Future Demand
Model overview and user guide

This resource paper was prepared as part of the Ministry's Future Demand project. The project has been examining how New Zealand’s transport system could or should evolve in order to support mobility in the future. The paper provides background to the model used to quantify the scenarios, guidance on how to use the model, and the technical specifications of the model.

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This paper is presented not as policy, but with a view to inform and stimulate wider debate.
Disclaimer

This model was developed by the Ministry of Transport, for the sole purpose of being able to provide a simple qualitative to quantitative ‘read-across’ of scenarios developed as part of the Future Demand project. The Ministry of Transport, and its employees and agents involved in its preparation and publication, do not accept any liability for its contents or for any consequences arising from its use. People using the model, whether directly or indirectly, should apply and rely on their own skill and judgement when considering the values they input into the model, and the interpretation of the results. They should not rely on its results in isolation from other sources of advice and information. If necessary, they should seek appropriate legal or other expert advice in relation to their own circumstances, and to the use of this model.

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Introduction

This model, used for examining future changes in private vehicle travel, was developed as part of the Future Demand strategy project led by Professor Glenn Lyons. The Future Demand project started in March 2014 and was one of three of the Ministry’s strategy projects. The project used a scenario planning methodology\(^1\) where four plausible futures were developed based on two critical uncertainties, the cost of energy (high or low) and societal preference about interaction (physical or virtual). These critical uncertainties, along with other key drivers of change, were identified through engagement with stakeholders in three workshops in June 2014 (see Appendix 1. Summary of key drivers) and formed the basis for developing qualitative depictions of four plausible scenarios for New Zealand in 2042.

The critical uncertainties and those drivers of change that could be quantified were developed into a simple aggregate model. The model’s purpose was to provide quantitative estimates of private vehicle kilometres travelled (VKT) corresponding to each of the four qualitative scenarios. The output of VKT values from the model is heavily dependent on the levels chosen for each of the critical uncertainties/drivers, as well as assumptions about the extent to which these drivers will affect levels of demand in the future. It is important to note that the principal determination of the range of VKT values produced by the model for the Future Demand project is the scenario planning methodology, designed to examine plausible futures, which produced the four qualitative scenarios.

The model results are indicative only, and are not intended to be used as forecasts, or to support or reject any specific policy or investment decision.

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\(^1\) Insights into the scenario planning methodology. Ministry of Transport Future Demand strategy project paper, 2014.
Future Demand Model Overview

Objective of the model
This model estimates changes in private vehicle travel when assumptions about key drivers that may affect future travel demand are changed. The model was developed to allow users to estimate changes in private vehicle kilometres travelled (VKT) under a range of possible futures. It was specifically designed as a simple, open model to provide an indication of change and a tool that others could experiment with. Our goal was to stimulate debate and encourage others to use and develop this model to help New Zealand explore its future.

Methodology used to develop the model
The model was developed as outlined below:

► Existing regression models\(^2\) were used to establish a baseline for private vehicle kilometres travelled (VKT)\(^3\) per capita
► Data from the New Zealand Household Travel Survey (HHTS) was used to determine average private VKT by age groups\(^4\), reason for travel and urban/rural split\(^5\)
► Population projections for three age groups sourced from Statistics New Zealand (StatsNZ) were used to project private VKT by age groups
► Two different population projections from StatsNZ were used — the 50\(^{th}\) percentile (median) series, and the very high migration scenario series
► StatsNZ population projections by territorial local authority were used to project the VKT split between urban and rural areas.

The existing regression models include Treasury projections\(^6\) for economic growth,\(^7\) a 32 percent increase in the real petrol price and a 50 percent increase in real diesel price by 2042. This gives a baseline projection for private VKT per capita and total private VKT.

Further technical details and critical assumptions regarding how the model was developed can be found in Appendix 2. Technical Notes.

In addition, the model was peer reviewed by two experts\(^8\). The model was revised to take their feedback into account where possible. The full reviews are provided in Appendix 3. Peer reviews of model.

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\(^2\) The existing regression models were those used by the Ministry of Transport for revenue forecasting. These are documented in a report prepared by Covec Ltd titled “Review of the NLTF Revenue Forecasting Model”, 1 May 2014.

\(^3\) Private VKT refers to travel done in private light four-wheeled vehicles and excludes travel by public transport and active modes.

\(^4\) The age groups were 0–14 years, 15–64 years, 65 years and over. Note the age group 0–14 years were assumed to have not driven.

\(^5\) Urban was defined as an urban area with a population greater than 30,000 (also referred to as a “main urban area” or “MUA”.)

\(^6\) These projections were current as at April 2014.

\(^7\) Real GDP projections under the two different population projections for 2014 to 2042 were 87 percent for the median series and 100 percent for the very high migration series.

\(^8\) Professor Phil Goodwin Emeritus Professor of Transport Policy, University College London and the University of the West of England, and Brian Bull, Concept Consulting Ltd, Wellington.
Influence of drivers of change on private travel

From a set of drivers of change suggested by stakeholders in workshops held in June 2014 (as listed in Appendix 1. Summary of key drivers), we have used only those that could be modelled to obtain quantitative results. As a consequence, the model cannot fully reflect all the drivers that have shaped the four scenarios and only provides an approximation of VKT values for each scenario.

Table 1 shows the five drivers included in the model and their assumed effects on travel demand in terms of private VKT.

<table>
<thead>
<tr>
<th>Driver</th>
<th>Assumed impact on passenger travel</th>
<th>Impact on VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population aging</td>
<td>Older people drive less</td>
<td></td>
</tr>
<tr>
<td>Digital connectivity</td>
<td>Less need for physical travel</td>
<td></td>
</tr>
<tr>
<td>Urbanisation</td>
<td>People live closer to services and work</td>
<td></td>
</tr>
<tr>
<td>Fuel price increase</td>
<td>Drive less, more use of public transport, increase in active modes</td>
<td></td>
</tr>
<tr>
<td>Fuel efficiency</td>
<td>With same budget can travel more distance</td>
<td></td>
</tr>
</tbody>
</table>

1. Population aging

In the model, we considered the population aged ‘65 years and above’ as older people. According to StatsNZ data, the current proportion of older people in the New Zealand population is 15 percent. Under their median series projections, this is expected to rise to 24 percent by 2042.

The New Zealand Household Travel Survey (HHTS) shows that older people drive less on average than younger people. According to the HHTS, driver travel by older people (65 years and over) is 5,090km per person per year compared to 9,170km per person per year for 15–64 year olds (2008–2013 data). Older people drive less because of their life style changing (lower rates of participation in the labour market), less need for travel (for example, accompanying children) and increased likelihood of living near service centres such as medical facilities and shopping areas. This means an increase in the percentage of older population will probably reduce the overall demand for VKT.

2. Digital connectivity

A recent trend is for people to use digital (or online) facilities for work, social visits, education, shopping and to obtain other services such as medical advice. Recent travel patterns show the amount of travel for social visits and shopping has dropped by 15 percent over the past decade (2003–2006 to 2010–2013).
Based on HHTS data, the model differentiates between six reasons for private travel. Table 2 gives the assumed direction of impact of increased digital connection for each reason for travel.

Table 2: Assumed impact of digital connectivity

<table>
<thead>
<tr>
<th>Reason for Travel</th>
<th>Impact on VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work — main/other job</td>
<td>↓</td>
</tr>
<tr>
<td>Work — employers’ business</td>
<td>↓</td>
</tr>
<tr>
<td>Education</td>
<td>↓</td>
</tr>
<tr>
<td>Shopping/personal business</td>
<td>↓</td>
</tr>
<tr>
<td>Social visits</td>
<td>↓</td>
</tr>
<tr>
<td>Recreation</td>
<td>↑</td>
</tr>
</tbody>
</table>

With increased digital connectivity, people will need less physical travel. For example, they might opt to work from home. At the same time, less physical travel would save significant travel time. This is an incentive to increase some travel such as recreational travel. The model allows the user to change the amount of travel in each category by a percentage from the baseline projection.

3. Urbanisation

There is a growing tendency for people to opt to live in or closer to urban areas for convenience of travel and easy access to amenities. The HHTS (2008–2013 data) shows that people living in urban areas drive an average of 6,147km per person per year (25 percent less) compared to people living in rural areas who drive 8,160km per person per year.

According to StatsNZ, the current proportion of population living in urban areas is approximately 75 percent of New Zealand’s total population. Under the current median series projections, this proportion will rise to 81 percent by 2042. The model has the facility to test the changes in travel demand under different assumptions about this proportion, for example “What would be the effect on private VKT if urban population share increased to 85 percent by 2042?” The calculation of VKT is based on the relative amount of urban travel compared to rural travel as noted above.

4. Fuel price

Theoretically, one of the important factors that determine the demand for any good or service is the price of that good or service. For example, under normal circumstances, when price goes up, demand goes down. In the case of passenger travel, demand for private VKT can increase or decrease depending upon petrol and diesel prices. The model is able to estimate the demand for travel given different levels of petrol and diesel prices. The Treasury assumption currently in the model projects
fuel prices to increase by an average of 32 percent for petrol and 50 percent for diesel between 2014 and 2042.

5. Fuel efficiency for petrol vehicles
Fuel efficiency is defined as the distance that can be travelled per litre of fuel (or number of litres required to travel 100km). Generally petrol vehicles have become more fuel efficient over time. If a family has a certain amount of budget to spend on fuel, increased vehicle fuel efficiency means they can travel more kilometres with the same fuel budget. The model treats an increase in fuel efficiency as a reduction in the cost of fuel and consequently an incentive to travel more. Although people may not increase their amount of travel to spend all such money saved, the model assumes some increase in travel as a result of reduced costs.

In the model, current fuel efficiency is expressed as 9.87km per litre of petrol in the model (which is more commonly expressed as 10.1 litres per 100km). This is expected to rise to 10.48km per litre (9.5 litres per 100km) by 2042, which is based on historical trends of improvements in efficiency. Our current knowledge of the New Zealand fleet suggests that the maximum level of fleet petrol efficiency achievable over the next 30 years, given fleet turnover and technical advances, is about 14km per litre (7.1 litres per 100km).

Known issues with the model
The model estimates the baseline from the Ministry’s revenue forecasting model, which was developed for forecasting revenue. The revenue forecasting model is a short-term model, which provides estimates of VKT in the near future. However, there are uncertainties around the accuracy of extending the model to determine the baseline for 2042.

Several limitations of the revenue forecasting model should be kept in mind while estimating VKT over such a long period of time. The explanatory variables in the model strongly predict\(^9\) the level of VKT. This very high level of prediction is useful for short-term forecasting, but it raises doubt about its validity as a tool for long-term forecasts. As well as the economic variables, the model uses a time trend variable and a lagged dependent variable. Strong multicollinearity\(^{10}\) between some of these variables can cause problems in interpretation of coefficients and in long-term forecasting.

Because of multicollinearity, some of these coefficients may capture the effects of some other variables; therefore, the coefficients are not good estimates of elasticity. Also, as the coefficients can be unstable due to multicollinearity, another sample or part of the dataset used for estimating the model could give a different set of coefficient estimates.

The primary purpose of the revenue forecasting model was to estimate short-term revenue position, and it did not attempt to determine robust income or fuel price elasticities. Although the lack of accurate elasticity estimates was not a significant issue for revenue forecast (because the revenue

\(^9\) The model has a very high explanatory power (R\(^2\) of 0.99)).

\(^{10}\) Multicollinearity is where two or more explanatory variables in a multiple regression model are highly related to each other, rather than being relatively independent.
forecasting model allows other correlated variables to pick up the joint effects), it could affect this scenario development exercise.

The low petrol price elasticity (-0.04) of VKT per capita in the revenue forecasting model is an example. Since there has been an increasing trend in petrol price, its effect might have been partly captured by the coefficients of time trend and real Gross Domestic Product (GDP). The inability to separate out the effect that is captured by the fuel price variable from that captured by other correlated variables means that the scenario testing approach may understate the response of a fuel price change on the level of travel. However, for informing the direction and magnitude of the future demands, the revenue forecasting model is considered fit for purpose.

**Future demand model**

The future demand model makes adjustments to the baseline to obtain an indication of the likely variation from the baseline as a result of variation in key drivers: population, age distribution, fuel efficiency, fuel price, urbanisation, and digital connectivity. If these drivers are independent of the variables in the revenue forecasting model, there should not be any problem. The adjustments should give a good indication of the likely variation from the baseline.

However, issues arise because of trends in the drivers used in the scenarios. Part of the impact of these drivers might have already been captured by the time trend variable and also by other variables that are correlated with these drivers, resulting in double-counting. This limitation has been noted by some commentators.

In using the model, the scenarios developed considered much larger changes than have been observed in the recent past, and consequently the level of double counting may not have a large total effect.

