MINISTRY OF TRANSPORT
TE MANATŪ WAKA

Vehicle Fleet Model

(Version 202405, replacing Version 202204)

October 2024

Purpose of the model

This model projects the composition of the future motor vehicle fleet on the road, its travel, energy use (fuel and electricity), and greenhouse gas (GHG) emissions.

The model was previously known as the Vehicle Fleet Emissions Model (VFEM). The name change reflects the model's multiple uses.

This document describes what the model does, what input data it uses, what it produces, and how it works.

Software used

☐ **Excel**

☐ **Tableau**

☑ **SAS**

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1. Model purpose

The Vehicle Fleet Model (VFM) projects the future composition of New Zealand's motor vehicle fleet, vehicle kilometres travelled (VKT), energy use (both fuel and electricity), and greenhouse gas (GHG) emissions. It also projects changes in the vehicle fleet through registrations (vehicles added to the fleet) and scrappage (vehicles removed from the fleet). Its projections are at the national level, with disaggregation into various vehicle sub-categories.

In this update, VFM reports actual and estimated data for 2001 to 2022[1] and projects data from 2023 to 2055, with the measures disaggregated by:

- vehicle type
- power type
- engine size bracket (light vehicles) or gross vehicle mass bracket (trucks and buses)
- vehicle age
- vehicle import status (i.e. new or used).

Appendix 1 outlines the vehicle types, vehicle sizes, and power types included in the model.

2. Model updates

We have updated the projections of VFM for the base, fast, and slow electric vehicle (EV) uptake scenarios, where:

- the base EV uptake scenario aligns with major global EV trends[2]
- the fast EV uptake scenario is consistent with motor vehicle industry's forward purchase plans in New Zealand
- the slow EV uptake scenario reflects slower global EV trends.

The model results can be found in a spreadsheet published alongside this document. The raw data (wem202405) sheet contains detailed model output data, allowing users to perform customised analyses. Summary results for GHG emissions (CO_2-e), vehicle numbers in the fleet, and VKT can be found in the relevant sheets.

[1] In this update 2022 is the last historic year, in line with New Zealand's GHG inventory data (NZ GHG inventory).
[2] We have obtained information on global EV uptake trends through a literature review.

The model results include the following policy measures in this update[3]:

- Clean Car Discount Scheme (CCD) and Clean Car Importer Standard (CCIS)
- Road User Charges (RUC) exemption for electric vehicles
- Decarbonising the public transport (PT) bus fleet strategy
- New Zealand Emissions Trading Scheme (NZ ETS).

Please refer to the generic notes on the notes sheet for a brief description of these policy measures and for further analysis.

3. Model Input data

As illustrated in Figure 1, there are many inputs to VFM. They include:

- historic[4] vehicle fleet mix by vehicle type, size, age, and power type
- historic VKT trends
- historic vehicle scrappage patterns
- historic vehicle registration[5] patterns
- historic GHG emissions from road transport (from the GHG inventory data)
- historic fuel use by road transport[6]
- high-level projections of vehicle numbers and VKT by vehicle type
- high-level projections of vehicle registration mixes
- historic and future energy use (fuel and electricity) per 100 km travelled by a vehicle
- historic and future emission factors for fuel and electricity.

[3] The cut-off date for policy inclusion in this update is 31 May 2024. Although the Clean Car Discount (CCD) was repealed on 31 December 2023 and the Road User Charge (RUC) exemption for light EVs was repealed on 31 March 2024, their impacts will last for a long time, as the low or zero emission vehicles introduced into the light vehicle fleet due to these policies will remain in the fleet for many years.

[4] 'Historic' here refers to the time period before the first projection year. In this update, the historic years are from 2001 to 2022.

[5] Registrations refer to the vehicles newly added to the fleet.

[6] Data is sourced from MBIE's oil statistics (NZ oil stats), with rail diesel use data being provided by MBIE.

