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Road transport usage modelling: incorporating supply-side measures

Prepared for the Ministry of Transport

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Executive summary

Roading investment in New Zealand is funded in large part by the National Land Transport Fund (NLTF). NLTF revenue is driven by the amount of road transport usage.

The Ministry of Transport has a business requirement to forecast NLTF revenue and hence to forecast road transport usage. Further, the Ministry wishes to understand changes in the New Zealand land transport sector, and to form a view on how the future may take shape.

The Ministry has access to three models of road transport usage: the Deloittes/Covec revenue forecasting model, the NZIER scenario model and the Concept structural model. The Concept model is a prototype and could be further developed.

None of these three models incorporate supply-side measures. In other words:

- they do not consider how the availability of roading and public transport services may have influenced road transport use over recent years, and
- they do not consider how changes in the availability of roading and public transport services may affect road transport use over future years.

This report explains why it would be worthwhile to incorporate supply-side measures into the three models, and what would be involved in doing so.

Adding supply-side measures could potentially:

- improve the ability of the Deloittes/Covec model to forecast future NLTF revenue
- improve the ability of the NZIER scenario model and the Concept structural model to produce a reasonable range of scenarios of future road transport use
- improve the ability of the Concept structural model to explain changes in the key elements of road transport use, and hence NLTF revenue, over the last decade.

Key challenges would include

- 'spatialising' the Deloittes/Covec and/or Concept models – i.e. replacing a single model for the country as a whole with multiple models for various areas of the country
- collating key data on supply-side availability. It may be difficult to obtain predictions of future supply-side measures, on which to base predictions of future road transport use and NLTF revenue.

Concept believes that the Ministry could also benefit from:

- further developing its understanding of how the key drivers of road transport usage (and hence of NLTF revenue) have changed in recent years, and keeping this understanding up-to-date
- enhancing its forecasting framework to project a reasonable range of possible future outcomes – rather than seeking to produce a single 'point estimate'.

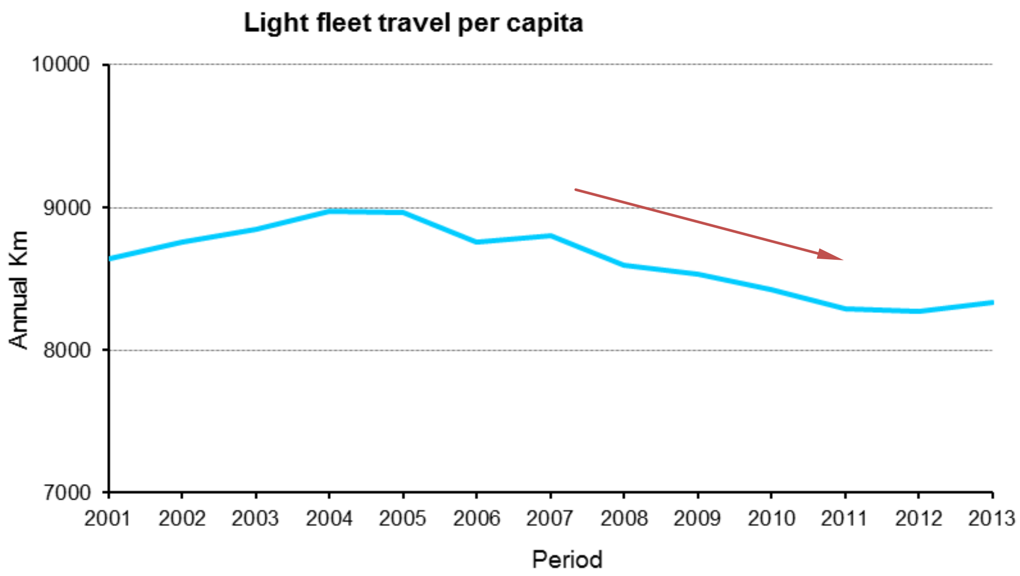
Concept believes that the Ministry's current modelling suite does not fully support these goals.

1 Introduction

1.1 There is considerable uncertainty about future road transport usage

Car usage in New Zealand has decreased over the last decade (Figure 1). Vehicle kilometres travelled (VKT) per capita, excluding heavy vehicles, declined by an average of 1% per year between 2005 and 2013.

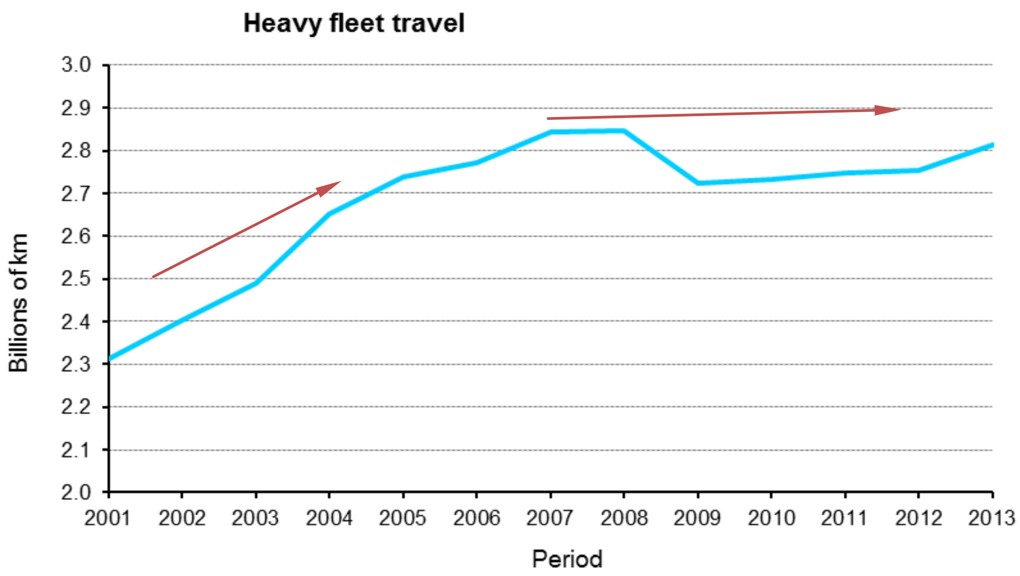
Figure 1: Declining trend in car use



It is not clear whether VKT per capita will continue to decrease, become static, or begin to increase again.

Heavy vehicle usage increased until 2007 (Figure 2), but became more static thereafter.

Figure 2: Increasing trend in heavy vehicle usage



Internationally, declines in passenger-car VKT – both on an absolute and a per capita basis – have been recorded in numerous advanced economies over the past decade. The key drivers for this trend are not well understood.

The Ministry has proposed five hypotheses to explain the observed trend:

- *travel saturation* – there is only so much travel people can fit into their day[1] and developed economies are reaching a saturation point for personal demand for vehicle travel. Traffic congestion can contribute to this saturation point being reached
- *peak car* – there has been an attitudinal change; people are not as interested in driving and car ownership as previously and are making lifestyle decisions that reduce their car use[2]
- *changing markets* – the advent of cheap air fares in the early 2000s is prompting people to undertake more social trips by air rather than by car. Increased access to public transport may also encourage mode switching away from private car transport
- the *digital age* – increasing use of the internet for activities such as online shopping is reducing people's demand for travel
- *interrupted growth* – the slowdown in economic growth following the global financial crisis of 2008 (GFC) has dampened demand for personal travel – but demand will recover as economies recover.

These hypotheses are not mutually exclusive – for instance, increased internet usage and cheaper air fares may both contribute to reduced road VKT. They are also not exhaustive – there may be other factors at work.

The first four hypotheses – *travel saturation, peak car, changing markets* and the *digital age* – can collectively be referred to as *sustained reduction* hypotheses. If they hold true, then VKT per capita should remain at current levels or continue to decline. If, instead, the *interrupted growth* hypothesis is true, then VKT per capita should soon recover to pre-GFC levels.

Actual outcomes may lie somewhere between these two extremes.

1.2 The Ministry requires road transport usage modelling

Roading investment in New Zealand is funded in large part by the National Land Transport Fund (NLTF). The main sources of revenue flowing into the NLTF are:[3]

- petrol excise duties (PED)
- RUCs.

These revenue streams are driven by the amount of road transport usage.

The Ministry has a business requirement to forecast NLTF revenue. In particular, the National Land Transport Act 2003 (Act) requires that *"the Crown's land transport investment strategy:*

- *must link the amount of revenue raised from road users with the planned levels of expenditure from the national land transport fund, and*
- *must, for the first 6 financial years of the GPS on land transport… address* [matters including] *likely revenue, including changes to the duties, fees, and charges paid into the NTLF".*

[1] Sometimes referred to as the 'time budget for travel'
[2] *"Peak Car: Does it exist and is it evident in New Zealand?"*, unpublished Ministry of Transport internal report
[3] Other sources of revenue include excise duties on other liquid fuels, and motor vehicle registration fees.

However, the Ministry's interest in forecasting transport outcomes goes beyond this specific requirement to forecast NLTF revenue. The Ministry wishes to understand changes in the New Zealand land transport sector, and to form a view on how the future may take shape.

The Ministry has stated that it *"needs to improve its understanding of the likely patterns of transport demand in New Zealand over the longer term, and is looking to develop models that will help forecast longer term transport demand. It needs to develop models that are robust and adequately model the key influences determining transport demand."*

1.3 Three road transport usage models are currently available

The Ministry has access to three models of road transport usage – referred to in this report as the Deloittes/Covec revenue forecasting model, the NZIER scenario model and the Concept proof-of-concept structural model – or collectively 'the three models'.

1.3.1 The Deloittes/Covec revenue forecasting model

A brief history of the development of the Deloittes/Covec model

Until 2010, the New Zealand Institute of Economic Research (NZIER) carried out modelling and forecasting of NLTF revenue for the Ministry.

Deloitte Access Economics (Deloittes) reviewed the revenue forecasting model used by the Ministry, found that the results were not accurate in some respects, and published a new model of NLTF revenue in 2011.[4] Deloittes reviewed its own model in 2012 and recommended some changes.[5]

Covec reviewed the Deloittes model, found that the results were not accurate in some respects, and published a report recommending extensive changes to the Deloittes model in 2014.[6]

We understand that the Ministry plans to accept Covec's recommendations. In this report, we will use the term 'Deloittes/Covec model' to indicate the model that will be produced by taking Deloittes' model as of 2013 and making the changes recommended by Covec.

These revenue forecasting models all have some features in common. They are all:

- *predictive* models – their primary purpose is to forecast NLTF revenue in future years
- *econometric* models – they are based on observed historical relationships between the quantities to be predicted and demographic /economic predictor variables (such as GDP or population)
- *national* models – they do not break down the quantities to be predicted between parts of the country.

There have been significant methodological differences between the successive generations of models. For instance, the Deloittes model of PED volume[7] was an error-correction model,[8] while the Covec model of PED volume was the product of a linear regression model[9] of per capita VKT and a simple trend model of vehicle efficiency.

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4 *"Review and redesign of the National Land Transport Fund revenue forecasting model"*, unpublished report by Deloitte Access Economics

5 *"Review of NLTF revenue forecasting model"*, unpublished report by Deloitte Access Economics

6 *"Review of the NLTF Revenue Forecasting Model"*, unpublished report by Covec

7 'PED volume' is the amount of petrol (in Ml) on which excise is paid in a given year

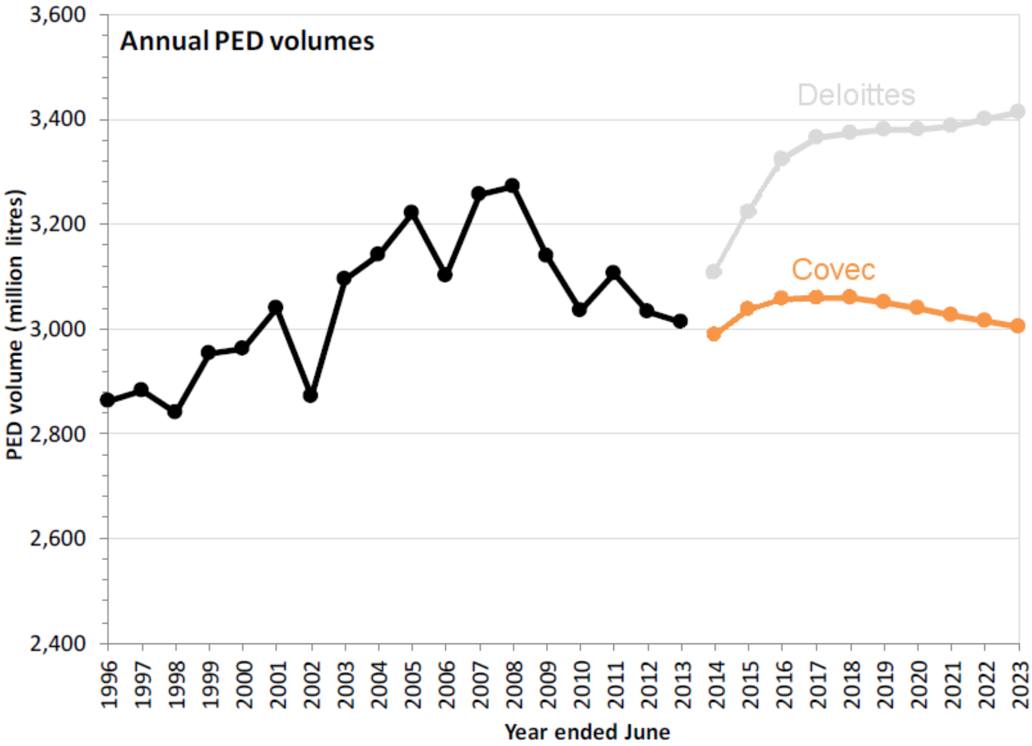
8 An error-correction model has two components – one representing the long-term trend, and another (with different predictor variables) representing short-term deviations from the long-term trend.

