Estimated effect of mode shift and speed interventions on motor vehicle emissions and air pollution health impacts in Auckland

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Executive summary

This is the third report in an investigation of the impacts of speed management interventions on greenhouse gas emissions and air quality.

The purpose of the first two reports was:

i. A review of information and literature about the effect of speed limits on emissions;[2] and
ii. A review of literature about the effect of traffic calming measures on emissions[3].

The purpose of this report is to summarise the methodology and results of modelling undertaken to estimate the impacts of speed management in Auckland and to compare these with the potential impacts of greenhouse gas emission reduction policies.

A separate summary report provides an overview of all three reports[4].

Key findings from this report are:

- Modelling undertaken by the Auckland Forecasting Centre predicts that speed reduction policies will not significantly affect vehicle emissions in Auckland.
- As with any modelling exercise, there is some uncertainty in the results. However, the modelling provides a useful estimate of the overall likely emission impacts of speed management across Auckland.
- Modelling predicts that significant reductions in vehicle emissions and air pollution health impacts would be achieved if emission reductions targets are achieved (targets to reduce light duty vehicle kilometres travelled and increase the percentage of electric vehicles in the light fleet).

[2] Metcalfe and Boulter (2022)
[3] Gilbert and Boulter (2022)
[4] Metcalfe (2023)

Contents

Glossary of terms and abbreviations

CH_4	Methane, a greenhouse gas
CO	Carbon monoxide
CO_2	Carbon dioxide, a greenhouse gas
CO_2-e	Carbon dioxide equivalent, a way to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming
Euro	European vehicle emission legislation
EEA	European Environment Agency
ERP	Te hau mārohi ki anamata, Aotearoa New Zealands first emissions reduction plan
EV	Electric vehicles
GHG	Greenhouse gases
HAPINZ 3.0	Health and Air Pollution in New Zealand study (2016 base year)
MSM	Auckland's transportation forecasting model, the Macro Strategic Model
NO_X	Oxides of nitrogen, including nitric oxide nitrogen dioxide and nitrous oxide
NO_2	Nitrogen dioxide, an air quality pollutant
N_2O	Nitrous oxide, a greenhouse gas (not to be confused with NO_2 which is an air quality pollutant)
PM	Particulate matter
TERP	Auckland Council transport emissions reduction pathway
VEPM	Vehicle Emissions Prediction Model, developed by Waka Kotahi to predict air emissions and fuel consumption for the New Zealand fleet
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound

1. Introduction

1.1 Purpose

This is the third report in an investigation of the impacts of speed management interventions on greenhouse gas emissions and air quality commissioned by Waka Kotahi NZ Transport Agency (Waka Kotahi) and Auckland Transport.

The purpose of the first two reports was:

iii. A review of information and literature about the effect of speed limits on emissions (Metcalfe and Boulter, 2022); and
iv. A review of literature about the effect of traffic calming measures on emissions (Gilbert and Boulter, 2022)

The purpose of this report is to summarise the methodology and results of modelling undertaken to estimate the impacts of speed management in Auckland and to compare these with the potential impacts of greenhouse gas emission reduction policies.

A separate summary report provides an overview of all three reports (Metcalfe, 2023).

1.2 Structure and content of this report

This report is structured as follows:

- Section 2 provides background information on motor vehicle emissions as well as the models that we use to estimate emissions and air pollution health impacts.
- Section 3 describes the methodology used in this report to estimate motor vehicle emissions and air pollution health impacts for a range of scenarios.
- Section 4 summarises the results of modelling.
- Section 5 presents key conclusions.