Vehicle Fleet Model

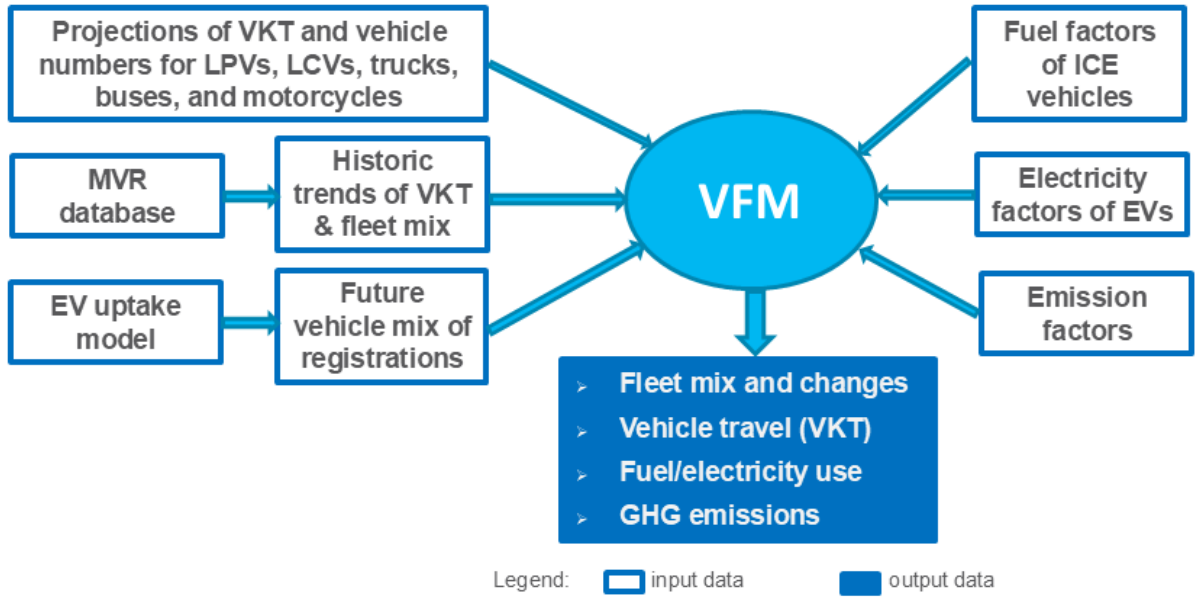

Figure 1: A schematic modelling process of VFM

Data on historic fleet composition, VKT, scrappage and registrations are obtained from an analysis of the Motor Vehicle Register (MVR) database. The emission factor data (kg CO_2-e/litre of fuel or kg CO_2-e/kWh of electricity) is provided by the Ministry of Business, Innovation and Employment (MBIE). Energy economy factors for different vehicle categories are sourced from research commissioned by the Ministry[7].

When developing the high-level projections of VKT and vehicle numbers for the five vehicle types (Figure 1), projections for population and gross domestic product (GDP) are the key inputs, provided by MBIE (refer to Appendix 2). These vehicle types include light passenger vehicles (LPVs, generally cars and SUVs), light commercial vehicles (LCVs, generally vans and utes), trucks, buses, and motorcycles.

The VFM then separates the truck category into two subcategories based on historic trends: medium trucks and heavy trucks (refer to Appendix 1) to better align with the input data from the EV uptake projection model. As described in section 4, additional data inputs are required in the EV uptake model, and for estimating the impacts of policy measures (for example, fuel prices).

[7] Metcalf J. and Sridhar S. (2016), Real world energy use projections for VFEM; Report prepared for Ministry of Transport.

4. Methodology

VFM is a SAS-based bottom-up model[8]. It projects key fleet measures by vehicle sub-categories (refer to Figure 1 and Appendix 1) in multiple steps. The first step is to input the projections of VKT and vehicle numbers (fleet size) for the five broad vehicle types as shown in Figure 1. We develop these projections in a separate process.

4.1. High-level projections of VKT and vehicle numbers by vehicle type

Both the New Zealand Household Travel Survey data[9] and the New Zealand Census data on household types are analysed. This analysis produces historic person-km data for household (non-commercial use) travel modes, including light vehicle drivers, motorcyclists, and public transport (PT) users. Projections of their person-km are then developed by assuming the same growth rate as population growth, which are adjusted by assumed changes in average travel per capita.