9 A linear regression model finds a best-fit statistical relationship between the variable to be predicted and one or more predictor variables.

These methodological differences, coupled with changes in the input assumptions used for prediction, have sometimes resulted in substantial differences in predictions. For instance, Figure 3 shows Deloittes and Covec forecasts of PED volume. The gap between the two is approximately 2% for the year ending June 2014, increasing to 9% in the year ending June 2017.

The uncertainty as to which of these forecasts will be most correct does not necessarily imply that either of them was carried out improperly. Rather, it may be indicative of the general uncertainty about future road transport usage. Car use may go up, go down or stay the same.

Figure 3: Deloittes and Covec predictions of PED volume (reproduced from Figure 6 of the Covec report)



This image was digitally edited to remove other data series from the graph. Any minor inaccuracy introduced in the process is regretted.

Features of the Deloittes/Covec model

The primary purpose of the Deloittes/Covec model is to predict annual NLTF revenue over the next ten years, with particular focus on the next three years.

The Deloittes/Covec model comprises:

- a model for projecting PED volume as the product of a linear regression model of per capita VKT and a simple trend model of vehicle efficiency
- a linear regression model of light/medium RUC volume
- a linear regression model of heavy RUC volume
- models for projecting other minor components of NLTF revenue
- a process for projecting combined NLTF revenue, as the sum of each volume component above multiplied by the corresponding price component.

In order to use the model for prediction, the user needs to enter the following input assumptions:

- economic growth and population

- prices of petrol, diesel and RUCs
- total values of imports and exports.

Other predictor variables were considered by Deloittes and/or Covec, but are not used in the model.

As applied by Covec, the Deloittes/Covec model produces:

- predictions of PED volumes that are consistent with *sustained reduction* hypotheses, in that total PED volume is predicted never to return to pre-GFC levels[10]
- predictions of rapid linear growth in light RUC volumes
- predictions of slow linear growth in heavy RUC volumes.

Deloittes provided some sensitivity scenarios. Covec did not carry out sensitivities, but instead showed confidence intervals showing the uncertainty of the projections. Appendix A comments on the extent to which these scenarios and confidence intervals represent the total level of uncertainty.

The Deloittes/Covec model is intended for prediction, rather than explanation. It was not designed to explain historical changes in road transport usage. It may be possible to gain some insight about key drivers by inspecting the model coefficients – but in the presence of multicollinearity[11] this may yield misleading results.

1.3.2 The NZIER scenario model

The NZIER scenario model was produced for NZTA in 2013,[12] and has since been made available to the Ministry. It is:

- a *scenario* model – its primary purpose is to produce a range of scenarios projecting transport usage over a horizon of years to decades
- a hybrid between an *econometric* model and a *structural* model – including both:
  - econometric elements, based on observed historical relationships
  - structural elements, based on logical relationships
- a *regional* model – it breaks down the quantities to be predicted between parts of the country.

The NZIER scenario model comprises submodels of:

- regional demographics, economic growth and incomes
- regional demand for household travel and freight
- the composition of the vehicle fleet
- travel volumes, and the consequent fuel usage and emissions.

The outputs of the model are predictions to 2040 of:

- private travel VKT
- public road transport VKT
- freight demand (t-km).

[10] This is partly a result of using a model structure that allows for a linear trend in VKT over time. In this case the estimated trend is downwards over time (regardless of economic or population growth).

[11] 'Multicollinearity' refers to the situation where predictor variables are correlated with each other.

[12] *"National long-term land transport demand model"*, NZTA research report 520, http://www.nzta.govt.nz/resources/research/reports/520/docs/520.pdf

In order to use the model for prediction, the user needs to use the interface to enter input assumptions on:

- economic growth, exchange rates, the inflation rate, the unemployment rate
- prices of oil, carbon prices, fuel excise and RUCs
- growth rates of specific industries
- regional net migration
- uptake of electric and alternative-fuel vehicles
- vehicle efficiency
- price elasticities of demand for transport.

There are various other input assumptions that are not presented to the user through the graphic user interface, but can presumably be specified in some other way.

As applied by NZIER, the model produces:[13]

- predictions of private travel VKT that are consistent with the *interrupted growth* hypothesis
- predictions of moderate linear growth in freight volumes.

NZIER used the model to produce several scenarios for the Ministry, showing the range of uncertainty. Appendix A comments on the extent to which these scenarios represent the total level of uncertainty.

The NZIER model is intended for scenario modelling, rather than explanation. It was not designed to explain historical changes in road transport usage. Nonetheless, the process of designing the model yielded some insights into drivers of change.

1.3.3 The Concept proof-of-concept structural model

The Concept model was produced for the Ministry in 2013.[14] Although it is operational, it has not been developed to its full potential. Rather, it is a proof-of-concept prototype, designed to show that the structural approach is feasible and can bring benefits.

The model is:

- both a *scenario* model and an *explanatory* model – its two purposes are:
    - to produce a range of scenarios projecting transport usage in future years
    - to break down road transport use in recent years and explain how the various components have changed over time. The prototype model could be enhanced to break down components in more detail.
- a *structural* model – the connections between inputs and outputs are based on logical relationships, rather than being estimated using statistical techniques
- a *national* model – it currently does not break down the quantities to be predicted between parts of the country, although this feature could be added to the prototype.

The structure of the Concept model is shown in Figure 4 overleaf, in the form of a tree diagram. Brown nodes may be read as 'wood', green nodes as 'leaves'. Each node indicates an annual data series and each line indicates a logical relationship.

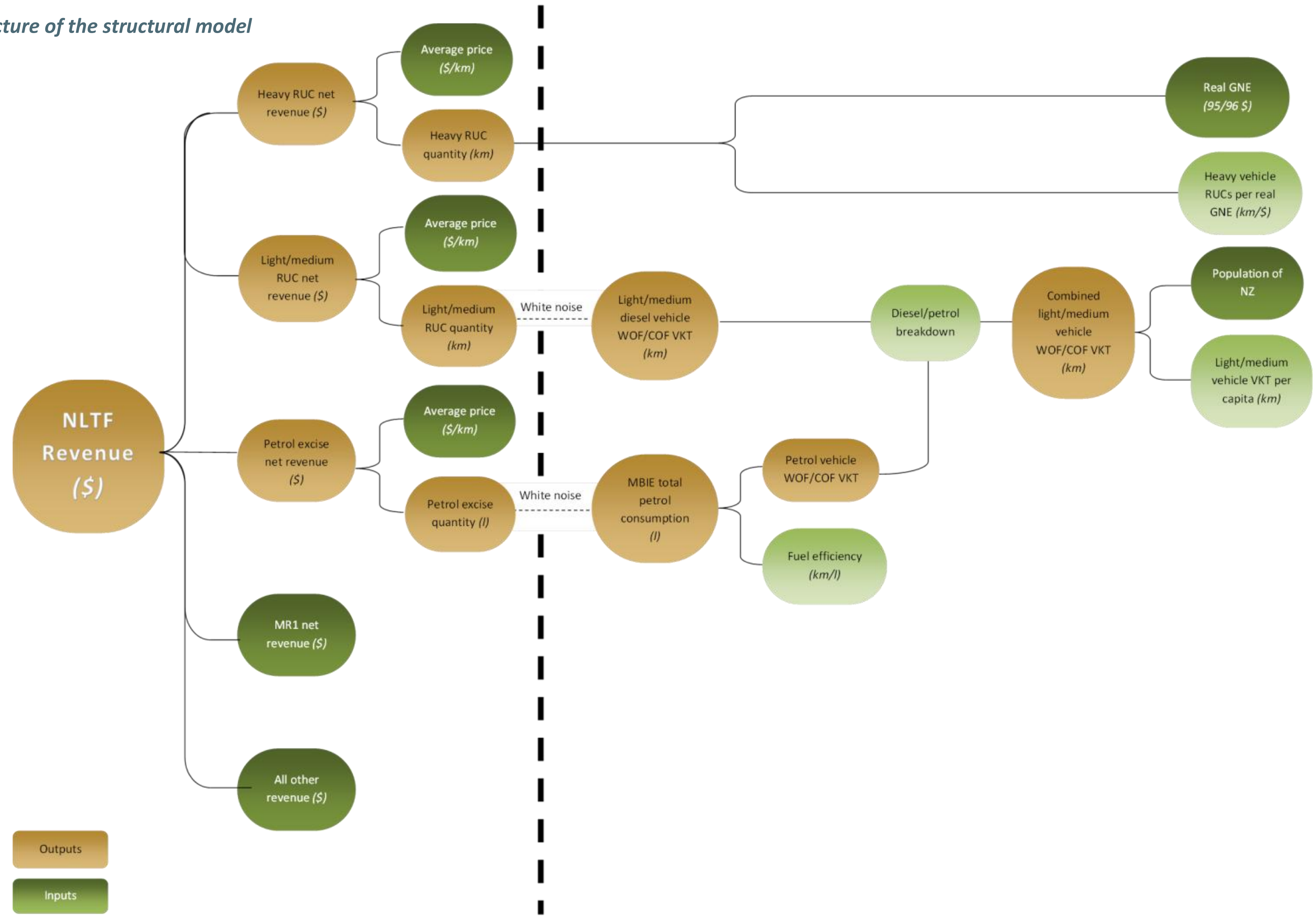
[13] As well as NZTA research report 520, see unpublished report *"Transport demand forecasts: NZIER report to Ministry of Transport"*.
[14] *"Structural modelling of NLTF revenue – first stage"*, unpublished report by Concept Consulting Group

For example, the brown node 'Heavy RUC net revenue ($)' is connected to the green node 'Average price ($/km)' and the brown node 'Heavy RUC quantity (km)' – because heavy RUC revenue is the product of heavy RUC price and heavy RUC quantity.

When the model is being used to explain historical data, the data values of brown and dark green nodes are known, and can be used to infer the data values of light green nodes.

When the model is being used to predict the future, the data values of green nodes are assumed, and can be used to infer the data values of brown nodes. The output is the leftmost brown node (the 'root' of the tree) – 'NLTF revenue ($)'.

Figure 4: The structure of the structural model



In order to use the model for prediction, the user needs to enter the following input assumptions:

- prices of fuel excise and RUCs
- economic growth and total national population
- the freight intensity of the economy (i.e. the amount of heavy RUCs used to produce each unit of gross national expenditure)
- light/medium VKT per capita
- the percentage of light/medium VKT that is travelled in diesel vehicles
- the average fuel efficiency of petrol vehicles.

When used for forecasting, the model can be used to generate:

- predictions of PED and RUC volumes that are consistent with *sustained reduction* hypotheses, by assuming that VKT per capita and freight intensity will remain steady or decrease further – *or*
- predictions of PED and RUC volumes that are consistent with the *interrupted growth* hypothesis, by assuming that VKT per capita and freight intensity will increase.

The model can be used to produce multiple scenarios, showing the range of uncertainty.

When used for explanation, the model can calculate the unknown quantities over the last few years and show how they have trended. Although the user may not know the *reasons* for the observed trends, they can at least identify which of the modelled quantities has changed, when, and how this has affected total revenue.

The proof-of-concept model could be developed further. The basic approach would be to pick a green node (leaf) and break it down further into its constituent parts. For instance:

- some of the components of the model could be spatialised – i.e. broken down between different regions of the country, or divided between urban and rural
- some of the components of the model could be broken down between vehicle types, sizes or ages – effectively building a small fleet model into the structural model
- passenger travel components of the model could be broken down by the demographic of the driver.

Options for further development of the structural model are discussed further in Appendix B.