**Conclusions**

The model's results should be treated as indicators only, keeping in mind the above-mentioned limitations. The outputs should be treated only as indicative, and not as forecasts for 2042. Indeed the premise of the Future Demand project is that in the face of a high degree of uncertainty about change to levels of VKT to rely (only) on forecasting techniques would be ill-advised. This is the reason that the project has used a methodology to examine plausible rather than predicted futures.
Using the model

The model is Excel-based and the spreadsheet needs to be macro-enabled to run the model. Different tabs function for different purposes as follows.

![Diagram showing different tabs]

**White tab** | Front page
---|---
**Blue tab** | Instructions
**Red tab** | Scenario testing
**Dark green tabs** | Scenario output and graphs
**Light green tabs** | Calculation of effect of individual factors
**Orange tabs** | Supplementary models
**Light grey tabs** | Supplementary data used in the modelling process

*Figure 1: The model tabs*

**The ‘Scenario testing’ tab**

The most important tab for a user is the red coloured tab labelled “Scenario testing”. This is the third tab from the left.

Scenarios are defined by inserting assumed values into the blue boxes. In the default mode, all the values are set to baseline values.

- Digital connectivity effect — 0 percent change in the amount of VKT by each reason for travel.
- Urbanisation effect — the urban share of the population remains at 75 percent
- Fuel price effect — 0 percent means the petrol and diesel prices increase by Treasury’s current projections
Fuel efficiency effect — by 2042 the average fleet fuel consumption is 10.48km per litre (or about 9.5 litre/100km)

Population growth — the population grows according to the projections in the StatsNZ median projection series.

Aging effect — ‘No’ meaning the age structure remains the same as in 2014.

To test any scenario that you wish to design, please use the following steps.

**Step 1: (Re)Set the model to default position**

Users can set the model to the baseline by clicking the button ‘Set to baseline’.

The baseline includes assumptions on the future projections for petrol and diesel prices, Gross Domestic Product (GDP) and population projections. Some of these can be changed within the spreadsheet (for example fuel and some aspects of the population projections), whereas others cannot (GDP and petrol price elasticity) as they are determined by external models.

**Step 2: Set the level of digital connectivity**

This sets the percentage changes in VKT per capita by 2042. The model will interpolate the baseline value to reach the 2042 value for each trip purpose. The default value for the change in VKT for each category of reason for travel is zero. The user has to enter values manually for each reason for travel. Enter negative values for a reduction in VKT.

<table>
<thead>
<tr>
<th>Digital connectivity effect</th>
<th>% change of travel for each reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work - main/other job</td>
<td>0%</td>
</tr>
<tr>
<td>Work - employers business</td>
<td>0%</td>
</tr>
<tr>
<td>Education</td>
<td>0%</td>
</tr>
<tr>
<td>Shopping/personal business</td>
<td>0%</td>
</tr>
<tr>
<td>Social visits</td>
<td>0%</td>
</tr>
<tr>
<td>Recreation</td>
<td>0%</td>
</tr>
</tbody>
</table>
**Step 3: Set the level of urbanisation**

This sets the percentage of urban population by 2042. This can be typed in the relevant cell or left at the default level of 75 percent, which is the current 2014 level. In this case, we assume the urban population percentage remains at the 2014 level. According to StatsNZ projections, the percentage of urban population is projected to rise to 81 percent by 2042. Users may use this value (81 percent) to use the StatsNZ forecast.

<table>
<thead>
<tr>
<th>Urbanisation effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban population share by 2042</td>
</tr>
<tr>
<td>75%</td>
</tr>
</tbody>
</table>

**Step 4: Set change in fuel price**

This sets the likely fuel price by 2042. For the default estimation of the baseline, the model uses fuel price increases as forecast by the Treasury. Users can set the growth of the fuel price based on Treasury’s projections by inserting 0 percent (baseline value) in the relevant cell. Otherwise, enter the value of a percentage increase by 2042 above the baseline.

<table>
<thead>
<tr>
<th>Fuel price effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in fuel price from baseline level</td>
</tr>
<tr>
<td>0%</td>
</tr>
</tbody>
</table>

Please note that the model uses the Treasury’s forecast as the baseline. This means any price change entered by the user will be added on the top of the Treasury forecast price change. Treasury’s current forecasts are for the petrol price to be 32 percent higher than today’s level by 2042, and for the diesel price to be 50 percent higher by 2042. This means that if a user entered a 10 percent increase of price change, the model counts it as 32 percent +10 percent for the petrol price change, and 50 percent +10 percent for the diesel price change. Please see the Technical Notes section for more details.

Note: The model does not accept price reductions greater than 100 percent (-100 percent)
**Step 5: Set the fuel efficiency factor**

The user can set the fuel efficiency factor in the respective cell (number of kilometres travelled per litre of fuel). The current value is 9.87km/litre of petrol. Under the baseline this is expected to rise to 10.48 km/litre by 2042. Therefore, the model uses this (10.48) as the default value.

<table>
<thead>
<tr>
<th>Fuel efficiency effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol vehicle efficiency (km per litre)</td>
</tr>
<tr>
<td>10.48</td>
</tr>
</tbody>
</table>

The model assumes that an increase in fuel efficiency is equivalent to a fuel price reduction and includes the change of price due to vehicle fuel efficiency on top of Treasury’s projected price changes (which are used as the baseline as discussed above in Step 4). (Please see the Technical Notes section for more details).

**Step 6: Activate/deactivate aging effect**

Users can activate or de-activate the aging effect by choosing ‘Yes’ or ‘No’ from the drop-down menu under the ‘Aging effect’ box. Choosing ‘No’, keeps the older population’s share of total population at the 2014 share. Choosing ‘Yes’ means the model uses the StatsNZ median projections series.

<table>
<thead>
<tr>
<th>Aging effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
</tr>
</tbody>
</table>
**Step 7: Select population growth scenario.**
This sets the population level by 2042. The user has two options to choose from a drop-down menu.

- **Medium population growth scenario** — StatsNZ’s stochastic (probabilistic) population projection using the 50th percentile.
- **High population growth scenario** — StatsNZ’s Very high migration scenario. Assumes a total fertility rate of 1.9 births per woman in the long term, a period life expectancy at birth of 88.1 years for males and 90.5 years for females in 2061, and annual net migration of 25,000.

Note that the GDP growth rate will be automatically adjusted to be consistent with the chosen population growth scenario.

**Step 8: View the summary results**
Once all the values are set, the model automatically calculates the results. Overall summary results appear as follows. The first line is the private VKT per capita in 2042 under the baseline values. The second line is the private VKT per capital under the scenario. The third line is the percentage difference between the baseline and the scenario in 2042.

<table>
<thead>
<tr>
<th>Summary results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per capita km by 2042</strong></td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Scenario results</td>
</tr>
<tr>
<td>% change from baseline</td>
</tr>
</tbody>
</table>

This sheet also has two graphs showing results of private VKT per capita and total private VKT.
**Step 9: View the detailed results**

In order to see the baseline values, please click the ‘Baseline’ tab.

To see the scenario results please click the ‘Scenario output’ tab.

There is a ‘Graphs’ tab to show most of the relevant graphs.

Please note that the left-hand side axis of the graphs relates to vehicle kilometres travelled per capita under the baseline and the scenario values. The right-hand side axis is the percentage change from baseline.

![Graph showing effect on passenger VKT per capita](image)

**Step 10: Saving the results**

You can save the summary results of each run by clicking the ‘Save Results’ button.

**Step 11: Clear results**

You can clear results of scenarios by clicking on the ‘Clear Results’ button.
Appendix 1. Summary of key drivers

The following drivers were identified by participants at a workshop held on 12 June 2014, as part of the Ministry of Transport’s Future Demand strategy project.

Participants identified a wide range of social, technological, economic, environmental, and political drivers that could influence society’s needs and aspirations to 2042. These were distilled into drivers that we thought could have the biggest impact on society. Using coloured dots, participants then tagged them as:

- Green: if they were very confident that the driver would have a major impact.
- Orange: if there were differing opinions on the impact and/or uncertainty about the driver.
- Red: if they were uncertain about the nature of the driver, but sensed that it could have a major impact.

This resulted in the development of three categories of drivers.

GREEN DRIVERS

These are drivers that were generally agreed to be influential in every scenario (although they could play out in different ways):

- Aging population
- Increasing urbanisation and shifting housing preferences, especially Auckland
- Digitally connected society
- Decentralisation of shopping/localisation of production (for example, 3D printers and online shopping)
- Rising costs of living and doing business (for example, food, fuel, resources)
- Rise of Asian economic and political power
- Society’s energy choices and resource management (including fossil fuels, biofuels, mining)*
- How proactive society is in responding to environmental changes/trends*

*These drivers may still be characterised by some extreme uncertainties, based on different choices/responses.

ORANGE DRIVERS

These are drivers that participants had some strongly different views on (a mixture of green and red coloured dots). There was agreement that they were likely to have a high impact, but views differed on the nature and direction of these drivers:

- Energy sources/fuels, availability and pricing
- Pressures on raw materials (for example, food, energy, water) and resource management responses
- Inequalities in wealth, access and employment, and how society responds
- New technologies driving new localised industries and business models
► Society’s resilience to climate changes and ecosystem disturbances/collapse (including extreme weather, oceans, fish stocks, pollution)
► Socio-political response to climate change
► How people govern, organise and make decisions in the future (for example, state-led, community-led, individualistic)*

*The governance driver was added after extra feedback from participants.

RED DRIVERS
These are drivers that were generally agreed to have ‘critical uncertainties’. Participants believed that the drivers would have a major impact, but were very uncertain what sort of role they would play in the future.

► Value changes (linked to community and identity)
► Automation, robotics and Artificial Intelligence (AI)
► Dematerialisation and smart infrastructure — including nanotechnology
► Ownership of the internet
► Rise of fundamentalism (political, corporate, religious)
► Security (personal and state)
Appendix 2. Technical notes

What to quantify?

The project required a framework to test four possible scenarios developed by the project team based on two key drivers with a high level of uncertainty — relative energy costs and the preference for digital or physical connectivity. The two key drivers gave four scenarios.

To quantify the four scenarios, we chose five key drivers that will have significant influence on future travel demand:

1) Digital connectivity
2) Urbanisation
3) Fuel price
4) Fuel efficiency
5) Population aging.

Effects of changes in these factors will be analysed under two population scenarios as follows:

► Medium population growth scenario — this assumes cyclical migration,
► High population growth scenario — this assumes very high migration.

Note that GDP growth rate is automatically adjusted to be consistent with the chosen population growth scenario.

The user first selects the population growth and then defines the scenario by setting the values for change in each factor. Once the values have been set, the model shows the combined effect of all five factors.

The following sections deal with each factor in more detail.

The reader may notice use of different terminology to refer to Vehicle Kilometres Travelled (VKT) at different times. These variations should be interpreted as follows:

1) Private VKT
   Private travel demand as estimated by the revenue forecasting model’s regression equations.
   Private VKT excludes commercial VKT.

2) Driver kilometres
   This refers to private travel demand derived from the Household Travel Survey (HHTS).
   Please also note that driver kilometres refers to the vehicle distance travelled in a light four-wheeled vehicle. It does not take into account the number of passengers travelling in the vehicle. It also excludes any commercial travel, including taxis.

Private travel demand derived from regression equations and HHTS are conceptually the same, but the values may be different due to the method of data collection or estimation.
The reader should also note that:

► Private petrol VKT always refers to light petrol diesel VKT.
► Private diesel VKT always refers to light private diesel VKT

**How does the model work?**

The model is a hybrid of regression equations and structural components. Figure A1 shows the model structure and its internal relationships. The first row shows the regression equations that were used to estimate the baseline.

The second, third and fourth rows show structural components that have been added to the baseline model for scenario testing of digital connectivity, aging and urbanisation respectively.

In the “Scenario output” sheet the annual changes in petrol and diesel VKT are shown. The scenario testing sheet summary result is shown, for example, values in 2014 and 2042 and percentage change from 2014 to 2042.
Future demand quantification model

November 2014

1) Baseline
2) Fuel Price
3) Vehicle efficiency effect inputs
   (resulted as a reduction in fuel price)

1) Baseline VKT per capita
2) Fuel price effect on VKT per capita
3) Vehicle efficiency effect on VKT per capita

Digital connectivity scenario
Percentage change in travel to work for work for education for shopping or personal business for social reasons for recreation

Change in VKT per capita by trip purpose
Digital connectivity effect on VKT per capita (for all trip purposes)

Aging of population scenario
Percentage of people aged 0 to 14 years 15 to 64 years 65 years and above

Change in VKT per capita by age group
Aging effect on VKT per capita

Urbanisation scenario
Urban population Rural population

Change in Total VKT
Urbanisation effect on VKT per capita

% difference in VKT per capita due to fuel price effect from baseline
% difference in VKT per capita due to vehicle efficiency effect from baseline
% difference in VKT per capita due to digital connectivity effect from baseline
% difference in VKT per capita due to aging effect from baseline
% difference in VKT per capita due to urbanisation effect from baseline

Combined % difference from baseline

Input data sources
HHTS MyT Revenue Forecasting Model NZTA StatsNZ Treasury

Intermediate calculations Intermediate result Final Result

Figure A1: Model structure
1.1.1 Digital connectivity effect

Driver travel is scaled by each reason for travel where the uptake of digital activity is considered to either increase or decrease the amount of travel done. For instance, in a scenario with a preference for digital contact, a person might travel to work once a week and work from home the rest of the week, rather than the current five times a week. This would be a decrease of 80 percent of travel to work.