VKT estimates for the five broad vehicle types for historic years are aligned with the Ministry's odometer-reading-based VKT data, and their historic vehicle numbers are aligned to the latest MVR data. The historic data can be found in the Ministry's annual fleet statistics[10].

Projections of total VKT for LPVs are calculated as the sum of projected VKT for household LPVs, and projected VKT for commercial LPVs. Generally, projections of VKT for household LPVs are developed by assuming the same growth rate as the growth of household driver person-km. This assumption is reasonable, as household drivers' travel will determine the distance travelled by household light vehicles. However, projections of VKT for commercial LPVs are based on the same growth rate as GDP growth. Projections of their vehicle numbers are developed using a similar approach, i.e., by assuming the same growth rate as their VKT.

A simple approach is used for the projections of VKT and vehicle numbers for LCVs by assuming the same growth rate as GDP.

Projections of VKT and vehicle numbers for trucks are developed by assuming the same growth rate as road freight tonne-km. Separate freight models are used to produce the freight tonne-km projections, with population and GDP projections as key data inputs. More information on the freight models can be provided upon request.

[8] A bottom-up modelling approach starts at the detailed and basic level and works upwards to form a comprehensive picture or solution.
[9] Please refer to https://www.transport.govt.nz/statistics-and-insights/household-travel
[10] Please refer to https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/annual-fleet-statistics/

Projections of bus VKT and vehicle numbers are made primarily based on the same growth rate as the PT person-km, while projections of VKT and vehicle numbers for motorcycles are developed by assuming the same growth rate as motorcycle person-km.

4.2. Projections of EV uptake

Projections of EV uptake are one of the key components in VFM modelling process, which we produce externally using a separate EV projection model. This EV model projects the relative shares of different power types in registrations for various vehicle types, based on total cost of ownership (TCO) analysis[11].

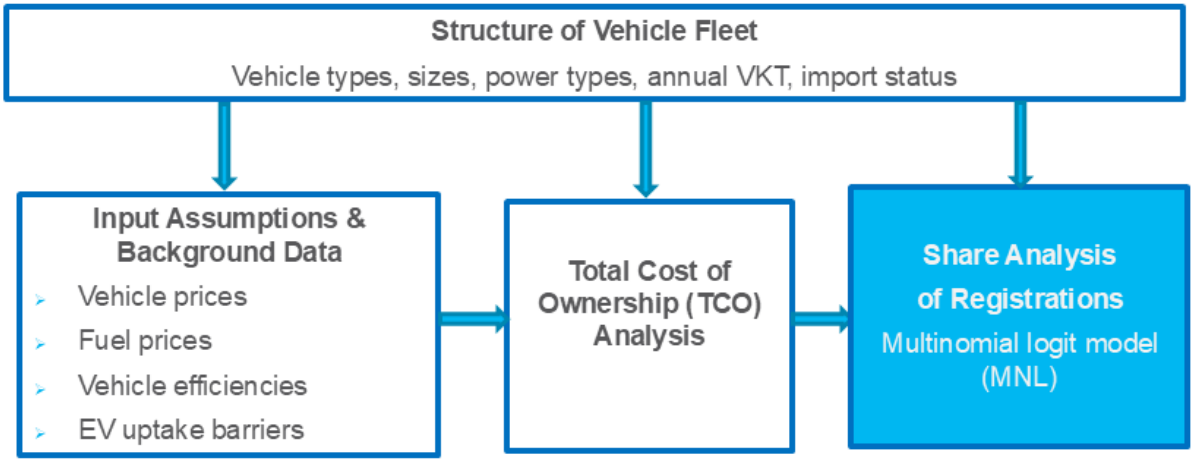

Figure 2: Structure of EV uptake projection model

As shown in Figure 2, the EV model consists of four main components: structure (composition) of vehicle fleet, input assumptions and background data, TCO analysis, and share analysis of registrations.