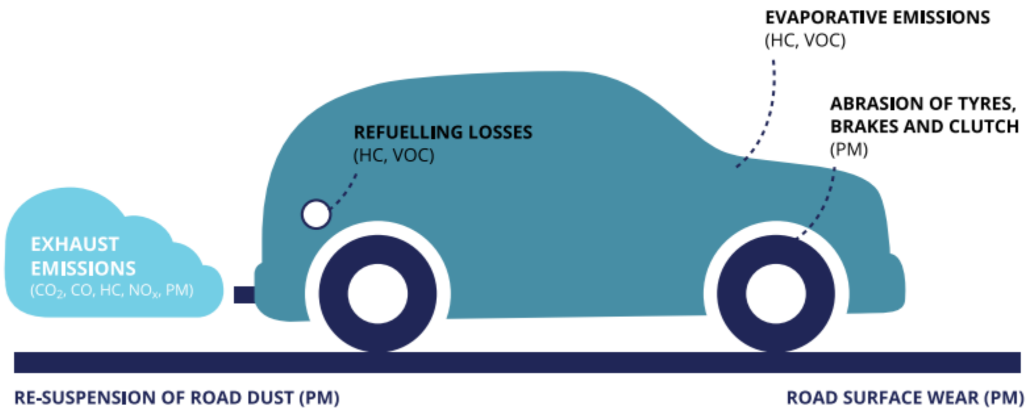
All calculations and results are provided in the accompanying spreadsheet.

2. Background

2.1 Emissions from motor vehicles

Vehicles are an important source of both greenhouse gases (which impact globally) and harmful air pollutants (which impact locally and regionally). Vehicles generate different types of air emissions as shown in Figure 1[5].

Figure 1: Different types of emissions from internal combustion engine vehicles. Abrasion emissions are the only direct emissions from electric vehicles.



Source: EEA (2016)

Note: CO_2=carbon dioxide; CO=carbon monoxide; NOx=nitrogen oxides; PM=particulate matter; HC=hydrocarbon; VOC=volatile organic compounds.

Internal combustion engines emit a range of pollutants via the exhaust. The amount of each pollutant released depends on the fuel used (e.g. petrol or diesel) and the engine technology (including emission-control equipment). The mechanical abrasion of vehicle parts and road surface wear also generate emissions. Abrasion is a key source of emissions of particulate matter and some heavy metals. Vapours can escape from vehicle fuel systems via evaporation and during refuelling, resulting in increased emissions of volatile organic compounds.

Greenhouse gases

Greenhouse gases (**GHGs**), also known as climate pollutants, are so-called because they contribute to global warming and climate change. The most important greenhouse gas emissions from motor vehicles are:

- Carbon dioxide (**CO_2**)
- Methane (**CH_4**)
- Nitrous oxide (**N_2O**)

Greenhouse gases can be short-lived with an atmospheric lifetime of days to ~15 years (e.g. methane) or long-lived with an atmospheric lifetime of more than 100 years (e.g. carbon dioxide). For ease of

[5] EEA (2016)

comparison, GHGs are typically expressed as carbon dioxide equivalents (**CO_2-e**), which is the amount of CO_2 which would have the equivalent global warming impact[6].

Harmful air pollutants

Harmful air pollutants are so-called because they can cause adverse human health effects. This report focuses on the two motor vehicle pollutants of most concern in New Zealand:

- Particulate matter – both particles smaller than 10 micrometres (**PM_{10}**) and those smaller than 2.5 micrometre (**$PM_{2.5}$**) – which arises primarily from diesel fuel combustion, brake/tyre wear and road dust.
- Nitrogen oxides (**NO_X**), in particular nitrogen dioxide (**NO_2**) – which is emitted primarily from diesel and petrol fuel combustion.

2.2 Greenhouse gas emissions from motor vehicles in Auckland

Transport is one of the largest sources of greenhouse gas emissions in New Zealand, accounting for 18% of Aotearoa's gross CO_2-e emissions (MfE 2022). Around 90% of transport emissions are from on-road motor vehicles[7].

Te hau mārohi ki anamata, Aotearoa New Zealand's first emissions reduction plan (ERP) sets out a pathway to achieve our GHG obligations (MfE 2022). To achieve current targets and obligations, motor vehicle GHG emissions need to reduce at a national level by approximately 41% by 2035 compared with 2019, and the transport sector needs to be largely decarbonised by 2050.