The methodology

Data from the HHTS was used to establish baseline driver distances per person, by reason, for travel for 2008 to 2013. As the HHTS identifies the reason for travel from the destination (for example, to work, to the shops), we also needed to take account of the travel home from said destination and any travel for which the reason was to help another person, for example taking a child to the doctor. The travel for the purpose of ‘accompanying someone’ was reallocated based on the proportions of travel from the car/van passengers’ travel reasons (Column B below). Then the driver travel home was reallocated based on the adjusted proportion of travel from reasons 1–6 (see Table A1).

Table A1: Average annual distance travelled by reason for travel and mode of travel (HHTS, 2008-2013)

<table>
<thead>
<tr>
<th>Million kilometres per year</th>
<th>Travel mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reason for Travel</td>
<td>A. Car/van driver</td>
</tr>
<tr>
<td>To home</td>
<td>10,989</td>
</tr>
<tr>
<td>1 Work (main/other job)</td>
<td>3,798</td>
</tr>
<tr>
<td>2 Employers business</td>
<td>2,694</td>
</tr>
<tr>
<td>3 Education</td>
<td>207</td>
</tr>
<tr>
<td>4 Shopping/ personal business/ social work/ medical /shopping</td>
<td>4,622</td>
</tr>
<tr>
<td>5 Social visits</td>
<td>3,520</td>
</tr>
<tr>
<td>6 Recreational</td>
<td>1,360</td>
</tr>
<tr>
<td>Accompany or transport someone</td>
<td>2,160</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>29,349</td>
</tr>
</tbody>
</table>
The steps in this process are described as follows:

**Step 1:** Calculate the ratio of ‘car/van passenger’ travel (Column B) in each of the six ‘reason for travel’ categories (1–6) excluding ‘home’ and ‘accompanying passenger’ categories as a percentage of the total of those six categories.

**Step 2:** Split the ‘car/van driver’ kilometres (Column A.) for the ‘accompanying another passenger’ (2,160 million km) using the percentages calculated in step 1.

**Step 3:** Add the kilometres calculated in step 2 to each of the ‘car/van driver’ reason for travel categories 1 to 6 in column A.

**Step 4:** Calculate the percentage by reason for travel based on totals calculated in Step 3.

**Step 5:** Split the total ‘car/van driver’ kilometres (29,349 million km) based on percentage calculated in Step 4.

We have set up the scenario testing facility as follows.

The model is set up to be able to change the driver kilometres for each reason for travel as a percentage increase or decrease for 2042 compared to 2014. The change in the driver kilometres is scaled as an equal percentage for each year.

The total of the 2042 scaled driver kilometres travelled is obtained by summing the scaled driver kilometres by each reason for travel. This is done for all age groups.

We then calculated the weighted average change by summing the change over the three age groups. The percentage driver kilometres by each age group in relation to total driver kilometres is the weight used to sum them.

After calculating the weighted average change, we calculated the gradual change as a percentage in each year to achieve the total change by 2042. This percentage change is then applied to the baseline private VKT per capita to estimate the overall deviation from baseline due to digital connectivity.

**Assumptions**

- The relativity of driver kilometres per capita between different age groups (that is, 0–14 year olds, 15–64 year olds and 65+ year olds) remains the same in future.
- HHTS data collected from 2008 to 2013 reflect the starting values for modelling.

Following is the notational summary of above methodology.

Let

\[ kpc^{xng}(b) = \text{driver kilometres per capita by 15–64 year olds under baseline} \]
\[ kpc^{old}(b) = \text{driver kilometres per capita by 65+ year olds under baseline} \]

Note: by definition \( kpc^{chd}(b) = 0 \)
Step 1: Obtain driver kilometres from HHTS

\[ ktot^{yng} = \text{total driver kilometres for 15–64 year olds} \]
\[ ktot^{old} = \text{total driver kilometres for 65+ year olds} \]
\[ ktot = \text{total driver kilometres for all age groups} \]

Step 2: Obtain driver kilometres by reason for travel from HHTS

\[ kpc_i^{yng}(b) = \text{driver kilometres per capita by 15–64 year olds by reason for travel under baseline} \]
\[ kpc_i^{old}(b) = \text{driver kilometres per capita by 65+ year olds by reason for travel under baseline} \]

Where \( i = 1 \) to 6 and refers to reason for travel as:

1. Work (main/other job)
2. Employers’ business
3. Education
4. Shopping/personal business/social work/medical
5. Social visits
6. Recreational.

Step 3: Apply change in driver kilometres by reason for travel

Let \( \Delta_i = \% \text{ change in driver kilometres by reason for travel due to scenario} \)

\[ kpc_i^{yng}(s) = kpc_i^{yng}(b). \Delta_i = \text{driver kilometres per capita by 15–64 year olds for each reason for travel under scenario} \]
\[ kpc_i^{old}(s) = kpc_i^{old}(b). \Delta_i = \text{driver kilometres per capita by 65+ year olds for each reason for travel under scenario} \]

\[ kpc^{yng}(s) = \sum_{i=1}^{6} kpc_i^{yng}(s) = \text{sum of driver kilometres per capita by 15–64 year olds under scenario} \]
\[ kpc^{old}(s) = \sum_{i=1}^{6} kpc_i^{old}(s) = \text{sum of driver kilometres per capita by 65+ year olds under scenario} \]

Step 4: Obtain overall proportionate change

\[ \theta^{yng}(s) = \frac{kpc^{yng}(s)}{kpc^{yng}(b)} = \text{change of driver kilometres per capita by 15–64 year olds due to scenario} \]
\[ \theta^{old}(s) = \frac{kpc^{old}(s)}{kpc^{old}(b)} = \text{change of driver kilometres per capita by 65+ year olds due to scenario} \]
Step 5: Calculate weights for age groups

\[ w_{\text{Young}} = \frac{k_{\text{tot,Young}}}{k_{\text{tot}}} = \text{weight of the driver kilometres for 15–64 year olds} \]

\[ w_{\text{Old}} = \frac{k_{\text{tot,Old}}}{k_{\text{tot}}} = \text{weight of the driver kilometres for 65+ year olds} \]

Step 6: Obtain weighted average proportionate change

\[ y = w_{\text{Young}} \cdot y_{\text{Young}}(s) + w_{\text{Old}} \cdot y_{\text{Old}}(s) = \text{weighted average change of driver kilometres per capita due to digital connectivity under scenario} \]

where \( w_{\text{Young}} + w_{\text{Old}} = 1 \)

Step 7: Calculate annual change due to digital connectivity effect

\[ \gamma_t = \gamma_{t-1} + \left( \frac{1}{n^2} \right) = \text{annual change in weighted-average-change-of-driver-kilometres per capita.} \]

where \( n^2 \) = number of years between 2014 and 2042

Step 8: Apply annual change to baseline to obtain scenario results

\[ PVPC_{t,p}^{\text{dig}}(s) = (1 + \gamma_t) \cdot PVPC_{t,p}(b) = \text{private petrol VKT per capita under scenario} \]

\[ PVPC_{t,d}^{\text{dig}}(s) = (1 + \gamma_t) \cdot PVPC_{t,d}(b) = \text{private diesel VKT per capita under scenario} \]
1.1.2 Urbanisation effect

Driver travel is scaled to take into account changes in the urban/rural-based balance of the population, as rural people currently travel more on average than urban people.

The methodology

We have applied a difference between urban and rural driver kilometres per capita as a guide to determine the effect of urbanisation.

The HHTS data show the following travel by urban/rural based population:

<table>
<thead>
<tr>
<th></th>
<th>National</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per capita driver km (km per person per year)</td>
<td>6,724</td>
<td>6,147</td>
<td>8,160</td>
</tr>
<tr>
<td>Change from national average</td>
<td>-9%</td>
<td></td>
<td>21%</td>
</tr>
</tbody>
</table>

In this context, ‘urban’ is defined as residing in an urban area with a population greater than 30,000 (StatsNZ definition of a ‘Main Urban Area’). From the above table, we see that urban people travel 9 percent less than the national average. Rural people travel 21 percent more than the national average.

Using StatsNZ population projections (based on the total projected growth in Territorial Local Authorities classed as Main Urban Areas between 2007 and 2013), we have projected the urban share of total population. We have estimated this share to be approximately 81 percent by 2042.

In order to do scenario testing, we applied the urban population share derived from the scenario to calculate the urban population. We then multiplied the estimated urban population by the calculated urban travel rate, using percentage difference of urban travel from the national average (9 percent from the table above). We then used the rural difference (21 percent) to calculate the rural driver travel.

Adding estimated urban and rural driver kilometres under the scenario we get total driver kilometres, which is then compared with the baseline to obtain deviation from the baseline.
**Assumption**

► Relativity between urban and rural driver kilometres per capita remains the same in the future.

We present the above methodology in notational terms as follows.

**Let**

\[ \begin{align*}
    VPC_t & = \text{private VKT per capita at time } t \\
    VPC_{t,p} & = \text{petrol VKT per capita at time } t \\
    VPC_{t,d} & = \text{diesel VKT per capita at time } t \\
    PVPC_t & = \text{private VKT per capita at time } t \\
    VT_t & = \text{total VKT per time } t \\
    PVT_t & = \text{total private VKT at time } t \\
    VT_{t,p} & = \text{total petrol VKT at time } t \\
    VT_{t,d} & = \text{total diesel VKT at time } t \\
    PVT_{t,p} & = \text{total private petrol VKT at time } t \\
    PVT_{t,d} & = \text{total private diesel VKT at time } t \\
    kpc & = \text{driver kilometres per capita for total population} \\
    kpc^u & = \text{driver kilometres per capita for urban population} \\
    kpc^r & = \text{driver kilometres per capita for rural population} \\
    MUA & = \text{Main Urban Areas (urban centres with population > 30,000)} \\
    POP^u_t & = \text{urban population at time } t \\
    POP^r_t & = \text{rural population at time } t \\
    \alpha_{07}^u & = \text{urban population share in 2007} \\
    POP_{07}^u & = \text{urban population in 2007} \\
\end{align*} \]

**Step 1: Calculate urban population growth**

\[
    g_t^u = \frac{POP^u_t}{POP^u_{t-1}} = \text{growth of urban population at time } t
\]

\[
    g^u = \frac{\sum_{2006}^{2031}(g_t^u)}{n3} = \text{average annual urban population growth}
\]

where \( n3 = \text{number of years between 2006 and 2031} \)

\[
    POP_{07}^u = \alpha_{07}^u \cdot POP_{07} = \text{urban population in 2007}
\]
Step 2: Estimate urban and rural population

\[ POP^u_0 = POP^r_0 = \text{urban population in initial period} \]

\[ POP^u_t = (1 + g^u). POP^u_{t-1} = \text{estimated urban population at time } t \]

\[ POP^r_t = POP_t - POP^u_t = \text{estimated rural population at time } t \]

Step 3: Calculate ratio of driver kilometres per capita

\[ \alpha^u = \frac{k_{pc}^u}{k_{pc}} = \text{ratio between driver kilometres per capita by urban population, and total population} \]

\[ \alpha^r = \frac{k_{pc}^r}{k_{pc}} = \text{ratio between driver kilometres per capita by rural population, and total population} \]

Step 4: Apply ratio of driver kilometres per capita to obtain private VKT per capita