Structure of vehicle fleet

The EV model estimates TCO for the following vehicle sub-categories:

- Vehicle type: LPVs, LCVs, and heavy commercial vehicles (HCVs, including trucks and buses)
- Power type: battery electric vehicles (BEVs), petrol and diesel plug-in electric vehicles (PHEVs), petrol and diesel internal combustion engine (ICE) vehicles

[11] TCO includes all the costs associated with owning a vehicle, such as the upfront purchase price, operation and maintenance costs, and depreciation. For battery EVs and plug-in EVs, a penalty is applied when estimating their TCO regarding driving range limitation and the limited vehicle models available in the market.

- Import status: new or used
- Vehicle engine size band or vehicle weight band[12]
- Average annual distance in the first year of registration: short, medium, and long (refer to Table 1)

Table 1: Average annual distance of vehicles in the first year of registration (km per annum)

Vehicle type	Short	Medium	Long
LPV	10,000	25,000	35,000
LCV	15,000	30,000	50,000
HCV	30,000	50,000	80,000

Input assumptions and background data

The EV model takes a scenario approach and makes a set of assumptions for the base, fast and slow EV uptake scenarios. Assumed petrol and diesel prices in future years can be found in Appendix 2. The medium projections of fuel prices, excluding the ETS component, are provided by MBIE. The New Zealand ETS unit carbon price is one component of the fuel prices. The ETS price pathway used in this update is same as the Reference scenario in MBIE's EDGS 2024[13].

Concerns about EV driving range and the limited EV models available in the market are barriers to EV uptake. Relevant penalties are applied when estimating the TCO of EVs.

TCO and registration share analysis

After taking assumptions of all cost components and penalties, the EV model estimates TCO (in $/km) for each vehicle sub-category. A multinomial logit model[14] is then applied to the TCO to determine the demand for each power type of vehicle.

The utility (U) of individual i who selects vehicle option j is given by:

$$U_{ij} = V_j + \varepsilon_{ij}$$

[12] Vehicle sizes of LPVs and LCVs are based on engine size: less than 1600 cubic centimetres (small), 1600 cc to 3000 cc (medium), greater than 3000 cc (large). Vehicle sizes of trucks are based on gross vehicle mass (GVM): less than 15 tonnes and greater than 15 tonnes. All buses are analysed in one category.
[13] Please refer to https://www.mbie.govt.nz/assets/Data-Files/Energy/electricity-demand-generation-scenarios-2024-assumptions.xlsx
[14] A multinomial logit model is used when the outcome variable being predicted has more than two categories that do not have a given rank or order. This type of model predicts the probabilities of the different possible outcomes of a categorically distributed dependent variable.

where j is petrol ICE, diesel ICE, BEV, petrol PHEV or diesel PHEV. Here V_j is the general utility attached to vehicle option j and ε_{ij} is an idiosyncratic element of utility (or disutility).

From the standard multinomial logit model, the share of buyers (S) who select option j is given by:

$$S_j = \frac{P_j}{\sum_j P_j} = \frac{e^{V_j}}{\sum_j e^{V_j}}$$

In other words, the ratio of the utility of option j to total utility is equal to the share of the buying population (P) who choose that option. Thus, the share of buyers choosing any option j can be expressed as:

$$\ln(S_j)=\alpha_j + \sigma \ln(U_j)$$

where α is a calibration parameter and σ is the elasticity of the share of buyers choosing option j with respect to the utility associated with that option. The price (in this case TCO) can be used as a substitute for utility (U_j).

New Zealand may face supply constraints for used EVs from Japan and these constraints are analysed based on historical EV registrations in Japan.

4.3. VFM simulation process

To project vehicle fleet composition in future years, the VFM uses historic vehicle fleet breakdown as the base data, specifically for the fleet years from 2001 to 2022. The process works through each projection year up to 2055, starting with the most recent, to determine the size and makeup of the future vehicle fleets. The steps that the model follows for each projection year are as follows:

- Use the recent vehicle scrappage rate (generally the last three years' averages, e.g. over 2020 to 2022) to calculate how many existing vehicles will be scrapped and how many will survive to the next modelled (projection) year.
- Determine how many vehicles of each type (LPV, LCV, medium truck, heavy truck, bus, motorcycle) need to be registered into the fleet in the next projection year to ensure that the counts of each vehicle type match the corresponding fleet size projections.
- Use the projected fleet mixes from the EV model to determine the composition of vehicles that will be newly registered in each vehicle type.
- By integrating the results from the last three steps, VFM finally projects vehicle numbers in each vehicle sub-category for each projection year.