In Auckland, even bigger emission reductions are required to meet targets and obligations. *Te Tāruke-ā-Tāwhiri:* Auckland's Climate Plan (Auckland Climate Plan) has a goal to reduce net emissions by 50% by 2030 (against a 2016 baseline) and achieve net zero emissions by 2050. To halve overall emissions by 2030, the plan estimates that transport emissions will need to reduce by 64% by 2030 (compared to 2016). Actions to achieve this target are set out in the Auckland Council Transport Emissions Reduction Pathway (**TERP**) (Auckland Council 2022)

2.3 Air pollution health impacts of motor vehicle emissions in Auckland

Harmful air pollutants are so-called because they can cause adverse human health effects ranging from increased morbidity (illness, e.g. increased respiratory hospitalisations) to increased mortality (loss of life, i.e. premature deaths). The effects depend on the pollutant itself, the concentration and the length of time exposed.

The air pollution health impacts of motor vehicle emissions in Aotearoa New Zealand are assessed in the Health and Air Pollution in New Zealand 2016 (HAPINZ 3.0) study (Kuschel et al 2022).

The study estimates that air pollution from motor vehicles results in 2,247 premature deaths, nearly 9,400 hospitalisations and over 13,200 cases of childhood asthma each year in New Zealand. These

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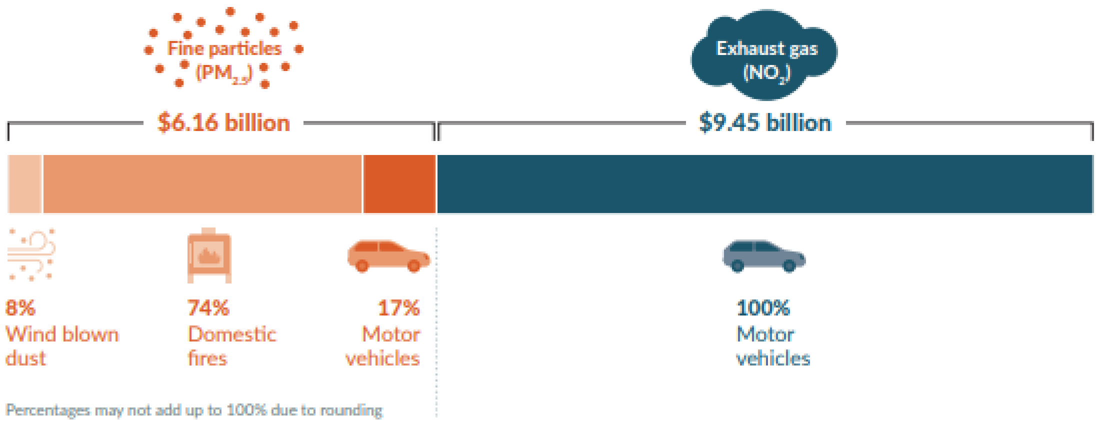
[6] This report only considers direct emissions of CO2-e from motor vehicles. Life cycle emissions from motor vehicles and transport infrastructure are not considered.

[7] *New Zealand's Greenhouse Gas Inventory for 2019* reports transport emissions at 14,655 kt CO_2-e, with road tranport emissions at 13,116 kt CO_2-e. https://emissionstracker.environment.govt.nz/

health impacts result in an estimated social cost of more than $10.5 billion per year (Kuschel et al 2022).

A substantial proportion of these health impacts and costs occur in the Auckland region, where the HAPINZ 3.0 study estimates that air pollution from motor vehicles results in 763 premature deaths, over 3,800 hospitalisations and 6,100 cases of childhood asthma each year. The health impacts of motor vehicle emissions in Auckland result in an estimated social cost of nearly $3.6 billion per year (Kuschel et al 2022).

Figure 2: Social costs of health impacts from human made air pollution in New Zealand. The estimated social cost of health impacts form motor vehicle air pollution (NO_2 and $PM_{2.5}$) is more than $10.5 billion. Source: MfE[8]



2.4 Models used in this assessment.

This section briefly describes the key models that are used in this assessment to quantify changes in vehicle emissions and air pollution health impacts. The overall methodology is described in chapter 3.

MSM model

The Auckland Macro Strategic Model (**MSM**) is the multi-modal (vehicles and passenger transport) travel demand model of the Auckland region, which is managed by the Auckland Forecasting Centre. It incorporates land-use forecasts from the Auckland Council with assumptions about future economic conditions, transport policies and investments, which are used to forecast typical weekday peak period travel demands over the next three decades.