(i) Baseline

\[ VPC^u_{t,p}(b) = \alpha^u. VPC_{t,p}(b) = \text{private petrol VKT per capita by urban population at baseline} \]

\[ VPC^d_{t,d}(b) = \alpha^u. VPC_{t,d}(b) = \text{private diesel VKT per capita by urban population at baseline} \]

\[ VPC^u_{t,p}(b) = \alpha^r. VPC_{t,p}(b) = \text{private petrol VKT per capita by rural population at baseline} \]

\[ VPC^d_{t,d}(b) = \alpha^r. VPC_{t,d}(b) = \text{private diesel VKT per capita by rural population at baseline} \]

\[ VT^u_{t,p}(b) = VPC^u_{t,p}. POP^u_t = \text{total private petrol VKT by urban population at baseline} \]

\[ VT^d_{t,d}(b) = VPC^d_{t,d}. POP^u_t = \text{total private diesel VKT by urban population at baseline} \]

\[ VT^u_{t,p}(b) = VPC^u_{t,p}. POP^r_t = \text{total private petrol VKT by rural population at baseline} \]

\[ VT^d_{t,d}(b) = VPC^d_{t,d}. POP^r_t = \text{total private diesel VKT by rural population at baseline} \]

\[ VT^{u+r}_{t,p}(b) = VT^u_{t,p} + VT^r_{t,p} = \text{total private petrol VKT by urban and rural population at baseline} \]

\[ VT^{u+r}_{t,d}(b) = VT^u_{t,d} + VT^r_{t,d} = \text{total private diesel VKT by urban and rural population at baseline} \]

\[ VPC^{u+r}_{t,p}(b) = \frac{VT^{u+r}_{t,p}(b)}{POP_t} = \text{private petrol VKT per capita by urban and rural population at baseline} \]

\[ VPC^{u+r}_{t,d}(b) = \frac{VT^{u+r}_{t,d}(b)}{POP_t} = \text{private diesel VKT per capita by urban and rural population at baseline} \]

(ii) Scenario

\[ \alpha^u_s = \text{Share of urban population under scenario} \]

\[ \alpha^r_s = 1 - \alpha^u_s = \text{Share of rural population under scenario} \]

\[ POP^u_t(s) = \alpha^u_s. POP_t = \text{urban population under scenario} \]

\[ POP^r_t(s) = \alpha^r_s. POP_t = \text{rural population under scenario} \]
\[ VT_{t,p}^u(s) = VPC_{t,p}^u(b). POP_t^u(s) = \text{total private petrol VKT for urban population under scenario} \]

\[ VT_{t,d}^u(s) = VPC_{t,d}^u(b). POP_t^u(s) = \text{total private diesel VKT for urban population under scenario} \]

\[ VT_{t,p}^r(s) = VPC_{t,p}^r(b). POP_t^r(s) = \text{total private petrol VKT for rural population under scenario} \]

\[ VT_{t,d}^r(s) = VPC_{t,d}^r(b). POP_t^r(s) = \text{total private diesel VKT for rural population under scenario} \]

\[ PVVT_{t,p}^{u+r}(s) = VT_{t,p}^u(s) + VT_{t,p}^r(s) = \text{total private petrol VKT for urban and rural population under scenario} \]

\[ PVVT_{t,d}^{u+r}(s) = VT_{t,d}^u(s) + VT_{t,d}^r(s) = \text{total private diesel VKT for urban and rural population under scenario} \]

\[ PVPC_{t,p}(s) = \frac{PVVT_{t,p}^{u+r}(s)}{POP_t} = \text{private petrol VKT per capita for urban and rural population under scenario} \]

\[ PVPC_{t,d}(s) = \frac{PVVT_{t,d}^{u+r}(s)}{POP_t} = \text{private diesel VKT per capita for urban and rural population under scenario} \]
1.1.3 Fuel price effect

The effects of different fuel prices are calculated using regression equations with fuel price as an independent variable.

The methodology

We use a regression equation for petrol VKT with petrol price as an independent variable, developed as part of the Ministry’s National Land Transport Fund (NLTF) revenue forecasting model recently developed by consultants, Covec Limited. We also use a second regression equation for diesel VKT with diesel price as an independent variable.

Please note that VKT estimated from these regression equations includes both private travel and commercial travel. In order to obtain private VKT, we removed the proportion of commercial travel from the total VKT. Private travel accounts for 94 percent of petrol VKT and 41 percent of diesel VKT. This ratio is assumed not to change over the period of the projections.

To test the impact of any price change, we changed the price in each equation as a percentage increase/decrease. Under Treasury forecasts, the petrol price will be approximately 32 percent higher in 2042 than 2014 and the diesel price will be approximately 50 percent higher. The model uses the Treasury forecast of fuel price increase as a baseline, and adds any price change by the user on top of the Treasury forecast. Therefore, if the user applies a 10 percent price increase, the model counts it as 32 percent plus 10 percent petrol price increase and 50 percent plus 10 percent increase in diesel price by 2042.

The following three steps were used to calculate the energy price effect.

Step 1: Create baseline

Use VKT equations from the NLTF revenue forecasting model.

Assumption

Treasury forecasts of petrol and diesel prices, GDP, CPI and imports hold under the baseline scenario.

Let

\[ P_{r,p}(b) = \text{real petrol price at baseline (based on the Treasury economic forecast)} \]
\[ P_{r,d}(b) = \text{real diesel price at baseline (based on the Treasury economic forecast)} \]
\[ P_{r,p}(s) = \text{real petrol price under scenario (based on growth forecast under scenario)} \]
\[ P_{r,d}(s) = \text{real diesel price under scenario (based on growth forecast under scenario)} \]
\[ RUC_t = \text{real Road User Charge} \]
\[ GDP(pc)_t = \text{real GDP per capita} \]
$M_t = \text{real imports}$

$Q2, Q3, Q4 = \text{quarterly dummy variables}$

$t = \text{time trend variable}$

$\alpha = \text{constant}$

$\beta = \text{regression coefficients}$

**Petrol VKT equation**

$$\ln VPC_{t,p}(b) = \alpha_p + \beta_{1,p} \ln P_{t,p}(b) + \beta_{2,p} \ln GDP(pc)_t + \beta_{3,p} \ln VPC_{t-1,p}(b) + \beta_4 Q2 + \beta_5 Q3 + \beta_6 Q4 + \beta_7 t$$

**Diesel VKT equation**

$$VT_{t,d} = \alpha_d + \beta_{1,d}P_{t,d}(b) + \beta_{2,d}GDP(pc)_t + \beta_{3,d}RUC_t + \beta_{4,d}RUC_{t+1} + \beta_{5,d}M_t + \beta_6 Q2 + \beta_7 Q3 + \beta_8 Q4 + \beta_9 t$$

**Step 2: Estimate VKT under scenario**

**Assumption**

- Treasury forecast GDP, CPI and imports under baseline scenario

**Petrol VKT equation**

$$\ln VPC_{t,p}(s) = \alpha_p + \beta_{1,p} \ln P_{t,p}(s) + \beta_{2,p} \ln GDP(pc)_t + \beta_{3,p} \ln VPC_{t-1,p}(s) + \beta_4 Q2 + \beta_5 Q3 + \beta_6 Q4 + \beta_7 t$$

**Diesel VKT equation**

$$VT_{d}(s) = \alpha_d + \beta_{1,d}P_{t,d}(s) + \beta_{2,d}GDP(pc)_t + \beta_{3,d}RUC_t + \beta_{4,d}RUC_{t+1} + \beta_{5,d}M_t + \beta_6 Q2 + \beta_7 Q3 + \beta_8 Q4 + \beta_9 t$$

**Step 3: Estimate private VKT**

**Private petrol VKT**

(i) **Baseline**

$$PVPC_{t,p}(b) = VPC_{t,p}(b), \mu^p = \text{private petrol VKT per capita at baseline}$$

where

$$\mu^p = \text{proportion of private petrol VKT}$$

**Scenario**

$$PVCP_{t,p}^{ens}(s) = VPC_{t,p}(s), \mu^p = \text{private petrol VKT per capita under scenario}$$

**Light diesel private travel**

(i) **Baseline**

$$VPC_{t,d}(b) = \frac{VT_{t,d}(b)}{POP_t} = \text{diesel VKT per capita at baseline}$$

$$PVPC_{t,d}(b) = VPC_{t,d}(b), \mu^d = \text{private diesel VKT per capita at baseline}$$
where

\[ \mu^d = \text{proportion of light diesel private VKT} \]

(ii) **Scenario**

\[ VPC_{t,d}(s) = \frac{VTK_{t,d}(s)}{POP_t} \] = diesel VKT per capita under scenario

\[ PVPC_{t,d}^{en}(s) = VPC_{t,d}(s), \mu^d \] = private diesel VKT per capita under scenario
1.1.4 Fuel efficiency effect

The effects of changing the vehicle fuel efficiency are calculated by examining the difference in fuel required under the different fuel efficiency from the baseline. We then apply that difference as a percentage increase or decrease in fuel costs into the regression equations from the previous section.

The methodology

The NLTF revenue forecasting model uses a calculated petrol vehicle fuel efficiency of 10.48km per litre of petrol by 2042. We used this as the starting point (baseline). Then we changed this value to see the change in private VKT, which we considered as the scenario.

The method of applying vehicle fuel efficiency in the model is as follows.

**Step 1:** We first calculated how many litres to travel one kilometre under the baseline and under the scenario.

**Step 2:** Then we calculated the difference in litres required to travel one kilometre in the two situations calculated in step 1.

**Step 3:** Then we assumed that any increase/decrease of litres required to travel one kilometre is equal to an increase/decrease in the price of fuel.

The implicit assumption is that if you require fewer litres of fuel to travel one more kilometre due to fuel efficiency, then you have an incentive to travel more. This is captured by an equivalent increase/decrease of fuel price.

We applied this percentage increase/decrease of the price of fuel to the petrol VKT equation and diesel VKT equation to obtain the VKT resulting from an increase/decrease of fuel efficiency. We then compared the VKT under the vehicle efficiency scenario with baseline VKT.

As noted in the section on the fuel price effect, the model used the Treasury forecast of fuel price as baseline and added any price effect due to fuel efficiency change on the top of Treasury forecast of price change.

Assumptions

- The rate of change in litres per kilometre due to vehicle fuel efficiency is equal to a rate of fuel price decrease/increase.
- Percentage change in diesel price due to diesel vehicle fuel efficiency is equal to percentage change in petrol price resulting from the petrol vehicle fuel efficiency gain.
The notational interpretation of the above methodology is as follows.

**Step 1: Calculate vehicle efficiency factor**

\[ VE_{t,p}(b) = \text{petrol vehicle fuel efficiency (number of kilometres per litre of petrol) at baseline} \]

\[ VE_{t,p}(s) = \text{petrol vehicle fuel efficiency (number of kilometres per litre of petrol) under scenario} \]

\[ \frac{1}{VE_{t,p}(b)} = \text{petrol vehicle fuel efficiency (number of litres of petrol per kilometre) at baseline} \]

\[ \frac{1}{VE_{t,p}(s)} = \text{petrol vehicle fuel efficiency (number of litres of petrol per kilometre) under scenario} \]

\[ E_t = \frac{VE_{t,p}(s)}{VE_{t,p}(b)} = \text{petrol vehicle fuel efficiency factor (= travel cost advantage).} \]

**Step 2: Apply vehicle fuel efficiency factor**

**Petrol vehicle fuel efficiency model**

Let

\[ P_{t,p} (s) = \text{price of petrol adjusted for vehicle fuel efficiency} \]

then

\[ P_{t,p}(s) = E_t \cdot P_{t,p}(b) = \text{price of petrol adjusted for vehicle fuel efficiency} \]

\[ \ln VPC_{t,p} (s) = \alpha_p + \beta_{1,p} \ln P_{t,p} (s) + \beta_{2,p} \ln GDP(p) \]

\[ + \beta_{3,p} \ln VPC_{t-1,p} (s) + \beta_4 Q2 + \beta_5 Q3 + \beta_6 Q4 + \beta_7 t \]

\[ PVPC_{t,p}^{ref} (s) = VPC_{t,p} (s) \cdot \mu^p = \text{private petrol VKT capita under scenario} \]

**Diesel vehicle fuel efficiency model**

\[ P_{t,d}(s) = E_t \cdot P_{t,d}(b) = \text{price of diesel adjusted for vehicle fuel efficiency} \]

\[ VVT_d (s) = \alpha_d + \beta_{1,d} P_{t,d}(s) + \beta_{2,d} GDP(p) \]

\[ + \beta_{3,d} RUC_t + \beta_{4,d} RUC_{t+1} + M_t + \beta_4 Q2 + \beta_5 Q3 + \beta_6 Q4 + \beta_7 t \]

\[ VPC_{t,d}(s) = \frac{VVT_d(s)}{POPt} = \text{diesel VKT per capita under scenario} \]

\[ PVPC_{t,d}^{ref} (s) = VPC_{t,d} (s) \cdot \mu^d = \text{private diesel VKT per capita under scenario} \]
1.1.5 Population aging effect

To capture the effects of an aging population, we have taken a projection of the future age structure of the New Zealand population, and used it to scale the baseline VKT based on currently observed differences in driver travel by age group, where those aged ‘65 years and older’ average less travel than those aged 15–64 years old.

The methodology

The following age groups have been used:

- 0–14 years
- 15–64 years
- 65 years and above.

Projected population age structures were taken from median StatsNZ projections from a 2011 baseline. Based on historical age structure and driver kilometre travel data, we calculated the current per capita driver kilometre as a base. Secondly we calculated the expected per capita driver kilometre in 2042 based on the change in age structure.