1.3.4 The three models were designed for different purposes

The three models serve different purposes, and therefore were built in different ways. Table 1 (overleaf) compares and contrasts them.

Table 1 Comparison between the three models

Feature	Deloittes / Covec revenue model	NZIER scenario model	Concept proof-of-concept structural model
Can be used to predict future road transport usage	Yes – produces predictions over a ten-year horizon, with the main focus being on the next three years	Yes – can be used to produce a range of scenarios extending out to 2040	Yes – can be used to produce a range of scenarios covering the next ten years
Can be used to explain past road transport usage	Of limited value as the model is purely forward-looking	Of limited value as the model is purely forward-looking. However, the process of designing the model may have yielded some insights into key drivers of road transport usage	Yes – the model can be used to decompose land transport usage over the last decade and see how various components have trended. If the model is developed further, it will enable the Ministry to 'drill down' in more detail on changes that have occurred
Regional or national	National	Regional	National
Type of model	Econometric	Econometric / structural hybrid	Structural
How the connections between inputs and outputs are determined	Statistical models fitted to historical data	Mixture of statistical models fitted to historical data, and logical relationships	Logical relationships
Subjective assumptions that need to be made in order to produce a forecast	Economic growth Population Prices of petrol, diesel, fuel excise and RUCs Total values of imports and exports	Economic growth Exchange rates Inflation rate Unemployment rate Prices of oil, carbon, fuel excise and RUCs Growth rates of specific industries Regional net migration Uptake of electric and alternative-fuel vehicles Vehicle efficiency Price elasticities of demand for transport *(There are other assumptions which need not be entered by the user – rather they are implicit)*	Prices of fuel excise and RUCs Economic growth Population Freight intensity of the economy Light/medium VKT per capita Diesel/petrol breakdown Average fuel efficiency of petrol vehicles *(Later versions of the model could break some of these assumptions down to a lower level)*

1.4 The Ministry is considering incorporating supply-side measures into these models

Congestion can impact on demand for travel. However, none of these three models incorporate supply-side measures.[15] In other words:

- they do not consider how the availability of roading and public transport services may have influenced road transport use over recent years, and
- they do not consider how changes in the availability of roading and public transport services may affect road transport use over future years.

The Ministry seeks advice on whether it would be worthwhile to incorporate supply-side measures into the three models, and what would be involved in doing so.

The Ministry has therefore retained Concept to provide this report, which:

- discusses the concept of supply-side measures in road transport, with a focus on "the effects of road congestion and public transport availability on VKT"
- explains how supply-side constraints could be built into the three models, and into potential new models
- identifies issues that may arise in the process, and addresses the extent to which the ability to address such issues may differ between econometric and structural modelling approaches.

1.5 The Ministry may additionally wish to progress other research directions

Concept acknowledges the value of incorporating supply-side measures into the three models.

Although it is outside the scope of this project, Concept suggests that the Ministry may also wish to progress other research directions. Concept believes that the Ministry could potentially gain considerable value from focusing its efforts on:

- cementing a detailed understanding of how the key drivers of road transport usage (and hence of NLTF revenue) have changed in recent years, and keeping this understanding up-to-date
- breaking down key data series to 'drill down' on the location, timing, and nature of changes that have occurred in recent years
- enhancing its forecasting framework to project a *reasonable range*[16] of possible future outcomes – rather than seeking to produce a single 'point estimate'
- assessing the sensitivity of its forecasts to key assumptions – i.e. determining which inputs have the most effect on the outputs.

Concept believes that the Ministry's current modelling suite does not fully support the goals above.

Neither the Deloittes/Covec model nor the NZIER scenario model is designed to explain how road transport usage has changed in recent years. They are both forward-looking models. A forward-

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[15] The models *do* consider some factors that could be considered as supply-side measures – for instance, the prices of liquid fuels – but not the specific supply-side measures that the Ministry has in mind. These are the availability of roading, public transport and cycle route services.

[16] 'Reasonable' in this context representing a compromise between the desire to show the full range of possible outcomes, and the desire to add value by narrowing that range to include only the more likely possibilities.

looking model is of considerable use when seeking to predict future demand, but of less use when trying to explain why the prediction turned out to be incorrect.

Neither the Deloittes/Covec model nor the NZIER scenario model is being used to produce a reasonable range of possible future outcomes. Appendix A discusses how these models have not demonstrated the total uncertainty of road transport use. The key problem is that they do not acknowledge that the future may not resemble the past.

Concept is aware that the Ministry has a statutory requirement to prepare a *point estimate* of NLTF revenue (as set out in Section 1.2). Nonetheless, Concept believes that the Ministry should still consider a reasonable range of outcomes at the modelling level:

- in order to determine where the point estimate should fall
- in order to caveat the point estimate and indicate the extent to which it may be an over- or under-estimate
- in support of its goal of "improving its understanding of the likely patterns of transport demand in New Zealand over the longer term".

Concept believes it is important for forecasting frameworks to recognise both:

- model inaccuracy – that is, the extent to which errors could occur even if the input assumptions (such as economic and demographic variables) were known with perfect foresight
- input uncertainty – that is, the input assumptions (such as economic and demographic variables) may prove to be incorrect. It is important to reflect the range of possible values of key drivers through scenario-based analysis, in order to understand the range of possible outcomes.

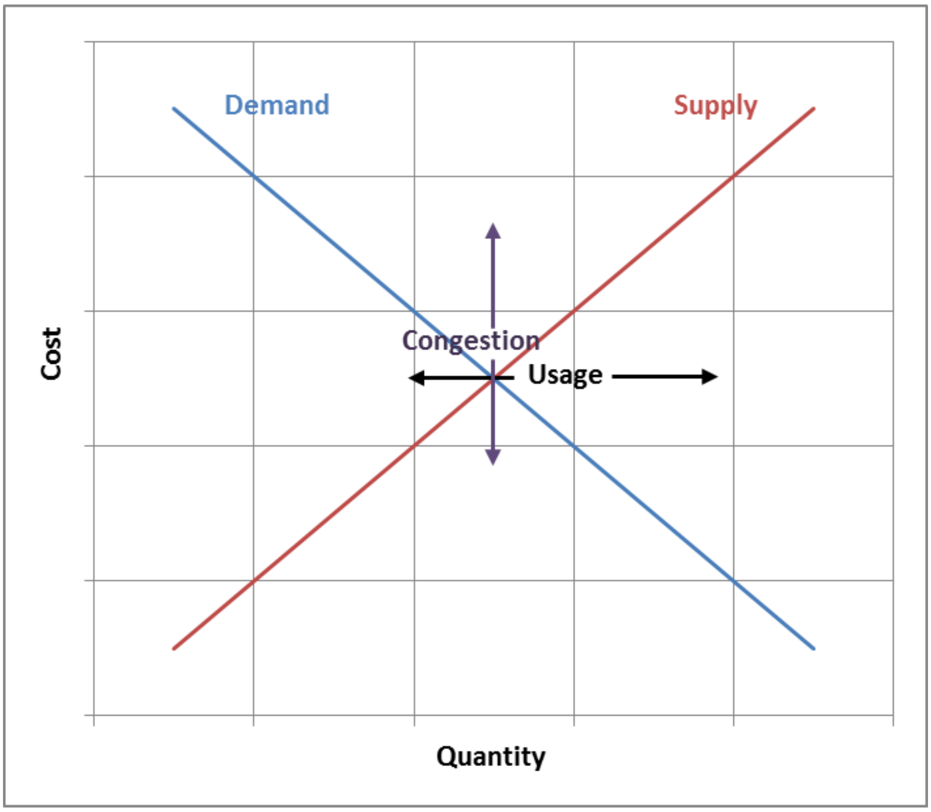
2 Terminology

It is first useful to establish some terminology for discussing supply-side measures.

Figure 5 sets out the key terms in a generic way:

- *quantity* represents the amount of transport services (which may include roads, bus services, train services, and/or cycle routes, depending on the application)
- *cost* represents the quality, convenience (i.e. time cost), and affordability (i.e. monetary cost) of accessing those transport services
- *demand* represents the desire for transport services – with demand decreasing as the 'cost' of the services increases
- *supply* represents the availability of transport services – with 'cost' increasing as the amount of transport services used increases
- *usage* is the actual level of transport use that occurs in practice, and is at the intersection of supply and demand
- *congestion* is the extent to which transport services are nearing capacity at the actual level of usage.

Figure 5: Demand, supply, congestion and usage



All these factors clearly vary over time – for instance, demand, usage and congestion are typically highest at weekday morning and evening peak.

It is important to appreciate that, although the three models described in Section 1.3 are sometimes referred to as *demand* models, they are actually *usage* models. They seek to predict the actual level of transport use, which is the intersection of supply and demand. At present, they do this by projecting historical levels of usage into the future – rather than projecting both *supply* and *demand* into the future, and calculating future usage as the intersection of the two.

Concept interprets the Ministry's request as seeking to determine:

- how historical changes in the supply/demand balance may have affected the level of usage in the past
- how possible future changes in the supply/demand balance may affect the level of usage in the future.

For instance:

- if roading investment had stagnated in the past in a particular region, and there was congestion, then this might have been one reason why road transport usage in that region had not increased
- if extensive bus network investment was planned for a particular region, then it could be expected that bus transport usage would increase in that region, and private vehicle transport usage would be less than would otherwise have been expected.

It should be noted that *supply* and *congestion* are innately spatial measures. The supply of roads, and the resultant level of congestion, varies greatly between urban centres and rural areas. Urban areas also differ greatly from rural areas in the availability of bus transport. Commuter train services in New Zealand are confined to two urban areas (Auckland and Wellington).

As a result, it makes little sense to model supply-side measures on a national level. It is more useful to consider them at a regional level, and to distinguish between urban and rural areas.

3 Supply-side factors can affect road transport usage

It is reasonable to expect that investing in the supply of transport services will:

- reduce the level of congestion (and thus the time cost associated with travel)
- increase the level of usage as users respond to this lower cost of travel

Likewise, failure to invest in the supply of transport services (against a background of increasing demand) can be expected to:

- increase the level of congestion
- reduce the level of usage.

These relationships can readily be observed at the micro level (e.g. for a single street, or on a single bus service). However, it is more difficult to discern their effect at the macro level. Investment in transport services surely has an effect on the routes people use, the time at which they travel, and the time they take to get to their destination. The key question is whether investment is observed to have a material effect on the *total distance* people choose to travel, or the transport modes they use – and hence on NLTF revenue.

As will be shown in the next two sections, there do appear to be situations where an increase in supply has affected road transport usage at a regional level. This supports the case for incorporating supply-side measures into the three models.

3.1 Increased road usage has been observed to follow road upgrade investments

The Ministry publishes statistics on regional VKT, broken down between local roads and State highways.[17] NZTA publishes statistics on the amount of roads in lane-km terms, again broken down between local roads and State highways.[18] Together, these datasets can be used to test whether major road transport upgrade investments are observed to lead to a material increase road transport usage, at the regional level.

The best example of a connection between investment and usage appears to be for State highways in the Auckland region. Figure 6 (overleaf) shows how a programme of investment that has increased State highway capacity (red line, in lane-km) has been followed by an increase in the usage of State highways (blue line, in VKT).

The graph shows that:

- Auckland State highway lane-km increased by an average of 2.5% per year over the five years to 2013
- Auckland State highway VKT increased by an average of 2% per year over the three years to 2013.

