statistics Office provides a variety of information on transport on their website.[59] Their database provides time series data on road vehicles and road traffic accidents. Road vehicle data is segregated by the variety of characteristics including canton, type of vehicle, year of first registration, fuel type, engine displacement (cm^3), power (kW), number of seats, total weight, emission rating according to EU code and energy efficiency class. Road traffic data segmentation includes by canton, type of crash, severity, road type, crash site type, condition of the driver, time and day, gender and age. The indicators published by the Federal Statistics Office are summarised in table A.7.

[59] See www.bfs.admin.ch/bfs/portal/en/index/themen/11.html

Table A.7 Road transport indicators published by the Swiss Federal Statistics Office

Type	Indicator	Segmentation(s)
Pressure	Price indices in passenger transport	Public/private/fuel
	Price indices in goods transport	Mode
	Revenue from road transport	Tax and fee type
	Economic costs of traffic	Mode, cost type (transport means, infrastructure, safety, environment)
	External costs of transport	Mode, external cost type
State: activity	Average daily distance per person	Reason for travel, transport means
	Number of day and overnight trips per person	Business and private, household income
	Goods transport performance index (tonne km)	Destination (import, export)
	VKT index	Mode
	VKT of private motor vehicles	Vehicle type
	VKT of goods vehicles	Vehicle type
	VKT of goods transported	Destination (import, export)
	Passenger-km	Mode
	Occupancy of passenger cars	Trip purpose
	Choice of means of transport	Trip purpose, region
	Daily travel time	Trip purpose
	Passenger traffic flow maps	Mode
	Goods transport VKT	Mode
	Goods traffic flow maps	Mode
	Trans alpine goods traffic volumes	Mode
State: energy and environmental	Energy consumption from transport	Fuel type
	CO_2 emissions from transport	Mode, vehicle type
	PM_{10} emissions from road transport	Vehicle type
State: safety	Victims of road accidents	Injury type
State: social	Transport enterprises and employment	Industry sector
State: performance	*None*	
State: condition	*None*	
State: inventory	Distribution of the number of cars per household	
	Area occupied by transport infrastructure	Infrastructure type
	Length of national highways	Highway type
	Stock of road motor vehicles	Vehicle type
	Stock of passenger cars	Engine capacity, fuel
	Stock of lorries	Payload
Response	Public expenditure on transport	Mode, government level

A6.2 Office of Public Transport in the Canton of Bern

The Office of Public Transport in the Canton of Bern has released two reports outlining a framework for the evaluation of public transport projects (Amt für öffentlichen Verkehr des Kantons Bern 2003; 2005).[60] The reports concern public transport performance and infrastructure at the regional and local level in Bern. The framework includes a number of measures and indicators used to evaluate the performance of various aspects of the public transport network.

Quantitative measures of performance include:

- level of coverage: number of communities without public transport
- local availability
  - percentage of population within 400m of public transport stops with local services
  - percentage of population within 750m of public transport stations with regional services
- service density: public transport points per region and per capita
- cost-efficient use of resources
  - farebox recovery ratios for different public transport services
  - cost per public transport point
- behaviour changes: modal split of individual motorised transport to public transport
- environmental: energy consumption per passenger km.

The Bern framework also includes qualitative measures based on surveys of residents and public transport users. Survey respondents are asked to give their subjective view of the result of public transport infrastructure projects, on a scale of seven ratings ranging from ‘major improvement’ to ‘major deterioration’. The factors assessed through these surveys include:

- public transport accessibility of the site: travel times and frequencies
- accessibility of ‘focal development sites’ and regional centres: travel times and frequencies
- quality of public transport:
  - convenience
  - timeliness
  - utilisation of seats
- cost of public transport
- transport safety
- quality of life in populated areas: distance to public transport stops/stations
- mobility services from the perspective of residents: connectivity of development priorities and homes
- intermodal transportation: connectivity of pedestrian, bicycle and park and ride to public transport
- local environmental pollution: noise and air emissions
- land use

[60] The reports are in Swiss German and our summary here is based on partial translations by NZTA staff and Google Translate.

- urban design: fragmentation effects
- modal shift to public transport from motorised individual transport

A7 Denmark

A number of road and rail transport indicators are published by Statistics Denmark in collaboration with the Danish Ministry of Transport.[61] The relevant indicators are summarised in table A.8.