We then obtained the difference between base per capita driver kilometres and expected per capita driver kilometres for years from 2014 to 2042. We used the percentage difference as the aging effect. We then applied this percentage difference to the baseline private VKT to obtain the deviation from the baseline due to the aging effect.

Assumption

- The relativity between per capita driver kilometres by different age groups (that is, children, young, and older people) remains the same in future.

Following is the notational summary of the method outlined above.

Let

- $POP_t$ = total population at time $t$
- $POP_{t}^{chd}$ = population aged 0–14 years at time $t$
- $POP_{t}^{yng}$ = population aged 15–64 years at time $t$
- $POP_{t}^{old}$ = population aged 65 years and above at time $t$

Step 1: Calculate population proportions by age group

- $prop_{t}^{chd} = \frac{POP_{t}^{chd}}{POP_t}$ = proportion of population aged 0–14 years at time $t$
- $prop_{t}^{yng} = \frac{POP_{t}^{yng}}{POP_t}$ = proportion of population aged 15–64 years at time $t$
- $prop_{t}^{old} = \frac{POP_{t}^{old}}{POP_t}$ = proportion of population aged 65 years and above at time $t$
Step 2: Obtain driver kilometres per capita from the New Zealand Household Travel Survey (HHTS)

\[ k_{pc} = \text{driver kilometres per capita for the total population} \]

\[ k_{pc}^{chd} = \text{driver kilometres per capita for 0–14 year old population} \]

*Please note that this is assumed to be zero as children under 15 years are below the legal driving age.*

\[ k_{pc}^{yng} = \text{driver kilometres per capita for 15–64 year old population} \]

\[ k_{pc}^{old} = \text{driver kilometres per capita for 65+ year old population} \]

Step 3: Calculate the weighted driver kilometres per capita

\[ w_{kpc} = \left( prop_{t}^{chd} \cdot k_{pc}^{chd} \right) + \left( prop_{t}^{yng} \cdot k_{pc}^{yng} \right) + \left( prop_{t}^{old} \cdot k_{pc}^{old} \right) = \text{weighted per capita driver kilometres at time } t \]

where: \( prop_{t}^{chd} + prop_{t}^{yng} + prop_{t}^{old} = 1 \)

Step 4: Calculate weighted driver kilometres per capita for baseline

\[ w_{kpc_{0}} = \frac{\sum_{2003}^{2014} w_{kpc_{t}}}{n_{1}} = \text{average of weighted driver kilometres per capita (the base)} \]

where \( n_{1} = \text{number of years between 2003 and 2014} \)

Step 5: Calculate aging effect factor

\[ AGEF_{t} = \frac{w_{kpc_{t}}}{w_{kpc_{0}}} = \text{Aging factor at time } t \]

Step 6: Apply aging effect factor to baseline private VKT

Let

\[ PVPC_{t,p} = \text{private petrol VKT per capita at time } t \]

\[ PVPC_{t,d} = \text{private diesel VKT per capita at time } t \]

\[ PVPC_{t,p}^{age}(s) = AGEF_{t}, PVPC_{t,p}(b) = \text{private petrol VKT per capita under aging scenario} \]

\[ PVPC_{t,d}^{age}(s) = AGEF_{t}, PVPC_{t,d}(b) = \text{private diesel VKT per capita under aging scenario} \]
1.1.6 Combined effect

We calculated the separate effects as percentage deviation from the baseline. The five drivers give five percentage deviations from baseline. We have to combine all five effects (percentage deviations from baseline) to obtain the total deviation from baseline. Suppose, for example, we have defined a scenario and its effects as follows:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Current value</th>
<th>New value</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aging</td>
<td>15%</td>
<td>23%</td>
<td>-0.9%</td>
</tr>
<tr>
<td>2. Digital connectivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Work (main job)</td>
<td>0%</td>
<td>-10%</td>
<td>-3.7%</td>
</tr>
<tr>
<td>• Employers business</td>
<td>0%</td>
<td>-10%</td>
<td></td>
</tr>
<tr>
<td>3. Urbanisation</td>
<td>75%</td>
<td>81%</td>
<td>-2.9%</td>
</tr>
<tr>
<td>4. Energy price</td>
<td>0%</td>
<td>20%</td>
<td>-1.0%</td>
</tr>
<tr>
<td>5. Fuel efficiency</td>
<td>10.48</td>
<td>12</td>
<td>0.7</td>
</tr>
</tbody>
</table>

To obtain full effect of all five factors we use following multiplicative formula.

\[ \alpha_t = \left(1 + \alpha_t^{age}\right)\left(1 + \alpha_t^{dig}\right)\left(1 + \alpha_t^{urb}\right)\left(1 + \alpha_t^{eng}\right)\left(1 + \alpha_t^{ref}\right) - 1 \]

Where:

- \(\alpha_t\) = Total effect
- \(\alpha_t^{age}\) = Aging effect
- \(\alpha_t^{dig}\) = Digital connectivity effect
- \(\alpha_t^{urb}\) = Urbanisation effect
- \(\alpha_t^{eng}\) = Fuel price effect
- \(\alpha_t^{ref}\) = Fuel efficiency effect

The reason for using \((1 + \alpha)\) is to avoid the total becoming larger than 100 percent.

After obtaining the combined effects of all factors that determined a particular scenario, the resulting private VKT under that scenario is compared to the private VKT calculated under the baseline.

In notational terms the process is as follows.

Let

- \(PVPC_{t,p} (b)\) = private petrol VKT per capita under baseline
- \(PVPC_{t,d} (b)\) = private diesel VKT per capita under baseline
- \(PVPC_t (b)\) = private VKT per capita under baseline
- \(PVPC_{t,p} (s)\) = private petrol VKT per capita under scenario
Step 1: Calculate change due to individual effects

Aging effect
\[
\alpha_{t,p}^{age} = \frac{PVPC_{t,p}^{age}(s)}{PVPC_{t,p}(b)} - 1 = \text{change in private petrol VKT per capita due to aging effect}
\]
\[
\alpha_{t,d}^{age} = \frac{PVPC_{t,d}^{age}(s)}{PVPC_{t,d}(b)} - 1 = \text{change in private diesel VKT per capita due to aging effect}
\]

Digital connectivity effect
\[
\alpha_{t,p}^{dig} = \frac{PVPC_{t,p}^{dig}(s)}{PVPC_{t,p}(b)} - 1 = \text{change in private petrol VKT per capita due to digital connectivity effect}
\]
\[
\alpha_{t,d}^{dig} = \frac{PVPC_{t,d}^{dig}(s)}{PVPC_{t,d}(b)} - 1 = \text{change in private diesel VKT per capita due to digital connectivity effect}
\]

Urbanisation effect
\[
\alpha_{t,p}^{urb} = \frac{PVPC_{t,p}^{urb}(s)}{PVPC_{t,p}(b)} - 1 = \text{change in private petrol VKT per capita due to urbanisation effect}
\]
\[
\alpha_{t,d}^{urb} = \frac{PVPC_{t,d}^{urb}(s)}{PVPC_{t,d}(b)} - 1 = \text{change in private diesel VKT per capita due to urbanisation effect}
\]

Fuel price effect
\[
\alpha_{t,p}^{eng} = \frac{PVPC_{t,p}^{eng}(s)}{PVPC_{t,p}(b)} - 1 = \text{change in private petrol VKT per capita due to energy price effect}
\]
\[
\alpha_{t,d}^{eng} = \frac{PVPC_{t,d}^{eng}(s)}{PVPC_{t,d}(b)} - 1 = \text{change in private diesel VKT per capita due to energy price effect}
\]
**Fuel efficiency effect**

\[
\alpha_{t,p}^{vef} = \frac{PVPC_{t,p}^{vef}(s)}{PVPC_{t,p}(b)} - 1 = \text{change in private petrol VKT per capita due to vehicle effect}
\]

\[
\alpha_{t,d}^{vef} = \frac{PVPC_{t,d}^{vef}(s)}{PVPC_{t,d}(b)} - 1 = \text{change in private diesel VKT per capita due to vehicle efficiency effect}
\]

**Step 2: Obtain the product of individual effects**

Let

\[\alpha_{t,p} = \text{total effect under scenario on petrol private VKT per capita}\]

\[\alpha_{t,d} = \text{total effect under scenario on diesel private VKT per capita}\]

\[
\begin{align*}
\alpha_{t,p} &= \left((1 + \alpha_{t,p}^{age})(1 + \alpha_{t,p}^{dig})(1 + \alpha_{t,p}^{urb})(1 + \alpha_{t,p}^{eng})(1 + \alpha_{t,p}^{vef})\right) - 1 \\
\alpha_{t,d} &= \left((1 + \alpha_{t,d}^{age})(1 + \alpha_{t,d}^{dig})(1 + \alpha_{t,d}^{urb})(1 + \alpha_{t,d}^{eng})(1 + \alpha_{t,d}^{vef})\right) - 1
\end{align*}
\]

**Step 3: Obtain private VKT under scenario**

Let

\[PVPC_{t,p}(s) = \text{private petrol VKT per capita under scenario}\]

\[PVPC_{t,d}(s) = \text{private diesel VKT per capita under scenario}\]

\[PVPC_{t,p}(s) = \alpha_{t,p} \cdot PVPC_{t,p}(b) = \text{private petrol VKT per capita under scenario}\]

\[PVPC_{t,d}(s) = \alpha_{t,d} \cdot PVPC_{t,d}(b) = \text{private diesel VKT per capita under scenario}\]

\[PVPC_{t}(s) = PVPC_{t,p}(s) + PVPC_{t,d}(s) = \text{private VKT per capita under future demand scenario}\]

**Step 4: obtain overall effect**

Let

\[\alpha_t = \text{total effect under scenario on private VKT per capita}\]

then

\[\alpha_t = \frac{PVPC_t(s)}{PVPC_t(b)} - 1 = \text{overall effect}\]

**Data sources**

The following data sources were used in the development of the model.

- Statistics New Zealand (StatsNZ)
- The New Zealand Treasury
- NZ Transport Agency
- Household Travel Survey (HHTS) - New Zealand Ministry of Transport
Appendix 3. Peer reviews of model

The model was peer-reviewed by the following people:

Professor Phil Goodwin, Emeritus Professor of Transport Policy, University College London and the University of the West of England

Brian Bull, MSc (Applied Statistics), and a BSc Hons (First Class) in Statistics, Concept Consulting Limited, Wellington
Future Demand Project - VKT Model Review

Phil Goodwin

Emeritus Professor of Transport Policy
University College London and the University of the West of England

Summary

I was asked to give an overall review of the New Zealand Ministry of Transport’s Passenger Travel Quantification Model, also called the VKT Model – here I call it ‘the model’ for short – which is intended to estimate the approximate aggregate amount of car traffic that would emerge from four different scenarios of (a) future energy costs and (b) the extent to which people may decide to exchange some physical travel for digital connectivity. The model is a simple, aggregate, easy to use and mostly transparent tool for thinking about some important influences and trends.

I view it as a useful and professional contribution to informing wider discussion of the range of futures which might confront the population of a developed, changing, market economy. I particularly approve of the intention to enable explicit consideration of five different future trends: digital connectivity and energy cost as the initial scenario dimensions; age structure of the population; the proportion of the population living in urban areas; and fuel efficiency. All these trends are not predetermined or precisely known, but the implications are large, and rarely considered in forecasts of traffic volumes. Taken together, these effects encourage thought about possibilities which are wider than the envelope of ‘higher’ and ‘lower’ bounds often considered as rather narrow statistical variation around a highly constrained future.

The fuel price demand elasticity embodied in the model, at -0.04, is substantially lower than international evidence of the effects of fuel price on traffic levels and fuel consumption, especially in the longer term. While appreciating that this is an output from a separate model used for short term revenue forecasting, I would suggest that a higher elasticity would be appropriate, for sensitivity testing and use.

In the short run, there are some clarifications about the way the model operates arithmetically which must be given, and a rather carefully drafted caveat about interpretation and use and status, designed to give maximum encouragement and help to users to frame their own choices and assumptions, while making it clear that that the results do not have the status of ‘official’ forecasts or assessments. Less immediately, I think an additional strength of the model is that it lends itself well to development of a substantial number of improvements, which will become increasingly relevant if thinking on the scenarios develops and there is interest in investigating their properties in more detail.
Terms of reference

This report, written under Ministry of Transport Contract 14/15-023, is an initial overview assessment of the New Zealand Ministry of Transport’s Passenger Travel Quantification Model\(^1\), based on its User Guide and Technical Annex, and the Excel Spreadsheet\(^2\) which operates it. The terms of reference were:

Review the Ministry’s VKT model and consider its logic, credibility, and operations in the context of general background knowledge about solved and unsolved issues in travel demand research - in NZ in some cases, and internationally in others.