In the next stage, the VFM projects VKT for each vehicle sub-category based on the detailed projections of vehicle fleet composition. It initially projects VKT using the following formula, assuming the same average travel per vehicle as in recent historic data:

VKT in a vehicle sub-category = Average VKT per vehicle x Vehicle numbers

The model then adjusts the VKT so that total VKT in each of the five broad vehicle types will equal to the high-level VKT projections (section 4.1).

VFM then works out the amount of liquid fuel and electricity required for each specific vehicle category in each year using the following formula:

Energy use = Energy economy factor (energy use / VKT) × Vehicle travel (VKT in a year)

Finally, GHG emissions are estimated for each specific vehicle category in each year using the following formula:

GHG emissions = Energy use × Emission factor

4.4. Incorporating the impacts of policy measures

As described above, VFM in this update has considered the impacts of the following policy measures: Clean Car discount (CCD), Clean Car Import Standard (CCIS), Road User Charges (RUC) exemption to EVs, decarbonising public transport bus fleet strategy, and the New Zealand Emissions Trading Scheme (NZ ETS).

Fuel prices are part of the input data to the EV uptake projection model and ETS unit carbon price is one component of the fuel prices. Therefore, the impacts of NZ ETS are accounted through the EV model. Similarly, the RUC exemption for both light and heavy EVs[15] is included in the assumptions of the EV model when estimating TCO. Hence its impacts are also considered through the EV model.

The CCD policy was repealed on 31 December 2023[16]. We have estimated its impacts starting from 2023 as this is the first projection year in this update. The Government's changes to the CCIS[17] will

[15] For more information on RUC exemption policy, refer to https://www.transport.govt.nz/area-of-interest/environment-and-climate-change/electric-vehicles-programme
[16] For more information on CCD, refer to https://www.transport.govt.nz/area-of-interest/environment-and-climate-change/clean-cars
[17] For more information on the changes to CCIS, refer to https://www.transport.govt.nz/assets/Uploads/Outcome-of-the-review-of-the-Clean-Car-Importer-Standard-11-June-2024-Redacted.pdf

take effect from 2025 and are also considered in this update. Under the CCD, a vehicle purchaser receives a rebate for buying a low emission vehicle but pays a fee for a high emission vehicle. Similarly, under the CCIS, a vehicle importer receives a credit for importing a low emission vehicle into New Zealand but incurs a charge for a high emission vehicle. Consequently, both CCD and CCIS affect the upfront purchase price of an imported vehicle. The VFM has estimated the impacts of these policies on the demand for different power types by adjusting their vehicle purchase price elasticities.

Appendix 1: Vehicle types, vehicle sizes and power types in VFM

Vehicle type	Number of size bands	Power type
LPVs (cars and SUVs)	5 cc bands	• Petrol • Diesel • Petrol hybrid • Diesel hybrid • (Battery) Electric • Petrol plug-in hybrid • LPG/CNG
LCVs (vans and utes)	5 cc bands	
Motorcycles	2 cc bands	
Medium trucks (3.5 tonne <GVM<= 10 tonnes)	3 GVM bands	
Heavy trucks (GVM > 10 tonnes)	4 GVM bands	
Buses	3 GVM bands	

Notes: LPVs refer to light passenger vehicles; LCVs refer to light commercial vehicles; cc (cubic centimetres) refers to engine size; GVM refers to gross vehicle mass; (Battery) Electric mainly includes battery electric vehicles (BEVs); with a small number of fuel cell electric vehicles being included as well.