Table A.8 Road and rail transport indicators published by Statistics Denmark

Type	Indicator	Segmentation(s)
Pressure	Construction cost indices for civil engineering projects	Project type
	Consumer price indices in transport sector	Cost type
	Revenue from transport taxes	Type of tax
State: activity	Road traffic volumes (VKT)	Type of vehicle
	Average daily motor vehicle traffic	Road segment
	Rail traffic	Railway system
	Average and peak work day train traffic	Type of train, section of line
	Passenger transport	Mode
	Rail passenger transport (passenger and passenger km)	Railway system
	National and regional rail passenger transport	
	Weight and tonne km of goods transported	Mode, type of goods
	Employment in the transport sector	Sub sector
State: energy and environmental	Energy consumption of road transport	Fuel type
	Emissions of nitrogen oxides from transport	Selected cities
	Emissions of particulate matter from transport	Selected cities
State: safety	Road traffic accidents	Vehicle type, type of accident, injury type, accident situation, region, speed limit
	Drivers in road traffic accidents	Vehicle type, sex, age, age of driving licence, level of alcohol in blood
	Railway traffic accidents	Railway system, type of accident, injury type, category of person
State: social	*None*	
State: performance	*None*	
State: condition	*None*	
State: inventory	Total length of road network	Road type, province
	Total length of rail network	Railway system, type of track
	New registrations of motor vehicles	Type of vehicle
	Stock of vehicles	Type of vehicle, region, age

[61] See www.dst.dk/HomeUK.aspx

Type	Indicator	Segmentation(s)
	New registrations of private cars	Fuel efficiency, fuel type, ownership
	Railway rolling stock	Type of rolling stock
	Seats and load capacity	Type of railway vehicle,
Response	Investment in transport network	Mode, type of investment

A8 Norway

Statistics Norway provides a variety of transport statistics on their website.[62] The statistics outlined in table A.9 are found in the Norwegian Public Roads Administration, Norwegian National Rail Administration sections of StatRes and the transport and communication section of StatBank.

Table A.9 Road and rail transport indicators published by Statistics Norway

Type	Indicator	Segmentation(s)
Pressure	Changes in the cost index for road construction	
	Changes in the cost index for road maintenance	
	Total cost indices for road goods transport	Type of road goods transport, sub cost indices
State: activity	Road and rail transport passengers	Mode
	Road and rail transport passenger km	Mode
	Road and rail transport tonnage carried	Mode
	Road and rail transport tonne km	Mode
	Vehicle km, vehicle km per vehicle	Vehicle type, age, region, fuel type
	Number of trips per 1000 inhabitants and average trip length	Mode, region
	Vehicle kilometres per 1000 inhabitants	Mode, region
	Public transport - passengers, passenger km, seat km, vehicle km, ticket revenues	Bus and rail
	Public transport - passengers, passenger km, seat km, place km, vehicles, vehicles km, vehicle hours, ticket revenues, subsidies, expenditure, running expense	Type of route (inter-county, intra-county, city), mode (bus and total)
	Bus transport - passengers, passenger km, seat km, place km, vehicles, vehicles km, vehicle hours, seats, capacity utilisation, vehicle km per inhabitant, vehicle km per vehicle, speed, fares per inhabitant, passenger km per inhabitant, length of fare, ticket revenues/subsidies per passenger/ vehicle km, expenditure/running expenses per vehicle km/vehicle hours	Region
	Rail public transport – passengers, passenger km, train km, train hours, vehicles, seat km, place km, line km, subsidies	
	Taxi transport – trips, turnover, hours offered, hours in operation, total length driven, length driven with	Region

[62] See www.ssb.no/english/

Type	Indicator	Segmentation(s)
	passengers, trips per inhabitant, km driven with passengers per inhabitant/trip, turnover per trip/hours offered, minutes driven with passengers per trip, capacity utilisation per km driven/hours offered, number of taxis, inhabitants per taxi	
	Enterprises and employment in transport sector	Sub sector
State: energy and environmental	Number of state road sections/spots exposed to slides that were improved in the last year	Region
	Number of people living in areas exposed to hourly mean concentration levels of NO_2 exceeding national goals from state road traffic	Region
	Number of people living in areas exposed to daily mean concentration levels of dust (PM_{10}) exceeding national goals from state road traffic	Region
	Noise annoyance from state road traffic, change in noise annoyance index (SPI)	Region
	Area of national parks and reserves encroached on by construction of state roads	Region
	Number of national heritage sites that were lost or reduced in value because of state road construction	Region
	Area of cultural environments that were lost or reduced in value because of state road construction	Region
	Area of cultivated landscapes that were lost or reduced in value because of state road construction	Region
	Area of farmland converted to transport use because of state road construction	Region
	Emissions of greenhouse gases from road traffic (CO_2 equivalents)	
	NO_x emissions from road traffic	
	Number of people exposed to indoor noise levels of more than 40dB from state road traffic	
State: safety	Number of inspections (for safety belts, heavy transport, driving and resting time)	
	Number of people in road traffic accidents (per 1000 inhabitants, per 1000 motor vehicles)	Injury severity, age of driver, sex, road user group, type of accident
	Number of accidents, injuries, persons killed in road traffic accidents	Region
	Number of moose and animals killed by motor vehicles	
	Share of people using safety belts	Urban/rural
	Share of people complying with driving and resting time regulations	
	Number of people in railway accidents	Injury severity (killed or serious), line, train type
	Average number of people killed in railway accidents in the last 20 years	Line, train type
	Number of moose and animals killed in railway accidents	Line, train type