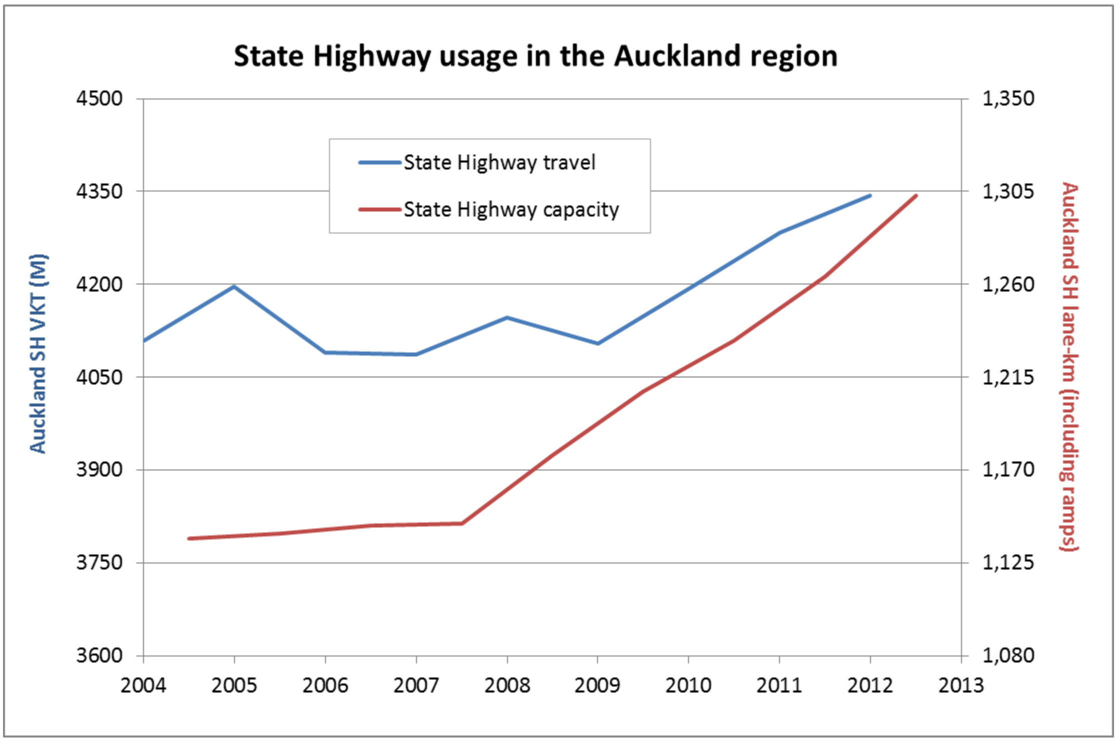
This trend of increasing VKT was not observed in other areas:

- national VKT increased by an average of just 0.5% per year over the same three-year period
- Auckland *urban local road* VKT was static over the same three-year period.

[17] http://www.transport.govt.nz/ourwork/tmif/transport-volume/tv001/
[18] http://www.nzta.govt.nz/planning/data/networks.html

Auckland urban congestion at morning and evening peaks decreased over the same period[19] – consistent with the framework set out in Section 2, under which an increase in supply should result in an increase in usage and a reduction in congestion.

Figure 6: An example where increased road usage has followed road upgrade investments



This example does not necessarily prove,[20] but is at least *consistent* with, a connection between increased supply-side availability and increased road usage at the regional level.

Most other regions of New Zealand do not show similar results. One possible exception is the Waikato region, where a substantial increase in the amount of urban local roads has roughly coincided with a substantial increase in local road VKT. However, Ministry staff are not certain that this is a genuine correlation – it may reflect a measurement, sampling or definitional issue.

3.2 Public transport improvements have resulted in increased public transport patronage

In Auckland, bus patronage increased by 50% between 2000/01 and 2012/13. Much of this increase was driven by increased demand due to external factors. However, some investment in bus related infrastructure over this period has provided a strong stimulus to patronage growth. In particular, investment in the Northern Busway (which opened in 2008) produced a very large increase in patronage on the corridor – with boardings increasing from under 1 million in 2007/08 to 2.43 million in 2012/13. This corridor accounts for about 4.5% of bus boardings.

The Ministry has provided Concept with a breakdown of statistics on regional bus usage, originally sourced from regional councils via the NZTA.[21] These statistics show a substantial increase in bus usage in the Auckland region from 2010 onwards (red line, Figure 7).

[19] http://www.transport.govt.nz/ourwork/tmif/networkreliability/nr002/

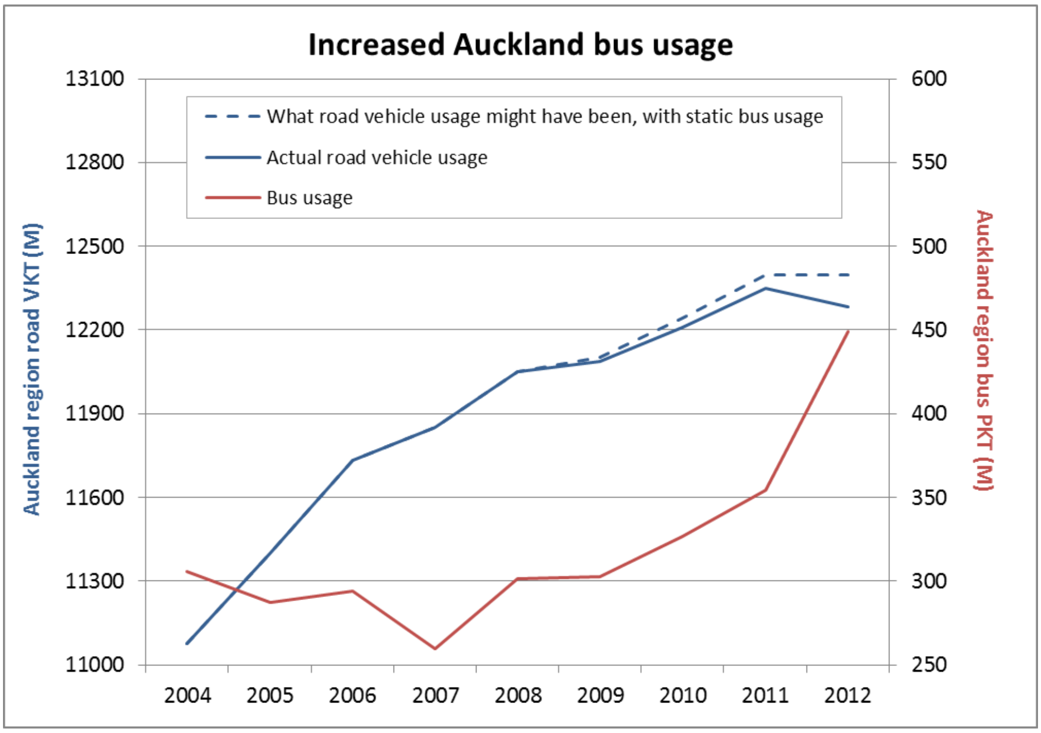
[20] The observed trend in Auckland State highway VKT is also consistent with an alternative hypothesis in which high population and economic growth (relative to the rest of the country) have driven increased road usage in the Auckland region. However, this hypothesis would not explain the lack of growth in Auckland *local road* VKT.

It seems reasonable to assume that if investments in the Auckland bus network had not taken place, then:

- bus patronage would not have increased at such a high rate[22]
- some travel that in reality was taken by bus, would instead have been taken by road
- private car VKT in the Auckland would have been higher
- there would have been more congestion at some times.

Figure 7 shows how VKT might have been higher in the Auckland region, if not for the increase in bus patronage. (The solid blue line shows actual road VKT in the Auckland region, the dashed blue line shows what road VKT might have been if each additional bus passenger-km was replaced by 1/1.5 road VKT. The 1.5 value denotes a nominal level of private vehicle occupancy.[23])

Figure 7: An example where public transport improvements have resulted in increased public transport patronage



This example is consistent with a connection between increased bus availability and increased bus usage at the regional level, and indicates that such a connection may have a material effect on car usage.

There are several other regions of New Zealand in which bus usage has increased substantially in percentage terms over the last few years. However, the absolute increase in bus passenger-km is far less for any of these regions than for Auckland.[24] Bus usage in Christchurch has actually reduced substantially since the Christchurch earthquakes.

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[21] There is an issue with the validity of the earlier statistics collected, as some regional councils used different data definitions.

[22] Even without investment, it seems reasonable to suppose that bus patronage might still have increased post-GFC.

[23] Broadly consistent with vehicle occupancy statistics from the Household Travel Survey.

[24] The closest is the Bay of Plenty, in which the increase in bus passenger-km over the last five years has been less than a tenth of the corresponding increase in Auckland.

4 Supply-side measures could add value to the three models

4.1 The Deloittes/Covec revenue forecasting model

The main purpose of the Deloittes/Covec model is to forecast NLTF revenue in future years. Adding information about supply-side measures might help the model to forecast more accurately.

In the process of refitting the model, the model could be offered new predictor variables relating to:

- availability of roads
- availability of bus services
- availability of train services
- availability of cycle routes.

Adding additional predictor variables may help, and cannot hurt, the fit to historical data. However, if supply-side measures are selected for inclusion in the model, they may or may not improve the predictive power of the model. There is no guarantee that adding additional predictor variables will yield more accurate results.

The Ministry should bear in mind that there is the potential for regression analysis to identify spurious relationships between supply-side measures and transport usage. It might, for instance, conclude that road transport usage in a particular area was *inversely* correlated with the supply of road services.[25]

Concept recommends that if the Ministry wishes to add supply-side measures to the Deloittes/Covec model, the model should first be *spatialised*. In this context, 'spatialising' means replacing one submodel (for instance, the submodel relating to light RUC volume) with multiple submodels for different areas of the country. Submodels for different areas would have different parameters, and might even include different sets of predictor variables. Section 0 discusses what would be involved in spatialising the Deloittes/Covec model.

The reasons for spatialising are that:

- supply-side variables are best expressed at a regional level – for instance, it does not seem helpful to conflate the supply of roads in urban Auckland with that on the West Coast of the South Island
- comparing *national* transport usage with *regional* supply-side measures is unlikely to yield meaningful statistical relationships
- therefore it is preferable to compare *regional* transport usage with *regional* supply-side measures.

4.2 The NZIER scenario model

The main purpose of the NZIER model is to produce long-term scenarios of road transport usage. Adding information about supply-side measures might help the model to provide a more reasonable range of scenarios.

The model could be augmented to allow the user to enter regional assumptions on:

- availability of roads

[25] In other words, the model might conclude that road transport usage decreases when roading investment occurs. This spurious result could come about as a result of a correlation between road transport usage and some third variable that happened to have been low at times when roading investment had been high.

- availability of bus services
- availability of train services
- availability of cycle routes.

The model could then be extended to consider the effect of these inputs on other variables. For example, the propensity of passengers to use bus transport could be made to depend on the availability of bus services in the relevant region.

Incorporating supply-side measures could help the model to provide more reasonable scenarios in (at least) three ways.

- Using available information about the future availability of bus services would surely aid the model to provide realistic regional projections of bus usage.
- Modelling the future availability of roads, bus and train services and cycle routes could potentially aid the model to provide a realistic range of projections of private vehicle usage, reflecting internally consistent scenarios.
- Modelling supply-side variables could make projections more internally consistent.

Concept recommends that if supply-side measures were to be added to the NZIER scenario model, the model's projections should first be validated at a regional level (see Section 5.2).

4.3 The Concept proof-of-concept structural model

The Concept proof-of-concept model has two purposes:

- *explanation* – breaking down road transport use in recent years and explain how the various components have changed over time
- *prediction* – producing scenarios of road transport usage (and hence NLTF revenue) covering a period of years.

With regard to *explanation*, the model could be enhanced to:

- partly explain trends in heavy RUC volumes in terms of supply-side measures – by breaking down heavy RUC transport into bus vs non-bus RUCs, and relating the growth of bus RUCs to changes in the availability of bus services
- partly explain trends in road passenger travel volumes in terms of supply-side measures – by breaking down land passenger transport KT into private vehicle, bus, rail, and cycle, and relating the growth of each mode to changes in availability.

With regard to *prediction*, incorporating supply-side measures could help the model to provide more reasonable scenarios in (at least) three ways.

- Using available information about the future availability of bus services would aid the model to provide realistic projections of heavy RUC volumes.
- Modelling the future availability of roads, bus and train services and cycle routes could potentially aid the model to provide a realistic range of projections of private vehicle usage.
- Modelling supply-side variables could make projections more internally consistent.

Concept recommends that if the Ministry wishes to add supply-side measures to the Concept proof-of-concept model, the model should first be *spatialised*. Section 5.3 discusses what would be involved in spatialising the Concept model.

4.4 Other potential new models

If the Ministry was to consider adding supply-side measures to new models of land transport usage,[26] then it should take into account that:

- adding supply-side measures can improve the ability of the model to explain trends in recent years
- incorporating supply-side measures *may* result in more accurate predictions for future years, but there is no guarantee
- the greatest improvement in predictive accuracy from using supply-side measures is likely to be yielded by:
    - using information about changes in the availability of the *bus* network in order to predict *bus* usage, or
    - using information about changes in the availability of the *rail* network in order to predict *train* usage
- modelling the uncertainty in supply-side measures can potentially aid the model to provide a realistic range of projections of land transport usage
- before adding supply-side measures, the model should be spatialised and the predictions should be validated at a regional level.

[26] Note that a useful reference on the process of modelling transport demand is "Drivers of demand for transport" (http://www.nzta.govt.nz/resources/research/reports/534/docs/534.pdf)

5 Steps required in order to incorporate supply-side measures

This subsection outlines the steps that should be considered by the model owners, if supply-side measures were to be incorporated into the three different types of models.