Comment on what the model’s core function is, the usefulness of that function, and whether or not there are deficiencies that must\(^3\) be addressed.

Provide a written report of the review”

I have been provided with a briefing about the background and discussions on the model, a review of the separate Revenue Forecasting Model\(^4\) which provides some of the inputs, and some discussions with a member of the modelling team. These have informed my thinking, but I have not tried to come to a view about potential inconsistencies between the model and other models, or their relative merits in terms of functionality, accuracy, or reliability: this would depend on a closer examination of those models than I have done.

Comments on deficiencies which ‘must’ be addressed required going through a process of thinking about work which would be useful without necessarily being immediately essential, and I report the results of this in the text rather than excluding them as being beyond my brief.

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\(^2\) Demand Forecasting Excel Macro-enabled Spreadsheet Version 1.10.2014
\(^3\) Emphasis in original
Personal Statement
I have visited New Zealand in the past, and have recently discussed current concerns with representatives of the NZ Ministry of Transport, including the lead person responsible for the Future Demand study, but would not claim to have close and detailed current knowledge of New Zealand transport. As a former Editor of two transport journals, I have a general awareness of transport research in countries outside the UK, including some international comparative work covering New Zealand, such as that published by BITRE in Australia. In the last few years I have been particularly involved, for OECD and as editor of special issue of the journal Transport Reviews, in research on the causes of a widespread phenomenon seen in many developed countries, where growth rates of car ownership and use have been declining in the last decade or more. I was co-author of a roundtable report on research on this subject prepared for the New Zealand Ministry of Transport.

During the period 2005 to 2011 (following my retirement from Director of the Transport Studies Unit at UCL) I was appointed to a part-time professorship at the Centre for Transport and Society, UWE, initially with Glenn Lyons, subsequently Graham Parkhurst, as Directors of that Centre. For the last three years that link has been an honorary status without employment or financial commitments, and this will continue in the future. I have no vested interest in NZ in general, or specifically on this subject.

Stated Rationale
The model emerged from a process of thinking about future scenarios, part of a general trend in policy thinking to move away from the idea of a single, deterministically defined future which is forecast by technical means, to the idea of a range of different possible futures, as yet undetermined. It is usually the case that forecasting a single future includes the possibility of a range of error around its characteristics, but the range is almost always much narrower than those contained in alternative scenarios.

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6 Available at http://www.tandfonline.com/toc/tttrv20/33/3#.U4x0IIPdWS0 (the overview paper by Goodwin and Van Dender, and paper by Metz, are open access and freely available – other papers require journal subscription, purchase or library access)
As I understand it, the ‘Future Demand’ project produced four scenarios for society and transport in New Zealand for 2042. The scenarios were seen as determined by different combinations of two principal dimensions: relative use of physical movement versus digital connection, and high versus low cost of energy. As is common in scenario-building, the four quadrants of the two dimensions were given names seeking to describe them in popular and understandable language. In this case they are ‘Live Local Play Global’, ‘Digital Decadence’, ‘Travellers Paradise’, and ‘Cooperative and Close’. They are intended to allow users of the model, and a thoughtful public as a whole, to engage in discussion about what sort of futures are plausible, and what their characteristics would be. This would assist informed discussion about what choices are available, in a context where people may still differ about whether those characteristics are for the better or worse.

The purpose of the model was then to provide a way of thinking about the measurable volume of road travel which would correspond with each of the four main scenarios, at an aggregate and necessarily rather simple level. It was not seen as a tool for producing the type of official traffic forecasts which many countries use as part of their formal road and transport planning processes, but rather as a way of putting quantified road traffic flesh on the qualitative bones of the thinking about the scenarios.

In order to consider quantified traffic implications, it is necessary to have a framework of measured or measurable quantities which can be manipulated in a systematic and logical way, so that general concepts must be operationalized in terms of recognisable variables. In order to consider the two ‘core’ variables defining the scenarios, it is logically essential to include energy price and digital connectivity as inputs, and volume of traffic as an output.

As all model-builders will recognise, it is then invariably found that the two original dimensions are not sufficient in themselves, but need to be broken down into some separate relationships and influences.

**Description of the model**

The model, operating as a macro-enabled Excel spreadsheet, provides year-by-year forecasts up to 2042, of vehicle km travelled (VKT), essentially by private cars and comparable light vehicles being used for personal and business travel, but not freight or service traffic. It operates at a highly aggregate level, i.e. at present the whole country, separating ‘types’ of area (primarily urban/rural) but not seeking to take into account the specific characteristics of
particular cities or areas, and not using an explicit road network defined geographically and topologically. The forecasts are controlled by user-selection of assumptions on five core variables, evolved from the initial two dimensions, namely age-structure of the population, the degree to which travel may be substituted by digital connectivity, the proportion of the population living in urban areas, fuel price, and fuel-efficiency of vehicles. The sensitivities of VKT to assumptions on these variables are parameters mostly with an empirical base, compared with a ‘baseline’ trajectory produced as forecasts given by a separate already existing model called the NLTF Revenue Forecasting Model, whose detailed operation I have not studied. The outputs from the model are reported both as absolute numbers and also as differences from this baseline trajectory.

**Ease of Use**

The user interface is attractively designed, and very nearly intuitively obvious even without use of the separate user manual: in practice I used the model by having the spreadsheet and manual open on adjacent extended screens, and I judge this gives as close to the maximum degree of accessibility to an interested non-specialist user as it is possible to imagine, without resort to gaming simulation tools which would raise entirely different orders of magnitude of complexity. It gives a good feel of being professional without being pompous.

It is very helpful having graphs instantly produced as output on the same page as entering different input assumptions, but a bit fiddly then switching between these and the numbers in the ‘scenario output’ tables, especially when trying lots of alternatives and forgetting which assumptions have been entered in a series. Perhaps some sort of accumulating accounting table could be kept of successive trials (similar to on-line shopping websites which store previous searches). I would say that these are not serious problems, but may deserve revisiting.

**Transparency**

The operation is mostly very transparent, with little or no ‘black box’ about it other than the actual algorithms and coding used by Excel, which I am content to leave hidden (as, I guess, most users would be).

There is one arithmetical point which is not made completely clear. I think that the way it operates is that the user specifies an end-value for 2042 of the various independent variables: this is then apportioned in 28 equal steps from the current year 2014 to 2042. There are two
main ways of doing this. First, it could be done by allowing for cumulative effects, eg a 28% increase over 28 years would not be represented by 1% growth per year, but by a little under 0.9% a year\textsuperscript{8}. An alternative would be to calculate the total effect in 2042 and then divide that in a linear way between the years, eg a 28,000 km difference by 2042 would be represented by 1000 km per year. The two resulting trajectories might not be visibly different for 28% growth, but could be for a sensitive response to a 100% increase, and the difference is particularly salient when the calculations are done by operating with the percentage changes implied in elasticities.

(I do not think that this is an issue of principle, one of these being ‘right’ and the other ‘wrong’, provided the arithmetic is consistent, though my own background leaves me more comfortable with the first approach).

In either case the resulting year-by-year trajectory is then plotted as a line which is compared with the base-line trajectory produced previously. Discussion of any substantive difference between the two trajectories would therefore be informed by consideration of the features of both models, not just one. I am not clear whether the model trajectory is produced from the base-line trajectory, as a set of year by year calculations, or produced separately and then compared with the base-line. This would make a difference if it was desired to test – for example - assumptions about uneven development over the years, which could be interesting. In the case of fuel price, the base-line trajectory has already made an explicit assumption about future fuel prices (and demand responses to them) so an input assumption to the model which involved a fuel price increase less than this would be seen as a higher demand level than the baseline, which is indeed evident in trials. This is discussed further below.

It would be necessary to have an extra paragraph or two with a more explicit description of the arithmetic.

There is sometimes a view that very easy access to a transparent forecasting model by users without a detailed technical background, but with interests in policy and vision, can lead to misunderstandings or misuse. This is perhaps an ideological judgement rather than a technical one: for my part, I think it is an essential part of modern technical democracy and a

\textsuperscript{8} I noticed that assuming a 28% increase in fuel price from 2014 to 2042 made the model forecast trajectory appear identical to the base-line, which for a 28 year forecast made me wonder just how the ‘1% a year’ calculation discussed above had been carried out, though perhaps it is just a coincidence or arises because the difference is not visible on the scale used. If the fuel price elasticity is raised to a level discussed below, the difference would be significant.
contribution to understanding and consensus. The careful description of assumptions then becomes essential to the user as well as to a wider audience: the manual already has rather clear and firm caveats, and these should be considered further if the model is opened to wider use. Given this, I see no reason to think it would cause irresponsible doubt.

The initial scenarios

I have to say that I don’t like the scenario labels chosen, which don’t work for me in the way intended, particularly ‘Paradise’ and ‘Decadence’. I would have been inclined more boringly to call them ‘high digital communication, expensive energy’, ‘low digital communication, expensive energy’, ‘high digital communication, cheap energy’, ‘low digital communication, cheap energy’. But I consider it is important not to get distracted from the content into a discussion about the labels, and emphasise that I treat this purely as a matter of personal taste, or perhaps prejudice, with no effect on judgement about the actual content of the model or its use. If in use the Ministry finds that these labels are unduly distracting, they can be changed, though it can be helpful to have bold labels which crystallise discussion.

The interesting aspect to me is that the user does not have to buy in to the scenarios as described. Some will find them useful and illuminating, indeed liberating. Others will find them a step too far from a world they recognise, or will want to exclude consideration of one or more scenarios on the basis of plausibility or policy. But intriguingly, there is a different route into the rationale for use of the actual functionalities of the model, which does not depend at all on any emotive responses to the words or the futures.

This is because the four scenarios, initially perceived as four quadrants in two dimensions, are operationalised in terms of a selection of five recognisable real world variables, namely the age structure of the population, the advance of digital connectivity, the proportion of the population living in urban areas, fuel price, and vehicle efficiency (efficiency being defined in terms of fuel use per distance driven). Thus the futures are translated into five variables, capable of varying independently of each other, which have an effect on vehicle kilometres capable of being estimated. Users can choose which combination of these effects they want to investigate, and choose their own scenario labels to apply to the combination.

Therefore I see the scenarios as described a useful insight into the motives and ways of thinking of the authors, but not a necessary condition for usefulness of the model. In other words, the model would work in exactly the same way whether the scenarios are as defined
or not – or even if they had never been invented – and it works in a different way from that which would obtain if the initial two dimensions had remained the only ones to be modelled. The key question becomes one of the model as operationalised, not the model as conceived.

So taking the description above of the way in which the five variables operate, ‘five variables, capable of varying independently of each other, which have an effect on vehicle kilometres capable of being estimated’, I would make the following comments.

five variables…

It is explicit that these five are only a subset of all the variables known, or suspected, of changing car use. There is an implicit choice to exclude variables such as ‘social expectations’ or ‘attitudes’ which are difficult, at the current stage of knowledge, to quantify. There is also omission of some variables which are rather well-established in transport demand modelling, of which I’d mention: public transport fares and quality of service; provision of facilities for walking and cycling; provision of road capacity; levels of congestion. In some ways these are all similar to fuel prices. There are other factors similar to age structure, such as gender structure, education, and migration. There are other important external technologies comparable with digital communication. There are more extended definitions comparable with urbanisation (suburban form, distinctions between new and historic towns, housing design). There are also the various measures of income and economic activity, known to be important (though in some countries evolving new relationships or parameters), which I think are envisaged to be taken care of in the base-line trajectory.

I have never come across any model, of any kind, in which it was difficult to make such a list of things not in the model. If the core of the model is found to be useful, it will almost certainly accrue additional variables and functions, and it is a great benefit that the model structure itself lends itself easily to such evolution. The key question is why these five variables as a starting point. I think I would distinguish them into two different groups.

Age structure, Digital connectivity, Urbanisation

The merit of treating these is very strong, namely that these are ‘big’ social trends, known to be rapidly changing, and rarely treated explicitly in transport demand forecasting. Sometimes the past trends, or more often levels, of these factors must, in some sense, be implicit in estimation of relationships, but their contribution is elusive, functional form
unspecified, and the resulting parameters are not easy to change to investigate possible
different future trends. It is a commonplace that the aging population, growth of cities, and
digital revolution are of huge global significance, and as soon as one has seen a model such
as this which allows thought about their future movement, it makes one dissatisfied with all
models not doing so.

The second more specific advantage of focussing on these variables is that age structure,
urbanisation, and digital connectivity have already emerged empirically, by hypothesis, and
theoretically, among the leading themes in the international research on lower rates of
growth, or declines, in car use\(^9\). Thus their inclusion in a model enables consideration of
factors which might reduce traffic growth or absolute volumes in the future, as distinct from
the dominant forecasting trends in models developed over the last 30 years, which have
almost all been more concerned about the increasing traffic volumes which they almost
always predict. These variables provide a framework which helps to fill a gap in thinking
about the future direction of traffic growth.