The MSM estimates vehicle emissions for each link in the transport network based on emissions factors from the Waka Kotahi Vehicle Emission Prediction Model (**VEPM**).

VEPM

In New Zealand, VEPM is used to estimate vehicle emissions from the fleet. The model is used in policy analysis and assessments of environmental effects. Information about VEPM is available on the Waka Kotahi website (www.nzta.govt.nz)

VEPM estimates emission factors based on detailed information about the New Zealand vehicle fleet, and how this is likely to change in future. VEPM emission factors can be adjusted for a range of

[8] MfE_HAPINZ3_A4-infographic (environment.govt.nz)

variables including for example, gradient, temperature, fuel quality, heavy vehicle load and average speed.

The HAPINZ 3.0 model

The primary tool developed in HAPINZ 3.0 is a Health Effects Model (Sridhar et al 2022). The model is an Excel workbook and allows end-users to output results nationally, regionally, by airshed or by district health board. End-users are also able to run scenarios for comparison with the base case, by selecting from a range of plausible input values of population, exposure and epidemiological exposure-response functions. The scenario option can be used to undertake sensitivity testing to test the effects of different assumptions, evaluate the effects of population and emissions trends, or review the effectiveness of different air quality management options.

2.5 Limitations and uncertainty of VEPM

The limitations of VEPM and the application of VEPM to assessment of speed interventions is discussed in some detail in Metcalfe and Boulter (2022). Some key findings from that report are discussed here. However, it is important to recognise that the results presented in this report are based on three separate models (the MSM model, VEPM and the HAPINZ health effects model). Each of these models will have some uncertainty, especially when estimating likely impacts more than 10 years into the future.

VEPM predicts real-world 'average-speed' emission factors. These emission factors are intended to represent typical emissions at a defined 'average-speed' for typical conditions (e.g. typical driving behaviour and typical levels of congestion for the defined average speed). So, for example, at low speeds less than 30 km/h, VEPM will estimate emissions for a vehicle operating in typical 30 km/h urban driving conditions, which include a significant amount of stop – start driving.

The first review report (Metcalfe and Boulter 2022) concluded that VEPM may overestimate any increase in emissions due to speed limit reductions on urban roads. This is because average speed models like VEPM assume typical driving conditions for the average speed – which means more acceleration and deceleration due to stop-and-go driving at lower average speeds. However, reduced speed limits don't generally increase the amount of stop-and-go driving and can make vehicles move more smoothly with fewer accelerations and decelerations.

The report (Metcalfe and Boulter 2022) went on to conclude:

- On balance, it seems that VEPM might slightly overestimate the GHG impact of speed limit changes, and that the net overall change in GHG emissions at the individual road level are likely to be small (an increase or decrease in emissions of less than 10% on affected roads, and across the affected network). Moreover, roads which have a 30 km/h speed limit often have a relatively low volume of traffic, and therefore the overall absolute change in GHG emissions at the regional or national level is likely to be negligible. This could be tested with further modelling.

The modelling presented in this report tests this conclusion - that the overall change in emissions due to speed limit reductions is likely to be negligible.

As with any modelling exercise, there is some uncertainty in the results. In particular, it is likely that VEPM overestimates any increase in emissions due to speed limit reductions on urban roads.

However, it is expected that VEPM will provide a useful estimate of the overall likely emissions impacts of speed management across Auckland.

3. Method

The results provided in this report are based on modelling undertaken by the Auckland Forecasting centre for a range of speed management scenarios using the MSM model. The MSM outputs included estimated emissions from the Auckland transport network for 2016 and 2031.

We adjusted the outputs from the MSM model to estimate emissions for a range of scenarios in 2035. These scenarios were developed to account for potential impacts of mode shift and electric vehicle uptake as well as speed interventions. The overall method followed these steps:

1. Develop a range of scenarios to compare the likely impacts of speed management interventions and greenhouse gas emission interventions.
2. Estimate emissions in 2035 for a base case and all scenarios (from step 1) using the MSM model outputs (VKT and estimated emissions) and VEPM.
3. Use the HAPINZ 3.0 health effects model to estimate the health impacts and corresponding social costs of the base case and each scenario in 2035 by the application of emission and population scalars.