5.1 The Deloittes/Covec revenue forecasting model

Step 1 – consider spatialising the PED, light RUC and heavy RUC volume submodels

As set out in Section 4.1, it would be preferable to spatialise the Deloittes/Covec model before incorporating supply-side measures. This would involve taking the following steps for each of the PED, light RUC and heavy RUC volume submodels:

- determining a suitable breakdown of the country into areas (possibly through some combination of regional and urban/rural splits – at a minimum, separating Auckland from the rest of the country)
- breaking down independent and predictor variables to the area level, where this is possible and meaningful (for instance, VKT, population and GDP can all meaningfully be expressed at the regional level)
- replacing the single submodel with one submodel per area (with model parameters, and possibly variable inclusion or even model structure, differing between areas).

Step 2 – create new predictor variables measuring supply-side availability

For each area defined in Step 1 (or nationally, if the Ministry decided not to spatialise the model) it would be necessary to produce new predictor variables measuring supply-side availability. These might include:

- availability of roads
- availability of bus transport services
- availability of rail transport services
- availability of cycle routes.

These predictor variables should be expressed on an annual basis, and should span from the beginning of the historical dataset used for fitting the model to the end of the assumptions dataset used for making predictions.

Potential data issues are discussed in Section 6.

Step 3 – refit models

The next step would be to refit the submodels, offering them the new supply-side variables in addition to the existing predictor variables. This process would include:

- determining whether the new supply-side variables should be included, and if so,
- updating the model coefficients to reflect the change in variable selection.

Step 4 – rerun models

The refitted models could then be used to make new predictions of road transport usage (and hence NLTF revenue). These predictions might or might not turn out to be more accurate than the current predictions.

5.2 The NZIER scenario model

Step 1 – validate the model at a regional level

The NZIER scenario model, unlike the Deloittes/Covec and Concept proof-of-concept models, is already regional. This would make it easier to incorporate supply-side variables. However, before doing so, the model's predictions should be validated at a regional level – if this has not already been done.

The NZIER scenario model has already been validated at a national level – in the sense that its short-term predictions of road transport use have been compared with, and found to be consistent with, recent historical figures. However, we are not aware of the equivalent work having been done at a regional level. It is not clear that short-term predictions of *regional* road transport use are consistent with recent historical figures. There may be a discontinuity between actuals and forecasts.

Step 2 – add new input variables measuring supply-side availability

For each region, it would be necessary to allow the user to specify the future values of supply-side measures. These might include:

- availability of roads
- availability of bus transport services
- availability of rail transport services
- availability of cycle routes.

These supply-side measures could be provided in several different ways – for instance:

- as an annual time series
- as a constant annual rate of increase
- as a single initial 'shock'
- with random variability around some form of trend.

It would be preferable to keep the total number of new parameters to a reasonably low level, consistent with other aspects of the model.

Potential data issues are discussed in Section 6.

Step 3 – enhance models

Linkages would need to be drawn between the above supply-side measures and existing model quantities. These could include:

- adapting the vehicle ownership submodel to reflect that households may be more likely to own a vehicle if road availability is relatively high, and availability of other land transport modes is relatively low
- adapting the freight demand submodel to reflect the effect of supply-side measures on freight mode shifts
- adapting the vehicle fleet submodel to reflect predicted changes in the number of buses operating
- adapting the household travel submodel to reflect the effect of supply-side measures on household transport mode choice and VKT.

Where possible, new parameters should be based on historical relationships. In other cases, they would need to be assumption-based.

Step 4 – rerun scenarios

The user could then proceed to:

- enter a range of supply-side assumptions, reflecting the current level of knowledge about future transport investment
- rerun the scenarios to generate a range of forecasts of future road transport usage.

5.3 The Concept proof-of-concept structural model

Step 1 – consider spatialising some parts of the model

As set out in Section 4.1, it would be preferable to spatialise some parts of the Concept model before incorporating supply-side measures. In particular:

- the 'heavy RUC quantity (km)' node, and the dependent leaves 'real GNE[27] ($)' and 'heavy RUCs per real GNE (km/$)', could be broken down by area[28]
- the 'combined light/medium vehicle WOF/COF[29] VKT (km)' node, and the dependent leaves 'population of NZ' and 'light/medium vehicle VKT per capita', could be broken down by area.[30]

This would be a helpful step in its own right, as it would enable the user to drill down on trends in vehicle use in different parts of the country.

Step 2 – add new variables measuring supply-side usage and availability

For each area defined in Step 1 (or nationally, if the Ministry decided not to spatialise the model) it would be necessary to produce new variables measuring supply-side availability. These would include:

- availability of roads
- availability of bus transport services
- availability of rail transport services
- availability of cycle routes.

These availability variables should be expressed on an annual basis, and should span from the beginning of the historical dataset to the end of the assumptions dataset used for making predictions.

For historical years only, it would also be necessary to provide the model with data on travel usage in each area. This would include:

- breakdown of heavy RUC quantities between bus and non-bus
- mean vehicle occupancy in private motorised road transport
- average person-km travelled by bus
- average person-km travelled by rail

[27] Gross national expenditure

[28] A breakdown of heavy RUC quantities between areas is not available, but could be approximated using available data including State highway heavy vehicle counts

[29] Warrant of Fitness and Certificate of Fitness – two ways in which the Ministry can gain information about the amount of travel undertaken

[30] A breakdown of light/medium vehicle WOF/COF VKT between areas is not available, but could be approximated using several existing data sources

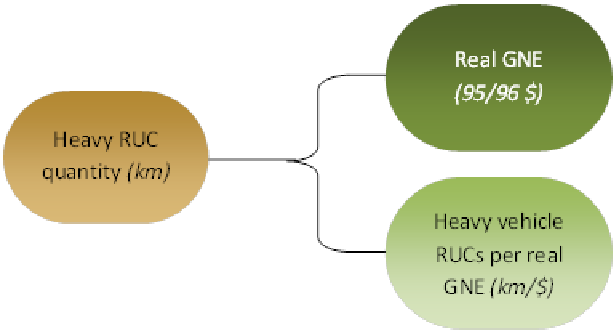
- average person-km travelled by cycle (on-road).

Potential data issues are discussed in Section 6.

Step 3 – enhance model

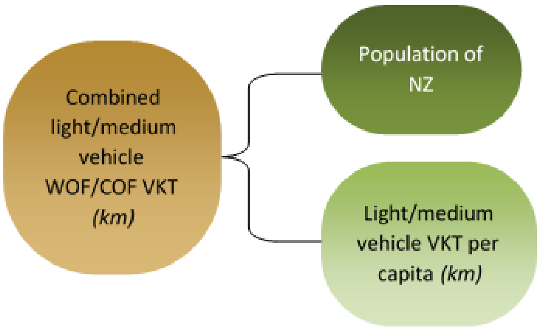
Some of the existing leaves of the model would need to be broken down further – as shown in the following diagrams. *(For simplicity, the diagrams do not show the proposed breakdown across areas.)*

The 'heavy RUC quantity' section of the model might change from this:

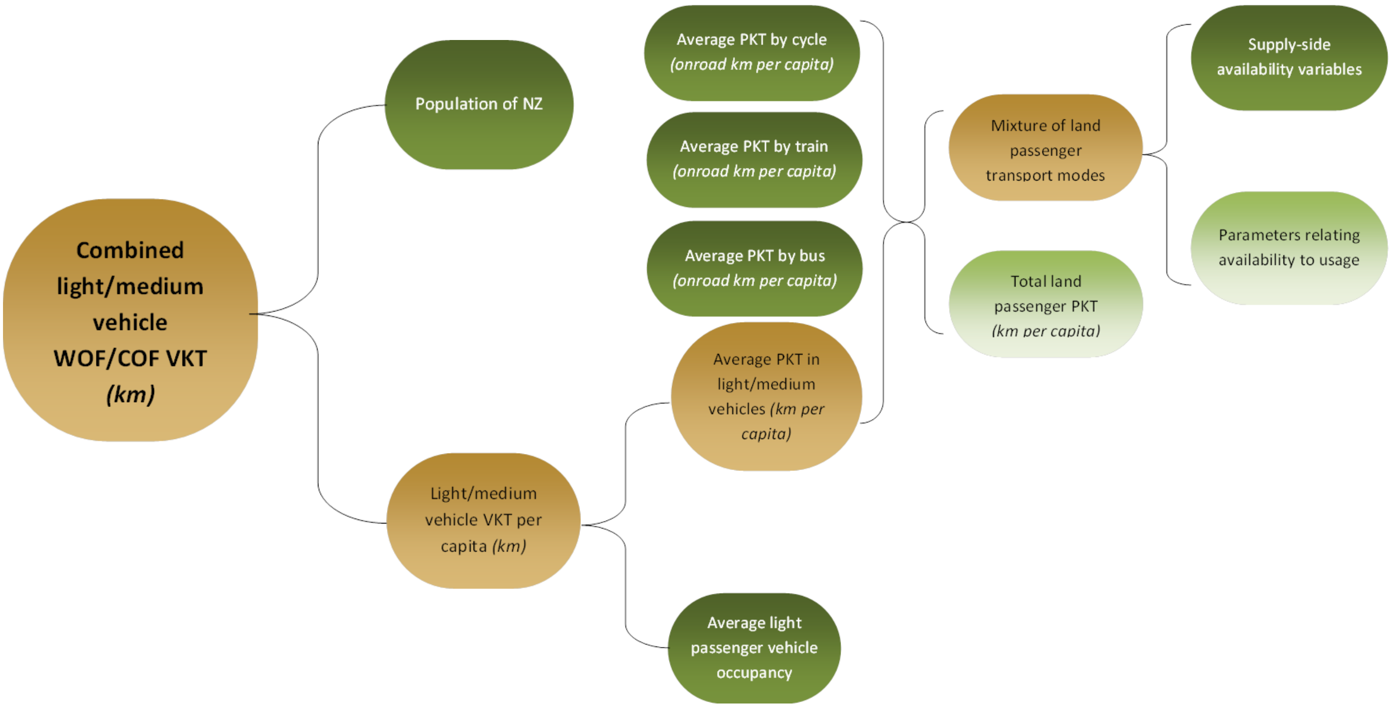


to this:

The 'combined light/medium vehicle WOF/COF VKT' part of the model might change from this:



to this:



Step 4 – rerun scenarios

The user could then proceed to:

- enter a range of supply-side assumptions, reflecting the current level of knowledge about future transport investment
- enter assumptions about the future relationship between supply-side availability and actual road transport usage
- rerun the scenarios to generate a range of forecasts of future road transport usage.

6 Supply-side data issues

6.1 Availability of roading services

Two ways of measuring the availability of roads are:

- an *input-based* approach – based on the amount of investment that goes into the roading network
- an *output-based* approach – based on the capacity of the resulting network.

It might seem that the level of congestion was a third way of measuring the availability of roads – but as set out in Section 2, congestion relates to the intersection between supply and demand, rather than measuring the level of supply.

Input-based data

Based on information provided by NZTA, it should be possible to construct data series measuring roading investment in different areas of the country. Each such data series should measure (on a cumulative basis):

- actual investment in past years ($)
- planned investment in future years ($).

Each of these data series may be a reasonable proxy for changes in the quality of the roading network in the relevant area.

Only upgrade expenditure should be included – maintenance expenditure should be excluded.

Where possible, the money spent on a multi-year investment should be attributed to the year in which the investment begins to deliver increased capacity.

Investment projections may only be available for the next few years. If the forecast horizon is longer than that, it may be necessary to make assumptions about the level of investment in the later part of the horizon.

Output-based data

NZTA provides historical data on the amount of roads (as lane-km) in different areas of the country.

It may be possible to project these data series into the future, based on information provided by NZTA about planned upgrades.

6.2 Availability of bus services

Two ways of measuring the availability of bus services are:

- an *input-based* approach – based on the amount of investment that goes into the bus network
- a *usage-based* approach – based on the amount of travel taken on buses. This is not a measure of supply as such, but may still be useful as a measure of the amount of travel that has been (in the past) and may be (in the future) diverted from other land transport modes.

Input-based data

The Ministry has access to information provided by regional councils, measuring the amount of expenditure on the bus network. These data can be converted into a cumulative series – which may be a reasonable proxy for changes in the quality of bus services in the region.

It may also be appropriate to include some portion of investment in roads that support bus services.

The Ministry may be able to source information from regional councils on future bus network expenditure. Some councils may be better placed to provide this information than others.

It may be necessary to make assumptions about the level of investment in the later part of the modelling horizon.

Usage-based data

The Ministry has access to information provided to NZTA by regional councils, measuring:

- bus passenger-trips
- bus passenger-km.

Concept understands that the Ministry has some concerns about the validity of past passenger-km data, but that there have been improvements in data reliability over time.

The Ministry may be able to source information from regional councils on expected bus network usage. Some councils may be better placed to provide this information than others. There is the possibility that some councils may take an over-optimistic view about potential use of bus services.