Type	Indicator	Segmentation(s)
State: social	*None*	
State: performance	Changes in travel time for chosen state roads	
	Uptime percent	Line, train type
	Freight train punctuality	Line, train type
	Interruptions due to defects in signalling system per km track	Line, train type
	Interruptions due to feeder station faultage per km line	Line, train type
	Capacity utilisation	Mode, region
	Passenger train – punctuality, regularity, utilisation of speed potential	Line, train type
	Passenger and freight train journey time	Line
State: condition	*None*	
State: inventory	Length of state roads	Region, speed limit, road type
	Length and number of tunnels on state roads	Region
	Number of driving licenses issued	
	Number of first time vehicle registrations	
	Number of workshops authorised to do periodical roadworthiness tests on vehicles	
	Number of driving schools	
	Share of tunnels on state roads with height restriction	Region
	Share of underpasses on state roads with height restriction of 4m or less	Region
	Share of km of state roads with poor or very poor road surface	Region
	Share of km of state roads with permissible axle load of 10 tonnes	Region
	Number of km of state roads opened for traffic	Region, road type (total, four lane, public transport)
	Number of km of central barriers built on 2 or 3 lane state roads in the last year	Region
	Number of km of state roads with rumble strip in the last year	Region
	Number of stops and intersections for public transport along state roads which were universally designed	
	Number of registered vehicles	Region, vehicle type, fuel type, type of transport
	Length of railway lines	Type of track, line
	Number of level crossings and level crossings per km	Line
	Number of crossings with barriers, lights and klaxons	Line
	Number of railway stations with passenger traffic	Line
	Number of railway platforms	Line

Type	Indicator	Segmentation(s)
	Number and length of passing loops	Line
	Number of park and ride car parks	Region
	Number of parking spaces for disabled persons	Region
	Average age and age distribution of private vehicles	Make, vehicle type
Response	Expenditure on public roads	Cost type
	Expenditure on railway infrastructure	Cost type
	Turnover, operating income, operating costs, production value, value added in transport sector	Sub sector, employment group

A9 OECD

The OECD currently collects and publishes a limited amount of data on transport indicators for member countries, summarised in table A.10. These indicators cover some high-level freight transport activity, road safety measures and expenditure on transport infrastructure investment and maintenance.

Table A.10 Road and rail transport indicators published by the OECD for member countries

Type	Indicator	Segmentation(s)
Pressure	*None**	
State: activity	Inland freight transport tonne km	Mode, country
	Inland passenger transport passenger km	Mode, country
	Rail containers TEU transported	Country
State: energy and environmental	*None**	
State: safety	Road injury accidents count	Country
	Road casualties count	Country
	Road fatalities count	Country
State: social	*None*	
State: performance	*None*	
State: condition	*None*	
State: inventory	*None*	
Response	Infrastructure investment expenditure	Mode, country
	Infrastructure maintenance expenditure	Mode, country

* The OECD publishes general economic (eg GDP) and demographic (eg population) and energy/environmental indicators for member countries separately from its publication of transport indicators.

Source: http://stats.oecd.org/

In 2001, the OECD conducted a study (OECD 2001) of the use of various road transport indicators in 13 member countries (Australia, Belgium, Denmark, Finland, Hungary, Japan, the Netherlands, New Zealand, Portugal, Sweden, Switzerland, the UK and the USA). This study included 15 road performance indicators and assessed their use in each of the participating countries. The specific indicators included in the study were:

1 Average road user cost: the average cost of running a medium car, a light diesel truck, and an articulated six-axle truck

2 Level of road user satisfaction: comparison of actual values against user expectations regarding travel time, travel time reliability and quality of road-user information

3 Unprotected road user risk: fatality risk for pedestrians, motorcyclists and cyclists

4 Protected road user risk: fatality risk for other road users not in the 'unprotected' category

5 Environmental policy/programme: a simple yes/no indicator of whether environmental policies or programmes are in place, together with qualitative information about the nature of the policy or programme

6 Market research processes: a set of simple yes/no indicators of whether any market research and customer feedback processes are in place