The MSM model outputs and our methodology are described in more detail in the following sections.

3.1 MSM model outputs

The overall potential impact of speed management interventions on motor vehicle emissions in Auckland was estimated with the MSM model by the Auckland Forecasting Centre for the following speed intervention scenarios:

- **2016 base year**: this is the base year emissions estimate from the MSM model
- **2031 base case:** this is the baseline projection from the MSM model which includes projects specified in the 2021-2031 Regional Land Transport Plan.
- **2031 speed management Approach 1**: 30 km/h permanent speed limits on all non-arterial roads within 1,000m of a school gate and 30 km/h variable speed limits during school start and end periods on all arterial roads within 400m of a school gate, plus introducing 40 km/h (and some 30 km/h) permanent speed limits on 30 selected high risk arterial roads across Auckland.
- **2031 speed management Approach 2**: 30 km/h permanent speed limits on all non-arterial roads within 1,000m of a school gate and 30 km/h variable speed limits during school start and end periods on all arterial roads within 400m of a school gate.
- **2031 area wide speed management**: 30 km/h on all urban non-arterial roads, 40 km/h on urban arterials, 80 km/h on level rural roads and 60 km/h on rolling rural roads.

The speed intervention scenarios are described fully by Flow Transportation Specialists (2022). Unadjusted emissions estimated from MSM are provided in the accompanying spreadsheet.

3.2 Development of scenarios

We adjusted the outputs from the MSM model to estimate emissions in 2035 for a range of scenarios to account for potential impacts of speed interventions, mode shift and electric vehicle uptake as described in the following sections.

Mode shift due to speed interventions

The MSM model does not account for any increase in walking, cycling and other active modes as a result of speed interventions. Literature suggests that speed interventions can increase the use of active travel modes, thereby reducing vehicle travel and GHG emissions (Thomas et al 2022). However, the likely extent of mode shift is difficult to quantify with any certainty. To investigate the likely impacts, we have evaluated a low and high scenario:

- **Low: 0.25% reduction in light vehicle kilometres travelled due to speed interventions**. Assume 2% of car trips shift to active modes, and that these are short 1.5 km average length trips. The average trip according to the MSM model is around 11km, so this equates to a reduction in vehicle kilometres travelled (**VKT)** of around 0.25%.
- **High: 3.5% reduction in light vehicle kilometres travelled due to speed interventions**. The Auckland Council TERP recognises speed limit reductions as a key requirement to supercharge walking and cycling. The TERP pathway would require mode share (by distance) of walking, cycling and micro mobility to increase to 16% compared with 2% in 2019. We assume, arbitrarily, that quarter of the increased mode share (about 3.5%) could be attributed to area wide speed interventions.

Mode shift and electric vehicle targets to reduce greenhouse gas emissions from transport

We have estimated the likely impacts of some key greenhouse gas emission reduction targets to provide context for the estimated impacts of speed interventions. These targets are from *Te hau mārohi ki anamata*, Aotearoa New Zealands first emissions reduction plan (**ERP**) (MfE 2022) and the Auckland TERP (Auckland Council 2022):

- **Reduce total kilometres travelled by the light vehicle fleet by 20% by 2035** (compared with 2035 baseline projections). This is the ERP target for VKT reduction across Aotearoa New Zealand. Subnational targets are being developed, and it is likely that the target for Auckland will be significantly higher than the national target.
- **Reduce total kilometres travelled by light vehicles by 50% in 2030 compared to 2019**. This is the estimated reduction in light vehicle travel that is required to meet Auckland greenhouse gas emission reduction targets in the Auckland TERP.
- **Increase the proportion of light duty vehicles that are electric to 30% in 2035**. This is the ERP target for Aotearoa New Zealand.

3.3 Scenarios modelled

The MSM model outputs (VKT and estimated emissions) were used to estimate emissions in 2035 [9]for a range of scenarios. The scenarios and key assumptions are summarised in Table 1. The methodology

[9] MSM produced information for 2031. This was then scaled for 2035 as discussed in section 3.4.

and assumptions are described in more detail in the following section. All calculations are available in the accompanying spreadsheet.