It may be necessary to make assumptions about the level of usage in the later part of the modelling horizon.

6.3 Availability of train services

Commuter train services are only available in the Auckland and Wellington regions, which simplifies the issue.

As with bus services, two ways of measuring the availability of commuter train services are:

- an *input-based* approach – based on the amount of investment that goes into the rail network
- a *usage-based* approach – based on the amount of travel taken on trains. This is not a measure of supply as such, but may still be useful as a measure of the amount of travel that has been (in the past) and may be (in the future) diverted from other land transport modes.

Input-based data

The Ministry holds information on expenditure on the train network and equipment. These data can be converted into a cumulative series – which may be a reasonable proxy for changes in the quality of train services in the region.

It would be preferable to exclude expenditure on rail freight services.

The Ministry may be able to source information from regional councils on future rail network expenditure.

It may be necessary to make assumptions about the level of investment in the later part of the modelling horizon.

Usage-based data

The Ministry has access to information provided to NZTA by regional councils, measuring:

- train passenger-trips
- train passenger-km.

- Concept understands that the Ministry has some concerns about the validity of past passenger-km data, but that there have been improvements in data reliability over time.

It may be necessary to make assumptions about the level of usage in the later part of the modelling horizon.

6.4 Availability of cycle services

Concept considers that, for on-road cycle transport, the most promising approach is *usage-based*. Investment-based approaches are less feasible, because most roading expenditure supports both driving and cycling, and it is difficult to separate expenditure between the two uses.

The Household Travel Survey[31] provides information about how people use cycles on-road, and includes historical figures for cycle travel in annual km per capita.

Some councils model projected transport demand for active modes at a regional level.

[31] http://www.transport.govt.nz/assets/Import/Documents/Cycling-2013.pdf

7 References

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"Transport demand forecasts: summary", unpublished report by NZIER for Ministry of Transport, December 2013

Appendix A. Existing models do not reflect the total uncertainty of road transport usage

As set out in Section 1.5, Concept believes that the Ministry could benefit by enhancing its forecasting framework to project a *reasonable range* of possible future outcomes – rather than seeking to produce a single 'point estimate'.

Concept is aware that the Ministry has a statutory requirement to prepare a point estimate of NLTF revenue. Nonetheless, Concept believes that the Ministry should still consider a reasonable range of outcomes at the modelling level:

- in order to determine where the point estimate should fall
- in order to caveat the point estimate and indicate the extent to which it may be an over- or under-estimate
- in support of its goal of "improving its understanding of the likely patterns of transport demand in New Zealand over the longer term".

Generally, it is important to distinguish between two main types of uncertainty in model forecasts:

1. model inaccuracy – i.e. the extent to which errors could occur even if the input assumptions (such as economic and demographic variables) were known with perfect foresight
2. input uncertainty – i.e. the input assumptions (such as economic and demographic variables) may prove to be incorrect.

The first uncertainty above may be due to (for example):

- the model not properly capturing and modelling all the different drivers that determine transport outcomes
- the nature of these drivers, and their effect, changing over time
- lack of historical data on drivers known to be important.

The second uncertainty is unavoidable. Key econometric and demographic variables cannot be predicted with certainty. The global financial crisis, for instance, was unpredicted. It is therefore important to reflect the range of possible values of key drivers through scenario-based analysis, in order to understand the range of possible transport outcomes.

Concept considers that the modelling work carried out for the Ministry by Deloittes, Covec and NZIER has not consistently provided a reasonable range of possible future outcomes. Nor has the work consistently distinguished between uncertainty in outcomes due to inherent uncertainty in key input drivers, and uncertainty arising from the statistical technique.

In some cases, the focus has been on providing a single point estimate (presumably in response to the Ministry's stated need for a point estimate). In other cases, a range of estimates has been provided – but the range has been too narrow because it has not incorporated all sources of uncertainty.

This Appendix provides several examples of land transport demand usage forecasts carried out for the Ministry or NZTA, shows the extent to which uncertainty has been acknowledged by the forecaster, and comments on the extent to which this reflects the total uncertainty.

In providing this analysis, Concept's aim is not to criticise the extensive forecasting work that has been capably carried out by Deloittes, Covec or NZIER, but rather to encourage the Ministry to extend its requirements to include the provision of a reasonable range of estimates.

Deloittes forecasts of April 2011

The main focus of the Deloittes report was on providing point estimates. Forecasts of PED, light RUC and heavy RUC volumes are shown in Figure 8 through Figure 10. They predict:

- PED volumes returning to pre-GFC levels within three years and slowly increasing thereafter
- light RUC volumes growing at a moderate rate
- heavy RUC volumes growing at a rapid rate.

There is no apparent acknowledgement that PED volumes might not return to pre-GFC levels in the short to medium term, or that growth in RUC volumes might slow.

Section 6 of the Deloittes report provides sensitivity scenarios. However, these scenarios differ only slightly from the base case, with:

- a 'higher GDP growth' scenario resulting in 2015/16 NLTF revenue being **0.8% higher** than in the base case
- a 'higher GDP *and* population growth' scenario resulting in NLTF revenue being **0.5% higher** than in the base case
- a 'sudden increase in oil price' scenario resulting in NLTF revenue being **1.2% lower** than in the base case.

Figure 8: Deloittes forecast of PED volumes, April 2011 (reproduced from Figure 3 of the Covec report)

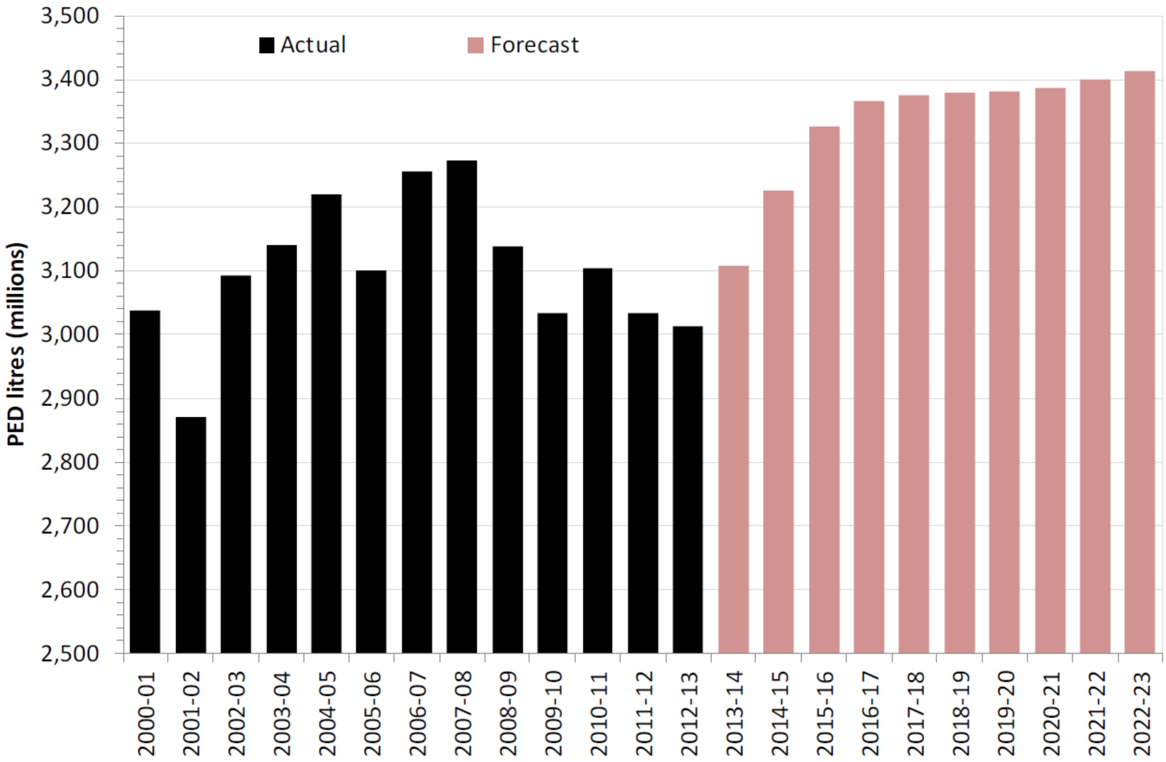
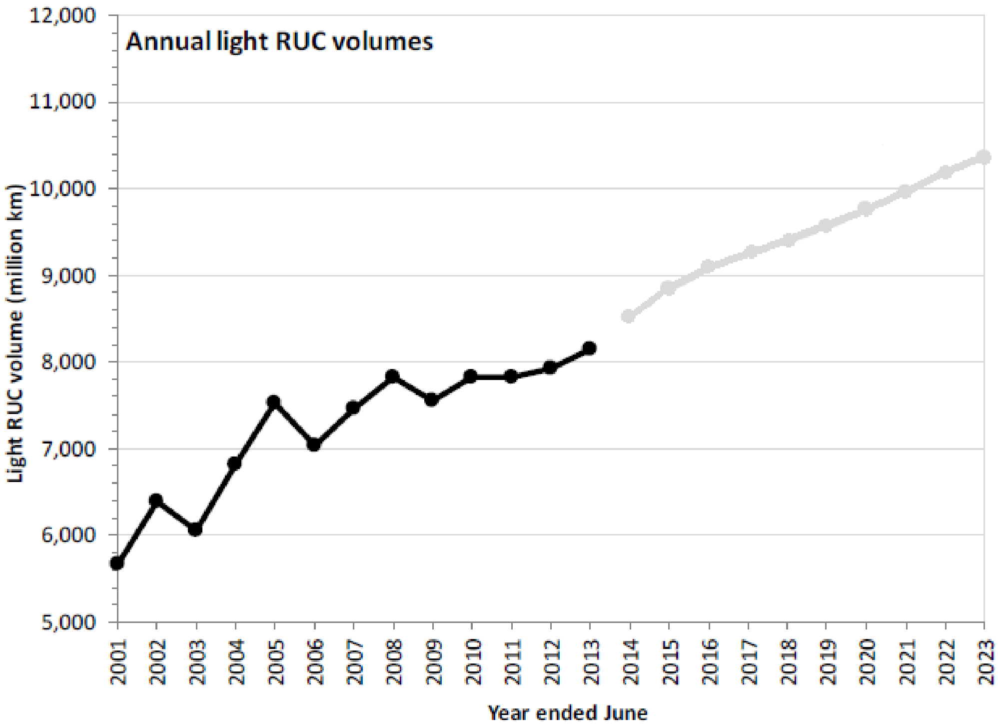
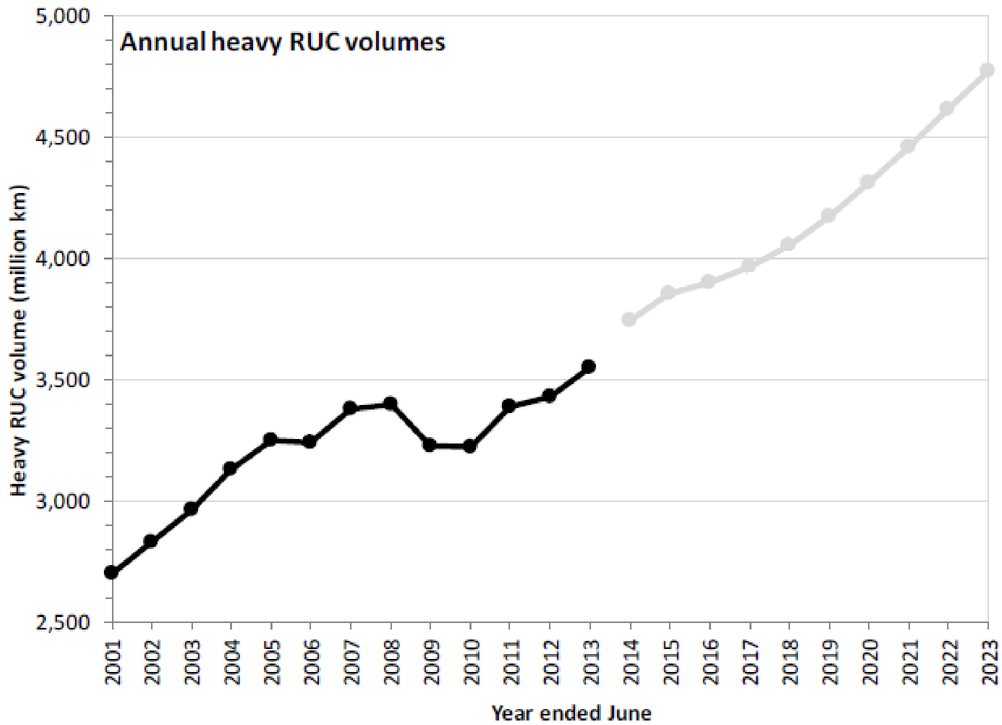


Figure 9: Deloittes forecast of light RUC volumes, April 2011 (reproduced from Figure 10 of the Covec report)



This image was digitally edited to remove other data series from the graph. Any minor inaccuracy introduced in the process is regretted.