7 Long-term programmes: a simple yes/no indicator of whether a long-term road programme exists, together with qualitative information about the characteristics of the long-term plans

8 Resource allocation: a set of simple yes/no indicators of whether standard and robust systems to resource allocation for road administration exist

9 Quality management: a simple yes/no indicator of whether a quality management system for road administration has been implemented, together with qualitative information about the characteristics of the system

10 Budget efficiency: qualitative information about how road administrators monitor budgeted and actual costs

11 Overhead percentage: the efficiency of road administration, defined as the administrative (fixed) costs of road administration divided by total costs

12 Value of assets: a measure of the net economic value of road infrastructure

13 Roughness: standardised measures of the roughness of the road surface

14 State of road bridges: percentage of engineering structures with various classes of major defects

15 User satisfaction: measures of road user satisfaction with the roading system.

Many of the above indicators relate to the road administration system rather than the transport system itself (ie indicators number 5, 6, 7, 8, 9, 10 and 11). While such indicators may be useful for benchmarking administration across countries, in our view the promotion of wellbeing will be best served by benchmarking the characteristics of the transport system itself.

A10 World Bank

The World Bank has developed a number of headline indicators for transport:

- The Rural Access Index estimates the proportion of the rural population who have adequate access to the transport system.
- The Road Condition Index is based on the percentage of the classified road network which is in a 'fair' or 'good' condition.
- The Logistics Performance Index is a benchmarking tool for comparing countries' performance on trade logistics.

A10.1 Rural Access Index

The Rural Access Index is a headline transport indicator which aims to highlight the critical role of access and mobility in reducing poverty in poor countries (Roberts et al 2006). Despite this objective, some of the measurements used are relevant to indicators of access to transport in developed countries. The types of indicators are percentage of households (by income quintile) with access in 0–30 minutes walking time to:

- primary school
- health post
- bus stop
- paved road.

In addition, data is collected on alternative transport means, difficulties in reaching the different facilities, road closures and their duration, etc.

In countries with national household surveys, these are used to obtain data. Elsewhere, simplifying approaches are used based on the length of the road network, habitable land area, road and population distributions.

A10.2 Road Condition Index

The Road Condition Index measures the condition of the following categories of roads:

- motorways
- highways, main or national roads
- secondary or regional roads
- other roads.

The index uses data from the International Road Federation's World Road Statistics. It does not appear to be very useful; for example, it has data for New Zealand for one year (2004) and suggests that 100% of New Zealand roads (it does not include 'other roads') are in good condition, where the options were 'good', 'fair' or 'poor'.

A10.3 Logistics Performance Index

The Logistics Performance Index is an index of relative performance of trade logistics (Arvis et al 2010). It addresses six areas of performance:

1 Efficiency of the customs clearance process

2 Quality of trade and transport-related infrastructure

3 Ease of arranging competitively priced shipments

4 Competence and quality of logistics services

5 Ability to track and trace consignments

6 Frequency with which shipments reach the consignee within the scheduled or expected time.

It is survey-based approach that askes respondents to rate a number of factors as: very low, low, average, high or very high. The factors include the competence of service providers, and of transport associations. It also asks about the costs and time taken to transport goods from an import/export port to or from a factory or other point of origin/destination. The focus of the survey and the index is on international trade. The results for individual factors are scored to a maximum of 5. The score for New Zealand is shown in figure A.2.

Figure A.2 Logistics Performance Index score and rank for New Zealand

	New Zealand	
Overall Logistics Performance Index	score	3.65
	rank	21
Customs	score	3.64
	rank	16
Infrastructure	score	3.54
	rank	26
International shipments	score	3.36
	rank	23
Logistics competence	score	3.54
	rank	26
Tracking and tracing	score	3.67
	rank	25
Timeliness	score	4.17
	rank	17

Source: http://info.worldbank.org/etools/tradesurvey/mode1a.asp?countryID=103#

A11 World Economic Forum

The World Economic Forum (WEF) publishes a large number of country comparison indicators, which including a small number of transport indicators. These are published in the WEF's annual *Global competitiveness report* (WEF 2011a) and the annual *Travel & tourism competitiveness report* (WEF 2011b). The WEF indicators are currently published annually for almost every country in the world. The transport indicators are:

- quality of roads
- quality of railroad infrastructure
- quality of ground transport network
- road safety: road traffic accident deaths per capita
- road density: kilometres of roads per square kilometre of land.