The inclusion of these three variables as explicit relationships and explicit manipulation is the
core strength of the model – the justification for its existence.

*Fuel price and fuel efficiency*

By contrast, it is not quite universal but very common indeed for transport models to include
fuel price as an explicit variable affecting future demand, and perhaps less common but still
widespread to include a measure of fuel efficiency, at least as modifying price per litre into
price per kilometre. Energy cost shares with the first group of variables an expectation that
future changes may well be big, and may well put downward pressure on car use, and has
wider global significance, touching on carbon emissions and climate change, energy security,
and global politics. In addition, any calculation of the financial implications of the scenarios
would need a handle to consider the tax component of the price of fuel, and the revenue
arising from it.

\(^9\) See, for example, Stokes, G (2013), Prospects for future levels of car access and use, *Transport Reviews*, 33 (3)
360-375, who reports results of a model “which gives transparent future scenarios, at the aggregate national
level. The model is based on age cohorts, with some degree of behavioural inertia, as the means of
incorporating the most frequently noted age-related feature of the new trends. This is modified by different
readings of the differential effects of population growth and location, immigration, and policy effects. Account
is also taken of different assessments of the future track of Western Economies and of the impacts that
economic factors have on travel behaviour...”.
Thus it is difficult to think that the objectives of the model could be realised without an explicit inclusion of fuel price, and fuel consumption, hence vehicle efficiency. In terms of fitness for the purpose of the scenarios as defined, inclusion of fuel price and economy is essential. But it seems to come in a different category, and prima facie not obviously bigger in size, or more important in thinking about the future, than other variables that in transport modelling terms would often be described as generalised cost. Thus the inclusion of fuel price does lead naturally to consideration of whether other generalised cost-like variables common in transport modelling should also be included.

At this stage my feeling is that a good case has been made for inclusion of the five independent variables used, and that there is scope for usefully extending this list, especially in transport cost-like variables – money prices, travel times, service levels, reliability, comfort and convenience, and the associated values (including the effect of digital connectivity on values of time, which significantly changes the relative advantage of public transport journeys). There are suitable default values from empirical research for initial development. I would see this as suitable for steady and thoughtful progress over a period of a year or two, rather than a drive for rapid implementation. Keeping to the idea of a broad-brush overview, an early stage could be to consider an overall indicator of the user cost of car use, and an overall indicator of the user cost of transport alternatives to car use, to sit alongside the digital non-transport alternatives already included. The modelling implications are not trivial, but nor are they disproportionately difficult. This would also help as a first stage of considering mobility as multi-modal, not confined to car use, which could turn out to be an increasingly important discriminator among the scenarios.

...capable of varying independently of each other...

It is easy (as in all such models) to think of ways in which the variables are not completely independent of each other. Age structure is related to digital take-up, which in turn is likely to take different forms in urban and rural contexts or in conditions of high and low fuel costs, which in turn would be different in urban and rural locations, and affect fuel efficiency, which is a damping effect on fuel price... and so on.

The fact that variables are correlated or interacting does not stop the variables being treated as ‘independent’ in calculations, which is done here, but does mean that some combinations are more plausible than others. There are two ways of handling that – either to include feedback loops into the model, or even more simply, to leave it to the users to think through the
internal consistency of their choice of values, perhaps with the aid of some flagged up reminders – ‘are you sure you want to assume both high fuel prices and low vehicle efficiency?’. No forecasts would be accepted without going through a discussion of this form, and there is an advantage of making this a discussion rather than internalising it into the hidden parts of a model. I would suggest that a commentary in the manual would be the simplest necessary level of treatment – ie suggesting that users always consider whether their chosen input values are plausible in combination (but not stopping them from choosing what they want), with the bigger issue of feedback loops in the model considered as a longer term possibility.

…capable of being estimated…

**Old-young and urban-rural splits** are provided with good data on present and past VKT, and therefore can be given an empirical base rather simply. I have not checked the detailed questions of accuracy or reliability of the New Zealand data used.

I suspect both may somewhat *under*estimate the calculated impact on the various scenarios, due to different forms of positive feedback, synergy, or dynamic effects, for which there is some empirical support. In other research, an age effect on car use has been seen in a widespread finding of lower car use among young people, especially male, with an indication that this is ramifying through the age cohorts as they get older. There are also quite separate age effects, due to the improving health of the younger old, and the increasing proportion of the elderly who are very old. The urban effect is seen in a tendency especially in successful inner cities for economic growth to be associated with rapid inward migration, increasing employment, higher densities, more local travel and better public transport, together not just reproducing the existing tendency for urban car use to be lower, but increasing it. (This also has the effect of separating total population from total car use: one cannot calculate a per capita car use and simply multiply it by population, since the relationship depends on where growing population is located, and the consequence that areas accommodating extra population will, by that fact, have increasing density).

A model using age structure and urbanisation explicitly is well placed to include such effects as (or if) the evidence and interest in them becomes stronger: I think it is a potential development for the future. It would probably mean using finer age groups, perhaps by decade, and segmentation into different types of urban (and rural) areas. The potential to do that can be kept open without difficulty.
**Degree of digital connectivity** is at present less well provided with empirical support, though that is emerging very quickly. At present the model operates more as addressing the question ‘what if a greater proportion of current travel diverted to online’, with a pragmatic limit on plausibility, than ‘what is the effect of greater online activity’, an empirical question to which the answer will be context-dependent. The empirical base of car use defined by journey purpose seems a good way of opening the door to that, giving the possibility of thoughtful distinctions such as the potential of home-working replacing some commuting, on-line shopping replacing some shopping trips, on-line feedback on student essays, business meetings, and forms of keeping in touch with distant relatives. It also provides a space for considering the impact of ‘working on the train’, and real-time information, on the relative attractiveness of public transport and driving, to the extent that modal choice is implied in a calculation of VKT.

Having opened that door, however, there will inevitably be discussion about the credibility and evidence base of different choices of parameters, so I would see a watching brief on research on this topic as being essential. There are also some forms of digital connectivity which are not a more-or-less straightforward substitution of two ways of delivering the same need, such as buying music on line or in a shop, but are new forms of activity for which there is no real current travel-based equivalent, such as massively multi-player online games involving social relationships (albeit sometimes rather strange ones) with other real people. The interaction with travel in this case may be more of a question of using up time which might otherwise be used for quite different activities.\(^\text{10}\)

**Fuel price and fuel efficiency** are both provided with a very large empirical data base, partly based on the calibrated coefficients of generalised cost in equilibrium transport models, and (more reliably, in my view) by short-term event-based surveys, and longer term econometric analysis of traffic levels, and fuel sales, using aggregate time series data. The best econometric evidence has an international literature, and gives well informed elasticities with respect to price (and supporting evidence with respect to incomes, and some cross-elasticities). At present the fuel price elasticity assumed in the model, -0.04, is the same as that used in the Revenue Forecasting model from which the base trajectory is produced. My

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\(^{10}\) It is an interesting possibility that such games could be a way of investigating (some of) the behaviours which could exist in the four scenarios considered, and others. This would not however be a viable development of the current model.
provisional view is that this elasticity is much lower than would be expected, and I would encourage the use of a higher value closer to the results reported in international research literature. This would have the effect of giving the ‘energy cost’ dimension of the scenarios a bigger impact as compared with the ‘digital communication’ dimension, which seems reasonable. However there are some solvable, but not trivial, technical issues in exactly how that should be done, and what values should be taken. These are discussed in the Appendix.

Conclusion

The model is a simple, aggregate, easy to use and mostly transparent tool for thinking about some important influences and trends. I view it as a useful and professional contribution to informing wider discussion of the range of futures which might confront the population of a developed, changing, market economy.

In the short run, there are some clarifications about the way the model operates arithmetically which must be given, and an issue about the fuel price elasticity which must be clarified, and (depending on the clarification) should either be changed or explained better: I would recommend changing it. There should be a rather carefully drafted caveat about interpretation and use and status, designed to give maximum encouragement and help to users to frame their own choices and assumptions, which would include the question of interaction among the five current variables, and a reminder of some of the variables which have a significant effect on VKT but which are not incorporated in the model. It would be useful to make it clear that that the results do not have the status of ‘official’ forecasts or assessments.

Less immediately, I think an additional strength of the model is that it lends itself well to thinking about a substantial number of improvements, and I have listed some of my own suggestions, as a programme of possible future development but not as an essential immediate change. While I find the current state of the model to be a very helpful way of focussing thought on future scenarios, I am sure that the more successful that function turns out to be, the more interest will grow in developing and extending it.
Appendix: Elasticity of Traffic and Fuel Consumption with respect to Fuel Price

The focus in the international literature on demand and revenue elasticities with respect to fuel price has tended to be on the progression of ‘short term’ elasticities typically a year, up to a ‘long term’ corresponding with a final equilibrium when detectable demand responses have settled down: empirically this is usually found in the range 5-10 years for around 95% of the effect (in most analyses asymptotic relationships are used, so one never actually reaches 100%). There is a separate literature on seasonal variation, and on the volatile initial demand responses that can apply in the first days or weeks after a price change, but these need to be considered separately from the effects which are important for forecasting over a number of years. Although as always there is a variation of results from study to study, and country to country, elasticities of the order of -0.04 would be seen as at the very low end of those results, even for the short term. The most salient results for revenue and demand forecasting are that (a) long term elasticities are of the order of twice as high as short term elasticities (due to delays in people fully adapting their behaviour), and (b) fuel consumption elasticities are of the order of twice as high as traffic volume elasticities (partly due to fuel price increases/decreases leading to greater/lower fuel efficiency).

It is possible, of course, that fuel price changes in New Zealand genuinely have very much smaller effects than elsewhere, and that possibility should not be excluded, but I think it is more likely that there are some specification and data issues in analysis which has been carried out essentially for a different purpose. The NLTFT Revenue Forecasting Model, as I understand, is mainly focussed on periods of less than three years ahead, using quarterly data. I have seen some statistical analyses carried out by Covec\textsuperscript{11} for the Ministry of Transport of which some of the functional forms were indeed capable of producing separate estimates of short and long run demand elasticities, but the results were not reported in this format, and the short run would, I think, be specified as a quarter, unlike the single year which is often used in the international literature. This means that the (very) short term can be dominated by a high volatility compounding both seasonal effects and immediate responses to price changes, and the long run equilibrium – if it is of the order of 5-10 years – is never material. The report’s footnote 13 says briefly “The estimated price elasticity of -0.04 also seems broadly acceptable”, but the values of elasticity are otherwise not discussed, or mentioned.

\textsuperscript{11} Schiff A and Small J, (2014) Review of the NLTFT Revenue Forecasting Model, Covec, for the New Zealand Ministry of Transport
The VKT model, with its 28 year perspective, does need to think in terms of longer time periods, and its year by year outputs suggest that the best way of handling this would be a cumulative build-up of price effects operating over a few years after a change in price. There are two technical issues that would then need solving.

First, the model should use not a single elasticity, but an elasticity function reflecting the empirical results that fuel price impacts build-up cumulatively from a lower short term impact to a higher longer term impact. (This is an issue for all equilibrium models used for forecasting over a number of years, though it is usually ignored). This means that strictly one should not apply each year’s price to the demand for the same year, but should in a more complex way roll forward the build-up over a number of years. I haven’t used Excel for this sort of calculation with a ‘memory’, but I think it should be easy, and not have a detectable effect on the virtually instant outputs. Regression models based on time series data can always have such relationships, but only if they have some form of distributed lag structure and maintain these lags when used in forecasting mode.

Secondly, comparison with the trajectory produced from the separate Revenue Forecasting Model needs rather careful control of the arithmetic, especially if a different demand elasticity is being used as well as different assumptions about the future progress of fuel price. There is no inherent difficulty about that, but users will be interested to know whether it is the different elasticity or the different fuel price which is mainly responsible.

For a sensitivity test using international default values in advance of NZ-specific long term estimates, I would offer the conclusions of one of the reviews I was involved in:\(^\text{12}\):

“If the real price of fuel rises by 10% and stays at that level, the result is a dynamic process of adjustment such that the following occur:
(a) Volume of traffic will fall by roundly 1% within about a year, building up to a reduction of about 3% in the longer run (about 5 years or so).
(b) Volume of fuel consumed will fall by about 2.5% within a year, building up to a reduction of over 6% in the longer run.”

No studies from New Zealand were available specifically for that review, but it had a strong international basis and the results were consistent with work done by others. I would in any case be interested to learn of any relevant empirical analysis on this topic to be carried out in New Zealand.