Figure 10: Deloittes forecast of heavy RUC volumes, April 2011 (reproduced from Figure 14 of the Covec report)



This image was digitally edited to remove other data series from the graph. Any minor inaccuracy introduced in the process is regretted.

In summary, the Deloittes forecast was not designed to provide a reasonable range of scenarios.

Covec forecasts of May 2014

The Covec report provided both point estimates and 67% confidence intervals. Forecasts of PED, light RUC and heavy RUC volumes are shown in Figure 11 through Figure 13. They predict:

- PED volumes remaining below pre-GFC levels, with a mild decreasing trend after about 2018
- light RUC volumes growing at a rapid rate
- heavy RUC volumes growing at a moderate rate.

Covec did not provide separate sensitivity scenarios.

Figure 11: Covec forecast of PED volumes, May 2014 (reproduced from Figure 7 of the Covec report)

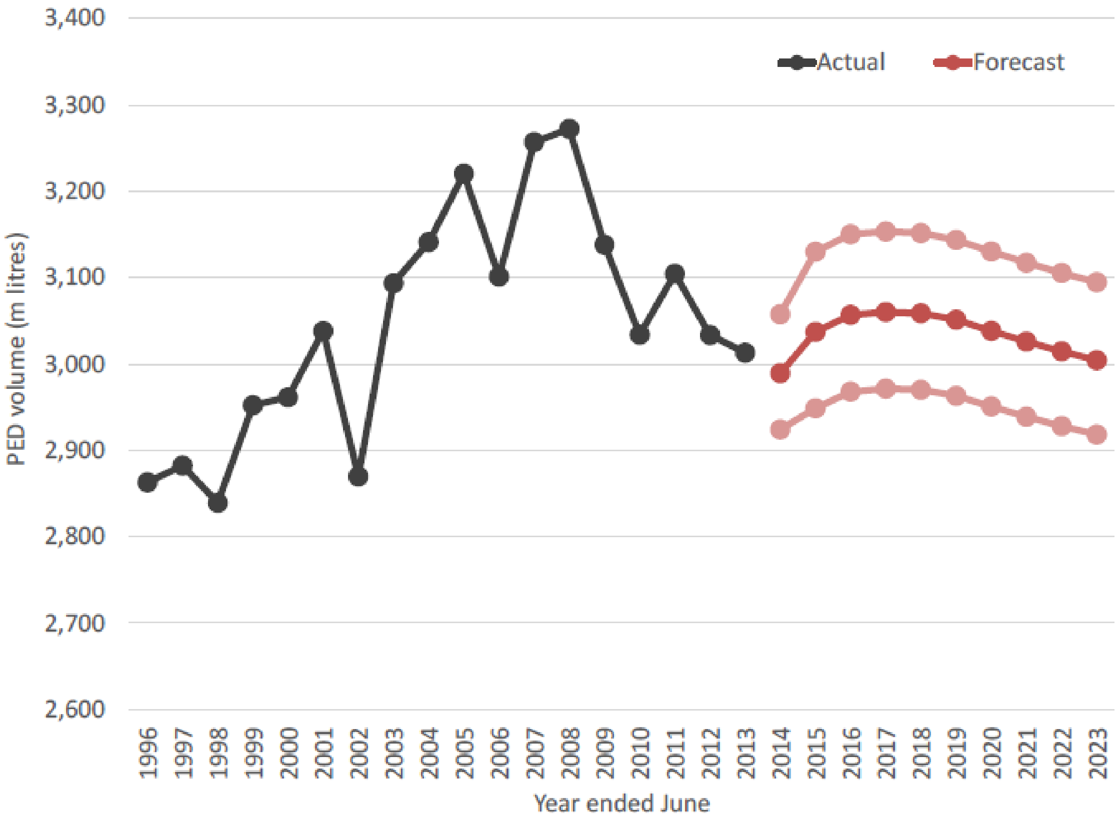


Figure 12: Covec forecast of light RUC volumes, May 2014 (reproduced from Figure 11 of the Covec report)

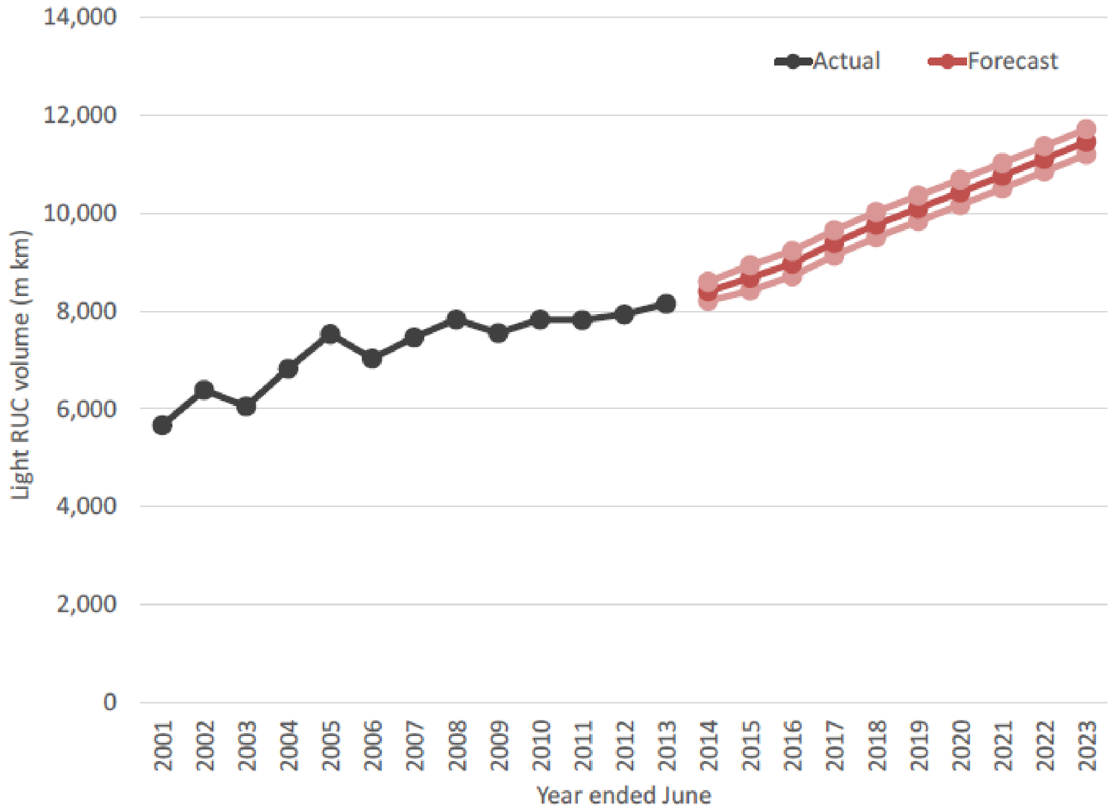
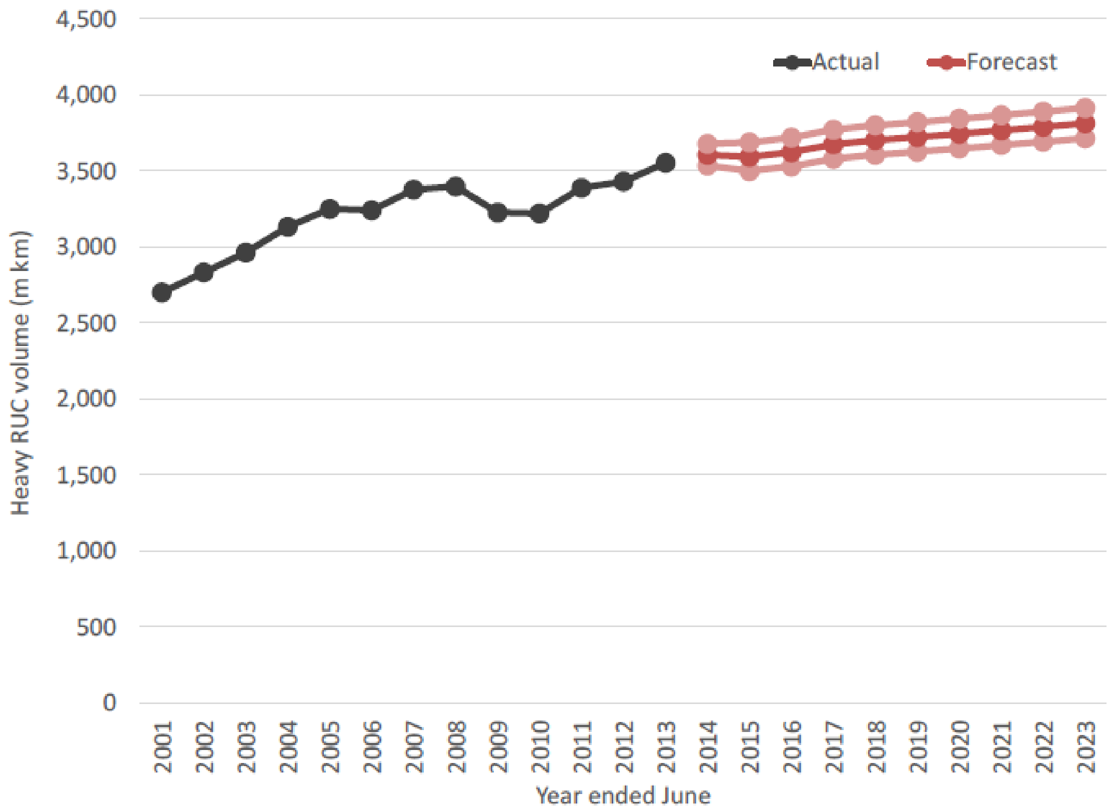


Figure 13: Covec forecast of heavy RUC volumes, May 2014 (reproduced from Figure 15 of the Covec report)



It is commendable that Covec has provided confidence intervals to show a range of possibilities. However, in the regression framework that Covec has used, confidence intervals do not show the full range of uncertainty in future road transport usage. There are five relevant sources of uncertainty:

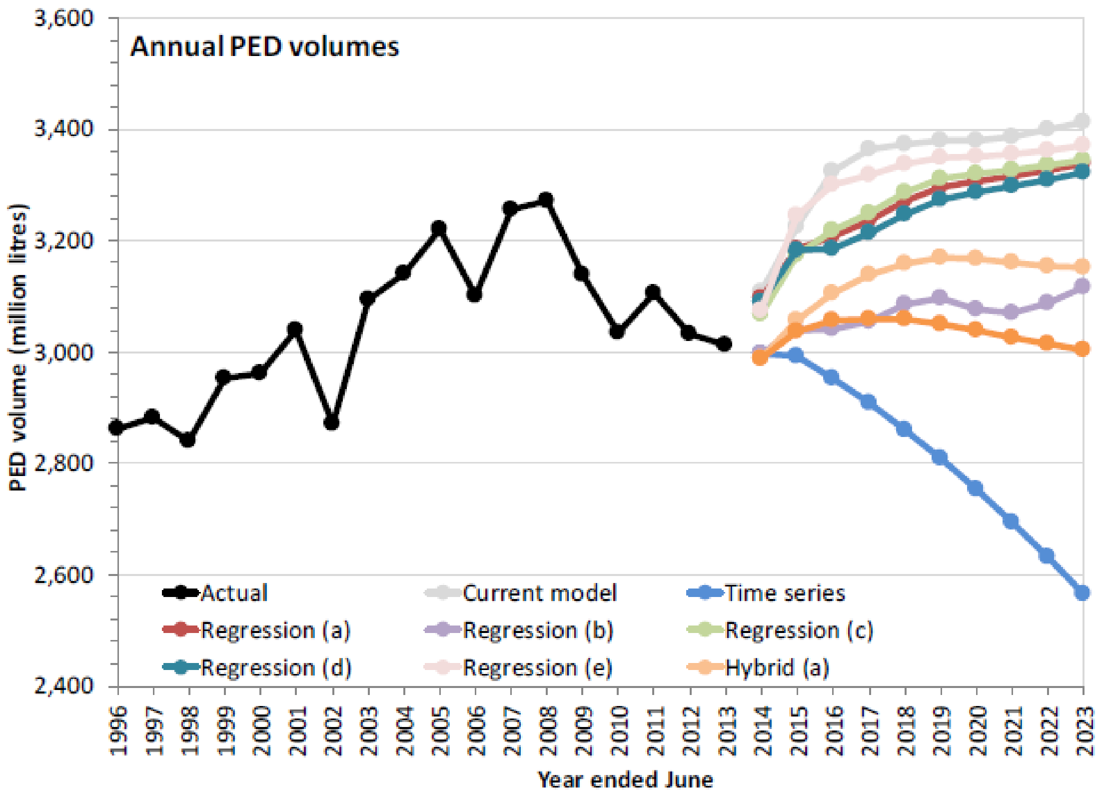
1. regression parameters may be estimated inaccurately *(as a result of the limited amount of historical data)*
2. there is natural random variation from year to year
3. the future values of the predictor variables (such as GDP and population) are uncertain
4. the true historical relationships between road transport usage and the predictor variables may not have followed the linear structure that was assumed
5. the relationships between road transport usage and the predictor variables may be different in the future from what they have been in the past.