The indicators relating to infrastructure quality are based on a survey of business executives in each country, and are therefore subjective in nature. These questions are phrased as follows:

How would you assess roads in your country? [1 = extremely underdeveloped; 7 = extensive and efficient by international standards]

How would you assess the railroad system in your country? [1 = extremely underdeveloped; 7 = extensive and efficient by international standards]

To what extent does your country's national ground transport network [buses, trains, taxis, etc] offer efficient, accessible transportation to key business centres and key tourist attractions within your country? [1 = not at all; 7 = extremely well]

In the most recent reports, New Zealand ranked 45/139 for quality of roads, 45/116 for quality of railroads, 32/139 for quality of the ground transport network, 24/139 for road safety, and 64/136 for road density. However, it is not clear whether higher or lower road density is optimal from a wellbeing perspective.

In addition, the WEF publishes high-level population, economic activity and emissions indicators, which partially relate to transport but are not transport specific.

A12 USA

In the USA, various road and rail transport statistics are published by many different agencies at national and state levels. Here we focus on standard aggregate measures at the national level.

A12.1 Bureau of Transport Statistics

The US Bureau of Transport Statistics (BTS) publishes an annual set of comprehensive statistics on the transportation system and related activity in the USA.[63] Table A.11 summarises the indicators relating to road and rail transport.

The BTS also maintains and publishes information about transportation facilities in the USA.[64] This includes details of the location and capabilities of major transportation infrastructure such as highways, railways and transportation terminals.

Table A.11 Road and rail transport indicators published by the BTS

Type	Indicator	Segmentation(s)
Pressure	Transportation fuel prices	
	Price of gasoline vs other goods & services	
	PPI for transportation services	
	PPI for transportation equipment	
	Average cost of owning and operating an automobile	
	Average passenger fares	Mode
	Average passenger revenue per ton-mile	Mode
	Average freight revenue per ton-mile	
State: activity	Vehicle miles	
	VMT and VMT per lane-mile	Functional class
	Passenger-miles	
	Principal means of transportation to work	
	Freight ton-miles	

[63] See www.bts.gov/publications/national_transportation_statistics/

[64] See http://1bts.rita.dot.gov/programs/geographic_information_services/maps/major_transportation_facilities/html/map.html

Type	Indicator	Segmentation(s)
	Consumption expenditure on transport	Category
	Employment in transportation	Mode, occupation
	Average wage and salary for transportation workers	Mode, occupation
State: energy and environmental	Sales of hybrid vehicles	
	Sales, shares and sales-weighted fuel economies	Vehicle type
	Energy consumption by the transportation sector	Fuel type, mode
	Demand for gasoline	Mode
	Motor vehicle fuel consumption and efficiency	
	Consumption of alternative and replacement fuels	Fuel type
	Fuel consumption	Vehicle type
	Transit industry electric power and primary energy consumption	Fuel type
	Rail freight fuel consumption and travel	Vehicle type
	Energy intensity	Mode, vehicle type
	Annual wasted fuel due to congestion	Urban area
	Annual wasted fuel per person	Urban area
	Air pollution emissions measures	Engine type, pollutant, vehicle type, urban area, fuel type
	Water pollution, noise and solid waste measures	
State: safety	Fatalities and fatality rate	Mode, functional system, vehicle type, accident type, day of week, time of day, weather, speed limit
	Injured persons and injury rate	Mode, functional system, vehicle type
	Accidents and accident rate	Mode, functional system, vehicle type
	Level crossing safety and rail property damage	
	Hazardous materials fatalities, injuries, etc	
	Transportation occupational fatalities	Mode
State: social	Number of disability-equipped buses	
	Number of disability-equipped rail stations	
State: performance	Person-hours of highway traffic delay per person	
	Travel time index	
	Roadway congestion index	
	Highway congestion index	
	Rail on-time performance trends	
	Railway hours of delay	Cause of delay
	Transportation labour productivity indices	Mode, occupation
State: condition	Median age of vehicles in operation	Vehicle type
	Condition of roadways	Functional system
	Condition of bridges	

Type	Indicator	Segmentation(s)
	Average age of urban transit vehicles	
	Condition of urban bus and rail transit maintenance facilities	
	Condition of rail transit infrastructure	
	Age and availability of locomotive and car fleets	
State: inventory	Road mileage	Road type, functional system
	Number of rail stations	
	Automobile and truck fleets	Use
	Motor vehicle production and wholesale sales	
	Retail new passenger car sales	
	New and used passenger car sales and leases	
	Number of trucks	Weight class
	Railroad locomotive fleet	Year built
Response	Government revenues and expenditures on transportation	Mode, level of government

Source: Bureau of Transport Statistics (2011).

A12.2 Rockefeller/Pew Report

A 2011 review by the Rockefeller Foundation and the Pew Center on the States (Rockefeller and Pew 2011) assessed the indicators collected and published by individual US states relating to transportation expenditure. The Rockefeller/Pew report does not itself contain any indicator data; however, it provides a useful summary of the types of transport indicators that are collected by at least some states.