About Concept

Concept Consulting Group Ltd (Concept) specialises in providing analysis and advice on energy-related issues. Since its formation in 1999, the firm’s personnel have advised clients in New Zealand, Australia, the wider Asia-Pacific region and Europe. Clients have included energy users, regulators, energy suppliers, governments, and international agencies.

Concept has undertaken a wide range of assignments, providing advice on market design and development issues, forecasting services, technical evaluations, regulatory analysis, and expert evidence.

Further information about Concept can be found at www.concept.co.nz.

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1 Introduction

The Ministry of Transport has retained Concept to review:

- the spreadsheet “Demand modelling data june years ver for review.xlsm” (“the spreadsheet”)
- the draft report “Future demand quantification model - user guide and technical appendix.docx” (“the user guide”).

Both files are dated 10 October 2014.

Together, these files describe a model of future private road vehicle travel (“the model”).

The Ministry has used the model to quantify five future travel scenarios – a baseline and four alternatives (“the scenarios”). The intention is that all these scenario quantifications should be credible.

The Ministry has specified that the scope of the review includes:

- the conceptual design of the model
- the implementation of the model in the spreadsheet
- the understandability and usability of the spreadsheet and user guide.

However, reviewing the scenarios or the process by which the scenarios were developed has been placed out of scope.

Concept has reviewed the model, spreadsheet and user guide. The key findings are that:

- the basic approach is sound
- there are possible problems with regard to the treatment of price elasticity, which should be addressed either by:
  - adding caveats
  - carrying out further analysis to seek to determine the true level of price elasticity, or
  - changing the structure of the model to make price elasticity an explicit assumption
- no errors have been identified in the spreadsheet
- overall, the spreadsheet is clearly laid out and easy to use. The user guide is also helpful. Some minor changes to support understandability and usability have been suggested.

The remainder of this document sets out Concept’s detailed findings.
2 Conceptual design

2.1 General support for the approach

The basic approach – i.e. taking a baseline model of private road vehicle travel and varying the model parameters to implement the various scenarios – appears sound.

The ways in which population aging, digital connectivity and urbanization are modelled all appear sound.

The model produces the required outputs – that is, projections at an annual, national level of:

- private road VKT per capita
- total private road VKT.

2.2 Possible problems with regard to price elasticity

Under the Covec model, VKT is quite insensitive to fuel prices. The model projects that, over a ten-year timeframe, and all else being equal:

- a 10% increase in real petrol prices would result in an 0.7% decrease in private petrol VKT
- a 10% increase in real diesel prices would result in an 0.8% decrease in private diesel VKT.

In economic terms, the implied long-term price elasticity of demand is about -0.07. This appears to be a low estimate of elasticity, by international standards. Estimates of the long-term price elasticity of private VKT are often several times larger. For instance, Espey, in her 1998 paper “Gasoline demand revisited: an international meta-analysis of elasticities” estimated that the average long-term price elasticity of demand for gasoline was -0.58.

There is no consensus on the long-term price elasticity of private VKT in the New Zealand context.

- Kennedy and Wallis, in their 2007 report “Impacts of fuel price changes on New Zealand transport”, recommended that a long-term elasticity of -0.24 should be used.

- On the other hand, Stephenson and Zheng, in their 2013 report “National long-term land transport demand model”, noted that Kennedy and Wallis’s estimate was probably too high and recommended that a long-term elasticity of -0.08 should be used. Stephenson and Zheng could potentially be correct – however, if so, it is not clear why private vehicle travel is so much less price-sensitive in NZ than in other countries.

- Covec’s model, as set out above, implicitly uses a price elasticity of -0.07. However, this should not be taken as strong evidential support. Covec’s model was not designed for the specific purpose of estimating elasticity. It may have attributed part of the price effect over recent years to a time trend effect and/or GDP effect. Further, Covec primarily intended its model to be used for forecasting over the next 3-4 years – rather than for forecasting over

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1 There might be debate about the values of the input assumptions used to model digital connectivity effects, but that debate is outside the scope of this review.

2 This means that, all else being equal, a 1% increase in delivered fuel prices, in real terms, is expected to result in an 0.07% decrease in private VKT per capita. A large negative elasticity means that demand is very sensitive to price: an elasticity close to zero means that demand is largely insensitive to price.


multiple decades, under conditions very different from those that have held in the recent past.\footnote{Covec’s report states that “the primary requirement is for forecasts... with a high degree of accuracy over the next three years. Forecasts over a ten year period are also required, but greater uncertainty beyond the three year horizon is acceptable.” Forecasts over a multi-decadal period were not initially contemplated. However, Covec was subsequently asked to extend the forecast out to 30 years – resulting in the version of the Covec forecast that was used to produce the model described in this document.}

The Ministry uses a wide range of fuel price assumptions in its scenarios. One scenario assumes that real petrol prices will rise to:

- $4.4 per litre in real terms by 2020
- $12.9 per litre in real terms by 2040.

Real diesel prices rise correspondingly.

Although Concept has not been asked to comment on the scenarios, Concept notes (in the hope that it may be helpful) that:

- such an increase in delivered petrol and diesel prices is not consistent with the Ministry of Business, Innovation and Employment’s projections,\footnote{See http://www.med.govt.nz/sectors-industries/energy/energy-modelling/modelling/pdf-docs-library/reference-scenario/energy-prices-414-4kb.xls.xls. Even in MBIE’s ‘high oil price’ scenario, the delivered price of petrol is only assumed to be $2.9/litre (in 2014 dollars) by 2020.} or with many projections internationally
- if real petrol and diesel prices did increase to such a high level, it is likely that travellers would respond by:
  - using much more efficient vehicles
  - using alternative fuels (such as wood, coal or natural gas derivatives, ethanol, and/or electricity) which should be available at a substantially cheaper price\footnote{The implication may be that the elasticities used in the Covec model are more reasonable for VKT than for petrol and diesel VKT.}
- scenarios were explicitly intended to represent credible possibilities, but it is not clear that petrol prices doubling by 2020 would meet that test.

Concept suggests that there are several options for resolving this issue. The Ministry could:

- proceed using the current modelling approach, while noting that there is considerable uncertainty about both the future prices of transport fuels and the sensitivity of VKT to these prices
- carry out further work to estimate the sensitivity of VKT to petrol and diesel prices, based on data from recent years, and then decide how to proceed further
- change the model so that it explicitly includes the sensitivity of VKT to petrol and diesel prices as a parameter that can be set by the user. This parameter might be held constant across scenarios, or might take different values in different scenarios. For instance, the scenario that currently assumes a 500% increase in fuel prices might instead assume a 250% increase in fuel prices, but with double the current level of elasticity.

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\footnote{Covec’s report states that “the primary requirement is for forecasts... with a high degree of accuracy over the next three years. Forecasts over a ten year period are also required, but greater uncertainty beyond the three year horizon is acceptable.” Forecasts over a multi-decadal period were not initially contemplated. However, Covec was subsequently asked to extend the forecast out to 30 years – resulting in the version of the Covec forecast that was used to produce the model described in this document.}
The best way of implementing the third option (i.e. changing the model) might be to adopt the following structure (in place of the current specification):

$$\ln(V_y) = k + \alpha \ln(P_y)$$

where:

- $V_y$ = private VKT per capita in year $y$
- $P_y$ = real petrol price in year $y$
- $\alpha$ is the assumed price elasticity of VKT
- $k$ is a constant, chosen so that $V_{2015}$ is equal to the average value of $V_y$ over the last few years for which VKT data are available.

In the absence of petrol price changes, this model would simply project that private VKT per capita would remain constant indefinitely. The Ministry could then apply other effects such as aging, digital connectivity and urbanization, just as it does now.

One attraction of using this structure would be its simplicity. In particular:

- there would no longer be a need to model petrol and diesel VKT separately – both would be covered by the single equation above
- there would no longer be a need to source projections of GDP or imports
- there would no longer be a need to handle quarterly data – all quantities would be dealt with at an annual level.

2.3 Choice of drivers

The choice of drivers is part of the design of the scenarios, which the Ministry has placed out of scope. Nevertheless, Concept suggests (in the hope that it may be helpful) that:

- the population ‘aging effect’ should be removed from the list of drivers, as the model results are largely insensitive to it
- the ‘urbanization effect’ could be removed from the list of drivers, as the model results are somewhat insensitive to it.

If the Covec model is retained, then:

- GDP could potentially be added as a driver, on the basis that:
  - it could vary between the scenarios
  - it would affect the projections of VKT per capita
  - even if the Ministry did not wish to include GDP as a key driver of its scenarios, other users of the model might want to experiment with its effect
- population could potentially be added as a driver, on the basis that:
  - it might vary between the scenarios
  - while it would not affect the projections of VKT per capita, it would affect the projections of total VKT
  - even if the Ministry did not wish to include population as a key driver of its scenarios, other users of the model might want to experiment with its effect.
2.4 Minor comments

The VKT projections are sensitive\(^9\) to the factors used to convert from \{all petrol/diesel travel\} to \{private petrol/diesel travel\}. It would be useful to provide some evidence for the factors used, which are:

- 93.5% for petrol
- 41.4% for light/medium diesel.

The model documentation should make it clear that the digital connectivity effect is incremental over the other effects. For instance, in a scenario where all digital connectivity inputs are set to \(-50\%\), projected VKT may be even less than half the baseline level, as a result of other effects such as fuel price increases.

Ideally, the fuel efficiency effect and the energy price effect would not be calculated separately and multiplied together. Rather, the two drivers would be combined to calculate a single effective fuel price, which should then be fed into the model. However, we do not anticipate that this change would make a significant difference to model results.

Likewise, the aging effect and the digital connectivity effect ideally would not be calculated separately and multiplied together. Rather, the model would assess the overall effect of the two changes combined. But again, we do not anticipate that this change would make a significant difference to model results.

\(^9\) The ratios between baseline and alternatives are not sensitive to these factors, but the \textit{absolute amount of} projected travel is sensitive.
3 Implementation

The Covec models, and the various data inputs, appear to have been transferred correctly into the spreadsheet.

The aging effect, digital connectivity effect, urbanization effect, energy price change effect, and fuel efficiency effect all appear to have been implemented correctly.

We have not audited all the cells in the spreadsheet, but have spot-checked a sample and found no errors.
4 Understandability and usability

4.1 The spreadsheet

Overall, the spreadsheet is clearly laid out and easy to use.

The meanings of some of the input cells on the ‘Scenario testing’ tab are not entirely clear. It would be helpful to add explanations (perhaps as mouseover comments) of:

- the meaning of the ‘Aging effect’ (based on the text from p10 of the user guide)
- the exact meaning of the ‘Energy price change effect’ (based on the text from p11-12 of the user guide, and making it clear that the effect is incremental and in real terms)

When the ‘set to baseline’ button is pressed, the grey bars on the two graphs on the ‘Scenario testing’ tab seem to show a meaningful trend, but in fact only show tiny rounding errors. This problem could be avoided in various ways – e.g. by fixing the range of the secondary axis, or by modifying formulae in the ‘Scenario output’ sheet.

Minor nit-picks on the ‘Scenario testing’ tab are that:

- it would be helpful to add four more buttons, each of which set the input cells to the appropriate values for one of the four alternative scenarios
- formatting could be slightly improved (e.g. to show some text that is currently obscured)
- cells that are not meant to be modified could be pushed further out of sight
- some terminology could be standardised (e.g. ‘VKT per capita’ instead of ‘passenger km per capita’ or ‘per capita km’, M instead of mn for million).

The Ministry could spend more time tidying up (or removing) content in the other tabs if it wished. However, it might not be the best use of time, as most users will have little need to go beyond the “Scenario testing” tab.

It would, however, be appropriate to remove the personal names from the “Scenario inputs” tab.

4.2 The user guide

The user guide is a helpful document. In fact, it goes well beyond being a user guide and takes the role of a clear but detailed explanation of the function and form of the model. The Ministry might like to consider labelling it as a “technical report” rather than a mere “user guide”. At this point, it would probably be preferable to move the explanation of how to use the model (pages 9-13) from the technical report into the spreadsheet itself.

The structure of the user guide (or technical report, as it may be) appears to still be evolving. It may be helpful to place a concise explanation of the structure of the model ‘front and centre’. Topics such as the way in which the model was developed, and the background behind each of the various factors, can be postponed until later in the document.

We have not audited all the formulae in the user guide, but have spot-checked a sample and found no errors.

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10 The same issue also arises in the ‘Graphs’ tab.
11 For example, the formula in cell AZ17 of the ‘Scenario testing’ tab could be changed from =AY17/H17-1 to =if(abs(AY17/H17-1)<0.0001,0, AY17/H17-1), and so forth.
Other comments are that:

- if possible, the original Covec report should be published and then cited in the user guide
- at any rate, the coefficients of the Covec regression models should be provided in the user guide
- a copyright statement, disclaimer and version number should be added
- a quick proofread before publication would be worthwhile.