Confidence intervals, such as those shown by Covec, only reflect source 1 – the uncertainty about the value of the regression parameters. They do not reflect sources 2, 3, 4 or 5. As a result, the confidence intervals should not be taken to represent the total level of uncertainty about future road transport volumes.

This result is consistent with intuition – it would be unrealistic to suppose that anyone could predict light RUC volumes in 2023 to within ±3% (as Figure 12 appears to show).

In fact, the Covec report clearly illustrates source 4 of uncertainty – "the true historical relationships between road transport usage and the predictor variables may not have followed the linear structure that was assumed" (Figure 14). Different model structures, which are all roughly equally well supported by the historical data, were found to yield quite different predictions.

Figure 14: A range of forecasts of PED volumes (reproduced from Figure 6 of the Covec report)



It is unfortunate that Covec, having developed a reasonable range of possible future outcomes, proceeded to discard most of them and settle on a single projection (the orange line in Figure 14[32]) – which may or may not come to pass.

NZIER forecasts of December 2013

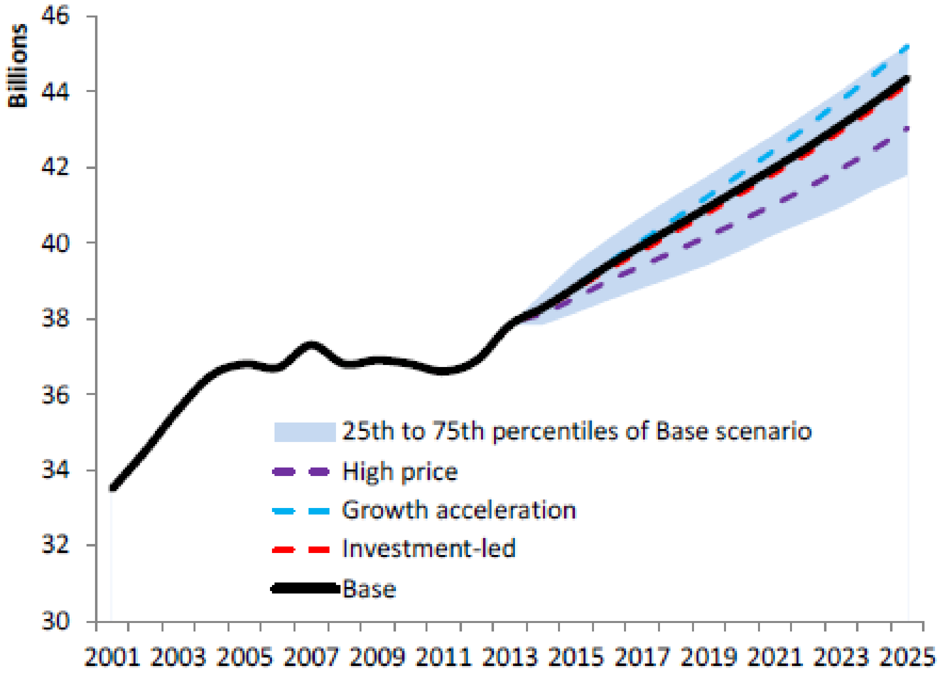
The NZIER report[33] included a base case scenario, which provided a point estimate and (for some outputs) 25th and 75th percentile estimates. It also included three sensitivity scenarios, each of which provided an additional point estimate. These were the:

- *high fuel price* scenario
- *growth acceleration* scenario (where population and economic growth increase)
- *investment-led demand* scenario (where public transport usage increases)

Forecasts of national road VKT, Auckland public transport, and national freight volumes are shown in Figure 15 through Figure 17. They predict:

- road VKT growing at a moderate rate
- Auckland public transport usage growing at a moderate rate, except in the *investment-led demand* scenario where it grows much faster
- freight volumes growing at a faster rate than road VKT.

Figure 15: NZIER forecast of road VKT, December 2013 (reproduced from Figure 8 of the NZIER report)



[32] This orange line was accidentally omitted from the legend of the plot.
[33] *"Transport demand forecasts: NZIER report to Ministry of Transport"* – unpublished report

Figure 16: NZIER forecast of Auckland public transport PKT, December 2013 (reproduced from Figure 9 of the NZIER report)

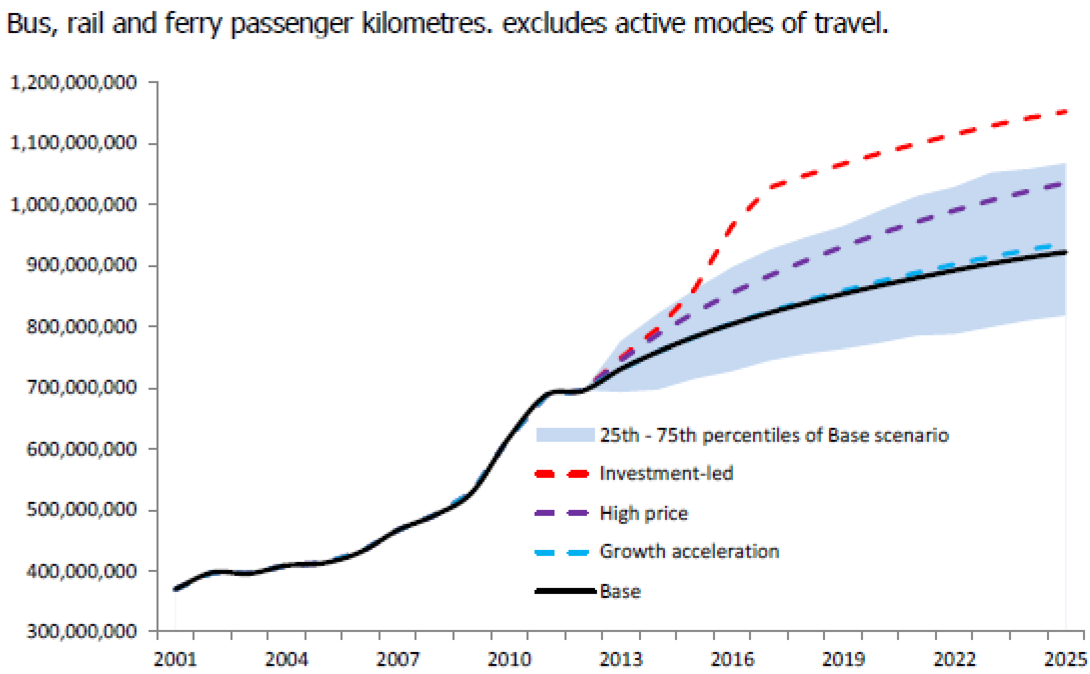
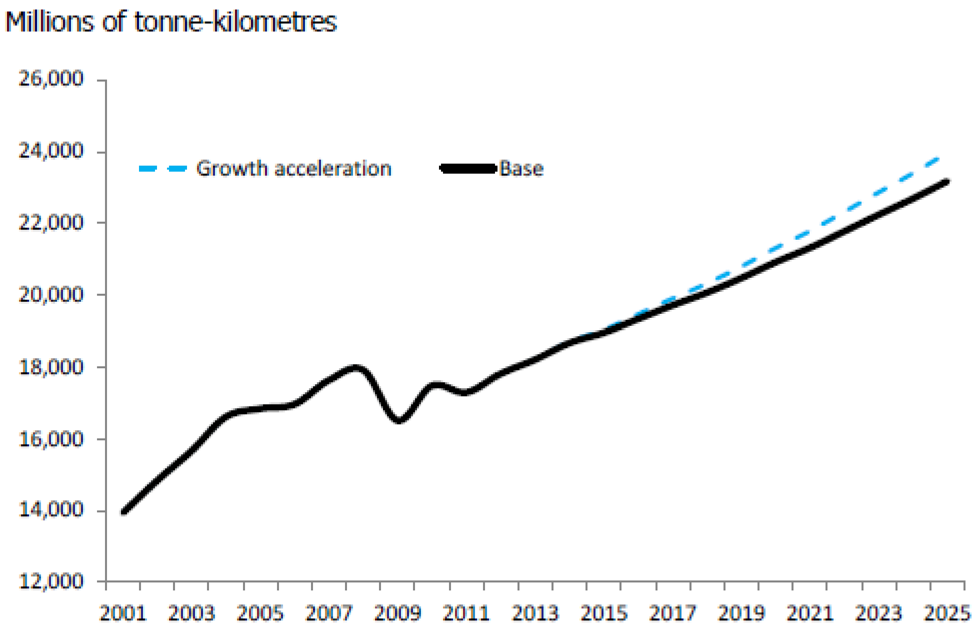


Figure 17: NZIER forecast of freight volumes, December 2013 (reproduced from Figure 11 of the NZIER report)



It is commendable that NZIER has provided a range of scenarios. However, in the hybrid economic/structural framework that NZIER has used, the range of scenarios does not show the full range of uncertainty in future road transport usage. There are five relevant sources of uncertainty:

1. model parameters may be estimated inaccurately *(as a result of the limited amount of historical data)*
2. there is natural random variation from year to year

3. the future values of the predictor variables (such as GDP and population) are uncertain
4. the true historical relationships between road transport usage and the predictor variables may not have followed the structure that was assumed
5. the relationships between road transport usage and the predictor variables may be different in the future from what they have been in the past.

The NZIER scenarios cover source 2 (random variation) and to some extent source 3 (uncertainty about predictor variables). They do not cover sources 1, 4 or 5. As a result, the scenario analysis should not be taken to represent the total level of uncertainty about future road transport volumes.

This finding is consistent with intuition – it would be unrealistic to suppose that anyone could predict road VKT in 2025 to within ±4% (as Figure 15 appears to show).

Appendix B. The Concept proof-of-concept model can be further developed

The Concept proof-of-concept structural model is not fully developed, which limits its use as an explanatory tool. In particular:

- while the model shows how much VKT per capita has changed and when it has changed, it does not show how VKT per capita has differed:
  - between regions of the country
  - between State highways and local roads
  - between demographic segments
  - between travel purposes
  - between passenger vehicle types
- while the model shows how much petrol vehicle efficiency has changed and when it has changed, it does not explain the changes in terms of the composition of the vehicle fleet
- while the model shows how heavy RUC volumes have changed and how the change correlates with changes in gross national expenditure (GNE), it does not show how heavy RUC volumes have differed:
  - between regions of the country
  - between State highways and local roads
  - between vehicle types (i.e. truck, trailer, bus) and sizes
  - between industries (for freight travel).

The structural model could be enhanced to include the above factors. This would increase the model's usefulness as a tool for explaining past trends, and might also help users to construct forward-looking scenarios that can highlight the likely implications of changes in different drivers of transport outcomes.

Enhancing the structural model would involve replacing one 'leaf' with a 'branch' bearing multiple 'leaves' – in other words, taking a variable that was not previously broken down, and breaking it down as a function of several new variables. In explanatory mode, changes over time in the old 'leaf' can now be explained in terms of changes over time in the new 'leaves'. In predictive mode, the user would formerly have provided input assumptions for the old 'leaf', but now enters input assumptions for the new 'leaves', which collectively determine the value of the old 'leaf' (which is now a 'branch').

In the first instance, Concept would recommend testing changes such as:

- breaking down VKT per capita by the age of the driver (with parameters estimated using Household Travel Survey data)
- breaking down heavy RUC volumes between freight and heavy passenger travel
- spatialising both VKT per capita and heavy RUC volume
- incorporating a fleet model breaking down both VKT and efficiency by age, type and/or size of vehicle.

However, some of these changes may not be feasible due to data availability. The data values of the new 'leaves' need to be known (or at least be able to be estimated) for recent years.

An equally valid approach would be to leave the structural model as it is, and use separate models to break down the key drivers listed above. These might include a passenger transport model to

describe VKT per capita, a fleet model to describe changes in petrol vehicle efficiency, and a freight transport model to describe the portion of heavy RUC volumes that come from freight travel.
The outputs of these models could be used as inputs to the structural model, and vice versa.