The Rockefeller/Pew report groups indicators into six categories:

- safety
- jobs and commerce
- mobility
- access
- environmental stewardship
- infrastructure preservation.

To enable consistent comparisons with the other benchmarks above we have reclassified the Pew/Rockefeller indicators into the types used above, and these are summarised in table A.12. The Pew/Rockefeller indicators focus on social and environmental impacts of the transport system, and its condition and performance. There are no pressure, inventory or response indicators, and only one activity indicator.

Table A.12 Road and rail transport indicators assessed in the Rockefeller/Pew report

Type	Indicator
Pressure	*None*
State: activity	Freight tonnage or ton-miles by value
State: energy and environmental	Emissions
	Fuel consumption
	Use of alternative fuels
	Air quality
	Water quality
	Recycling
State: safety	Fatalities
	Injuries
	Crashes
	Infrastructure-related safety
	Response to weather emergencies
State: social	Transportation access for elderly, disabled and low-income populations
	Access to multimodal facilities and services
	Access to jobs and labour
	Access to non-work activities
State: performance	Congestion/density
	Delay
	Travel times/speed
	Travel time reliability
	Accident response
	Transit on-time performance
	Freight travel times/speeds
	Infrastructure support for freight movement
	Business access to freight services
State: condition	Road condition
	Bridge condition
	Remaining life of roads and bridges
	Rail system condition
	Transit system condition
State: inventory	*None*
Response	*None*

Source: Rockefeller and Pew (2011).

A13 Summary

Table A.13 gives a simple summary of the types of indicators that are available for road and rail transport in the jurisdictions we have reviewed. A tick indicates that at least one indicator of the type corresponding to the column heading is available for the jurisdiction or agency listed in the column row. Some agencies/jurisdictions publish more indicators than others in each category, but this is not reflected in table A.13.

Table A.13 Summary of road and rail transport indicators that we have identified

Agency/ country	Press.	State							Resp.
		Act.	Energy & Envt.	Safety	Social	Perf.	Cond.	Inv.	
Australia: BITRE & ATSB	✓	✓	✓	✓				✓	✓
Australia: Austroads (current)				✓		✓	✓		✓
Australia: Austroads (future)			✓	✓		✓	✓		✓
Canada	✓	✓	✓	✓		✓	✓	✓	✓
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ireland		✓	✓	✓	✓			✓	
European Union	✓	✓	✓	✓			✓	✓	✓
Switzerland: Federal Stats Office	✓	✓	✓	✓	✓			✓	✓
Denmark	✓	✓	✓	✓				✓	✓
Norway	✓	✓	✓	✓		✓		✓	✓
OECD		✓		✓					✓
USA	✓	✓	✓	✓	✓	✓	✓	✓	✓

Safety is the most commonly reported indicator, with all agencies we reviewed reporting multiple measures of road safety, such as injury and death rates. Rail safety indicators are also available for many countries. We were able to find response indicators in most cases, although most of these are simply aggregate measures of government expenditure on road and rail investment and/or maintenance. Similarly, energy and environment indicators for road and rail transport are published by many of the agencies we reviewed, but most of these are aggregated measures of greenhouse gas emissions only. Activity indicators are also common, with many agencies publishing aggregate indicators like VKT and passenger km.

In contrast, social transport indicators (eg availability of public transport services) are relatively uncommon among the agencies that we reviewed. This may be due to the difficulties and costs associated with calculating these indicators, such as processing geographical and network data, and/or conducting surveys. Similarly, performance and condition indicators are less common, and these indicators also require collection and processing of relatively extensive datasets. Basic transport pressure indicators are published by some agencies, and for many countries other generic measures of transport pressure (eg population, GDP, etc) are available from other sources.

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Appendix B: People consulted

In addition to the steering group, we consulted with the following experts during the course of this project:

Person	Organisation	Field of expertise
Janice Brass	NZTA	Local roads and private road transport
Tony Brennand	NZTA	Private road transport
Paul Clark	NZTA	Private road transport
Dave Cope	NZTA	Public transport
David Darwin	NZTA	State highways
Balt Gregorius	NZTA	Data and monitoring
Rob Hannaby	NZTA	Environment
Lynley Hutton	NZTA	Local roads and private road transport
Peter Kippenberger	NZTA	Public transport
Marinus La Rooij	NZTA	Road freight and rail freight
Barbara Tebbs	NZTA	Public transport

Appendix C: Economic growth versus wellbeing

Here we briefly discuss the differences between economic growth and wellbeing. Economic growth refers to the change in total economic activity, which is usually measured by gross domestic product (GDP). GDP can be calculated as:

1 *Expenditure:* Total expenditure on all final goods and services, or

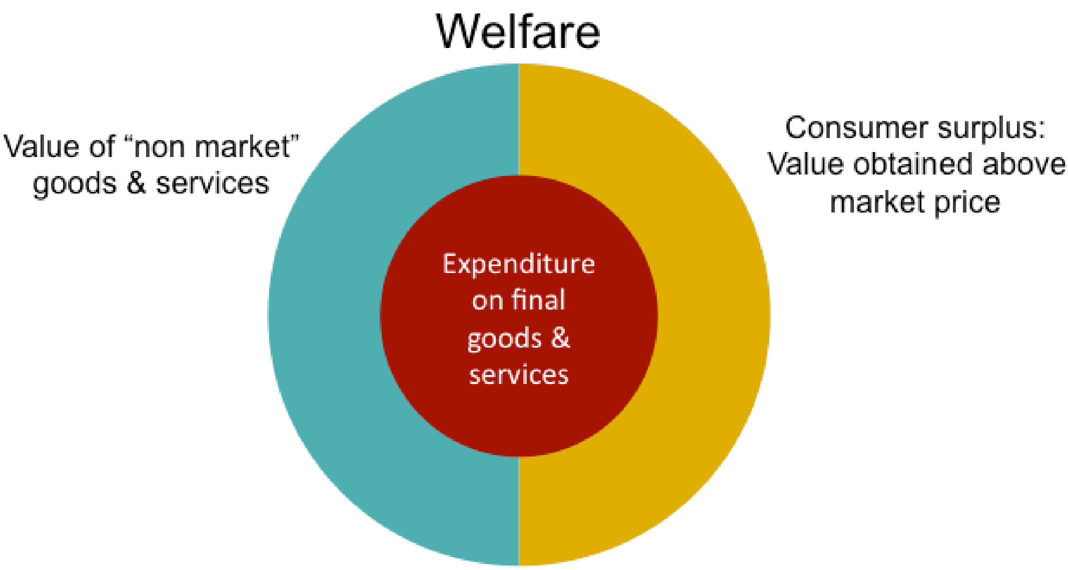
2 *Production:* The market value of all final goods and services, or

3 *Income:* The sum of all incomes of people living in a country.

Under all of these definitions, GDP focuses on the aggregate value of economic activity in the country within a given period of time. There are two main differences between GDP and the overall welfare of New Zealanders. First, GDP does not include the net value of non-market goods and services or activities, such as the pleasure that people get from visiting national parks or the option to drive to remote parts of the country, or the displeasure (negative externalities) created by pollution and congestion. Second, the value that people obtain from consumption of goods and services typically exceeds the market price that they had to pay, and this difference is known as 'consumer surplus'.

The general difference between GDP and welfare is illustrated in figure C.1, where GDP is represented by the red circle regarding expenditure on final goods and services, whereas welfare includes expenditure plus consumer surplus and the net benefits from non-market goods and services.

Figure C.1 Illustration of the differences between GDP and welfare



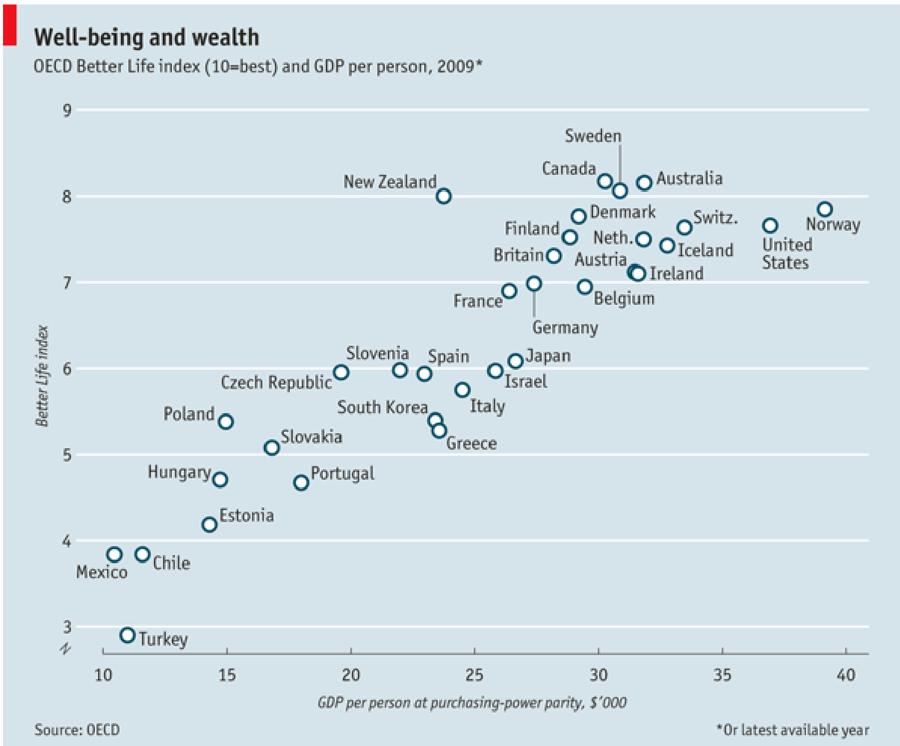
Furthermore, some events may not affect GDP and welfare in the same way. For example, investment that improves GDP could reduce overall welfare. Consider the construction of new transport infrastructure that facilitates more commercial activity by providing more reliable, quicker and lower cost transport links between potential exporters and export infrastructure such as a port. Such an investment would work to reduce the costs of production of local suppliers. This could in turn result in greater output because of increased exports which would be reflected as an increase in GDP.