Appendix 2: Key economic data inputs to VFM

Year	Population (Medium)	GDP (2009/10$, Million)	Petrol price (2018$/litre)			Diesel price (2018$/litre)		
			Low	Medium	High	Low	Medium	High
2022	5,127,970	275,927	$2.32	$2.32	$2.32	$1.96	$1.96	$1.96
2023	5,149,490	281,638	$2.37	$2.40	$2.43	$1.75	$1.78	$1.81
2024	5,179,310	285,968	$2.36	$2.42	$2.47	$1.73	$1.79	$1.86
2025	5,217,280	293,431	$2.28	$2.36	$2.44	$1.65	$1.74	$1.83
2026	5,263,710	302,171	$2.27	$2.38	$2.49	$1.63	$1.75	$1.87
2027	5,309,290	310,348	$2.25	$2.39	$2.52	$1.61	$1.76	$1.92
2028	5,354,050	317,972	$2.23	$2.40	$2.56	$1.59	$1.78	$1.96
2029	5,397,960	325,293	$2.20	$2.40	$2.59	$1.56	$1.77	$1.99
2030	5,441,000	331,960	$2.17	$2.40	$2.62	$1.52	$1.77	$2.02
2031	5,483,110	337,896	$2.14	$2.39	$2.65	$1.49	$1.77	$2.05
2032	5,524,190	343,579	$2.11	$2.40	$2.68	$1.46	$1.77	$2.09
2033	5,564,430	349,123	$2.08	$2.39	$2.70	$1.42	$1.77	$2.12
2034	5,603,700	354,522	$2.05	$2.39	$2.73	$1.39	$1.77	$2.15
2035	5,642,140	359,765	$2.02	$2.39	$2.77	$1.37	$1.77	$2.17
2036	5,679,740	364,861	$2.00	$2.40	$2.80	$1.37	$1.77	$2.18
2037	5,716,600	369,895	$1.97	$2.41	$2.84	$1.38	$1.78	$2.18
2038	5,752,840	374,927	$1.98	$2.41	$2.85	$1.38	$1.79	$2.19
2039	5,788,430	379,961	$1.98	$2.42	$2.86	$1.39	$1.79	$2.20
2040	5,823,270	384,984	$1.99	$2.42	$2.86	$1.39	$1.80	$2.21
2041	5,857,480	389,965	$1.99	$2.43	$2.87	$1.40	$1.81	$2.22
2042	5,891,140	394,882	$1.99	$2.43	$2.88	$1.40	$1.81	$2.22
2043	5,924,040	399,734	$2.00	$2.44	$2.88	$1.40	$1.82	$2.23
2044	5,956,180	404,527	$2.00	$2.44	$2.89	$1.41	$1.82	$2.23
2045	5,987,770	409,255	$2.00	$2.45	$2.89	$1.41	$1.83	$2.24
2046	6,018,420	413,900	$2.01	$2.46	$2.90	$1.42	$1.83	$2.25
2047	6,048,120	418,446	$2.01	$2.46	$2.91	$1.42	$1.84	$2.26
2048	6,077,050	422,891	$2.02	$2.47	$2.92	$1.43	$1.85	$2.26
2049	6,105,240	427,230	$2.02	$2.47	$2.93	$1.43	$1.85	$2.27
2050	6,132,460	431,441	$2.02	$2.48	$2.93	$1.43	$1.86	$2.28
2051	6,158,820	435,509	$2.03	$2.48	$2.94	$1.44	$1.86	$2.29
2052	6,184,410	439,427	$2.03	$2.49	$2.95	$1.44	$1.87	$2.29
2053	6,209,310	443,192	$2.04	$2.50	$2.96	$1.45	$1.88	$2.30
2054	6,233,490	446,798	$2.04	$2.50	$2.96	$1.45	$1.88	$2.31
2055	6,257,240	450,268	$2.04	$2.51	$2.97	$1.46	$1.89	$2.32

Appendix 3: List of abbreviations

Abbreviation	Definition
BEV	Battery electric vehicle
CCD	Clean Car Discount
CCIS	Clean Car Import Standard
CNG	Compressed natural gas
ETS	Emissions Trading Scheme
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
GVM	Gross vehicle mass
HCV	Heavy commercial vehicle
ICE	Internal combustion engine
LCV	Light commercial vehicle
LPG	Liquefied petroleum gas
LPV	Light passenger vehicle
MBIE	Ministry of Business, Innovation and Employment
MVR	Motor Vehicle Register
PHEV	Plug-in electric vehicle
PT	Public transport
RUC	Road User Charges
TCO	Total cost of ownership
VFM	Vehicle Fleet Model
VKT	Vehicle kilometres travelled