However, as well as providing lower cost transport links for exporters, suppose this new infrastructure created substantial nuisance for nearby properties, in the form of loss of amenity, additional noise disturbance, increased environmental pollution and reduced safety. These effects could cause the value of affected properties (and the welfare of the property owners) to fall substantially, but this loss would not be reflected in GDP figures, at least in the short term. Therefore, even though GDP may increase because of increased exports, overall welfare could fall if the (GDP) benefit is outweighed by the negative impacts on affected property owners.

In contrast, an investment in roading infrastructure that results in safer, more pleasant journeys with less noise pollution for nearby residents could potentially have little impact on GDP, particularly within the short term. However, such an investment could generate substantial welfare benefits for the wider community.

Nevertheless, at the aggregate level there is generally a positive correlation between economic activity and welfare or wellbeing. Figure C.2 shows the relationship between GDP per capita and overall wellbeing as measured by the OECD Better Life Index. This shows that people living in countries with higher GDP per capita tend to report higher levels of wellbeing.[65]

Figure C.2 Correlation between GDP per capital and wellbeing

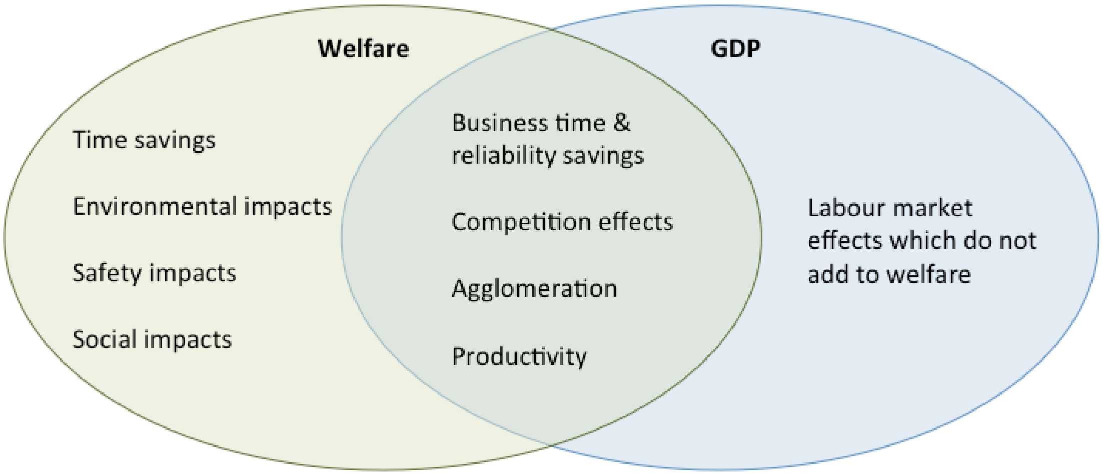


Source: The Economist online, www.economist.com/blogs/dailychart/2011/05/well-being_and_wealth

For transport, there is a similar overlap between components of welfare and GDP (figure C.3), with some factors that increase GDP also being positively related to welfare. However the magnitude of these effects relative to the effects that are not correlated with welfare is unknown and will be context specific. Therefore it is impossible to predict the actual degree of correlation between GDP and welfare for transport from a theoretical perspective.

[65] It is notable that New Zealand's wellbeing score is significantly above what would be expected given its level of GDP per capita. This suggests that New Zealanders may care relatively more than people in other countries about factors that affect wellbeing that are not captured in GDP.

Figure C.3 Relationship between welfare and GDP for transport



Source: Graham (2005)

C1 Reference

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