Table 1: Scenarios and key assumptions

Year	Scenario number	Scenario description	Key assumptions
2016		Base year 2016	2016 MSM outputs
2035		Base case 2035	Emissions calculated from 2031 MSM outputs with VKT extrapolated to 2035 (based on increase in VKT between 2016 and 2013 of approximately 1.5% per annum) and emission factors adjusted to 2035 (based on scaling factors derived from VEPM)
2035	1	Approach 1 (30 km/h permanent speed limits on all non-arterial roads within 1,000m of a school gate and 30 km/h variable speed limits during school start and end periods on all arterial roads within 400m of a school gate, plus introducing 40 km/h (and some 30 km/h) permanent speed limits on 30 selected high risk arterial roads across Auckland)	
2035	2	Approach 2 (30 km/h permanent speed limits on all non-arterial roads within 1,000m of a school gate and 30 km/h variable speed limits during school start and end periods on all arterial roads within 400m of a school gate)	
2035	3	Area wide speed intervention	
2035	4	Approach 1 + 0.25% VKT reduction	VKT and fleet weighted emission factors from scenario 1 except light duty VKT reduced by 0.25% (vs 2035)
2035	5	Approach 1 + 3.5% VKT reduction	VKT and fleet weighted emission factors from scenario 1, except light duty VKT reduced by 3.5% (vs 2035)
2035	6	Area wide + 20% VKT reduction	VKT and fleet weighted emission factors from scenario 3, except light duty VKT reduced by 20% (vs 2035)
2035	7	Area wide + 30% EV by 2035	VKT and fleet weighted emission factors from scenario 3, except light duty emission factors adjusted for 30% EV
2035	8	Area wide + 20% VKT reduction + 30% EV by 2035	VKT and emission factors from scenario 3 except light duty VKT reduced by 20% (vs 2035) and light duty emission factors adjusted for 30% EV.
2035	9	Area wide + 50% VKT reduction +30% EV by 2035	VKT and emission factors from scenario 3 except light duty VKT reduced by 50% (vs estimated 2019 VKT10) and light duty emission factors adjusted for 30% EV.

[10] 2019 VKT was interpolated between 2016 and 2038 MSM outputs, based on the average annual increase in VKT per annum between 2016 and 2031 (approximately 1.5%) in the MSM base case.

3.4 Estimating 2035 emissions.

Scenarios 1, 2 and 3

2035 emissions were estimated as follows for the base case and speed management scenarios (scenario 1, 2 and 3 in Table 1):

1. Extrapolate 2031 light-duty and heavy-duty VKT for each scenario to 2035:
   - based on the average annual increase in VKT per annum between 2016 and 2031 (approximately 1.5%) in the MSM base case
   - calculated for light-duty and heavy-duty heavy duty separately.
2. Estimate fleet weighted light-duty and heavy-duty emission factors for 2031 for the base case and speed management scenarios
   - based on VKT and total estimated emissions from MSM for the base case and each scenario
   - for CO_2-e, $PM_{2.5}$ (exhaust and brake & tyre), and NOx.
3. Apply a scaling factor to estimate fleet weighted light duty and heavy-duty emission factors for 2035:
   - A scaling factor was applied to all emission factors estimated in step 2 to estimate 2035 fleet weighted emission factors for the base case and each scenario.
   - Scaling factors were derived from VEPM 6.3 outputs. Factors were calculated for each pollutant, and for light and heavy duty separately as the ratio of 2035/2031 fleet weighted emission factors[11].
4. Calculate 2035 emissions for the base case and each scenario:
   - based on 2035 VKT estimated in step 1, and 2035 fleet weighted emission factors estimated in step 3
   - for light-duty and heavy-duty fleets separately.

Scenarios 4-6

To estimate 2035 emissions for scenarios 4-6 light duty VKT were adjusted. Emissions were calculated based on the adjusted VKT and relevant fleet weighted emission factors calculated in Step 3 above. Assumptions are summarised in Table 1.

Scenarios 7-9

To estimate 2035 emissions for scenarios 7-9, light duty fleet weighted emission factors were adjusted to estimate the impact of 30% of the fleet being electric. Emissions were calculated for each scenario based on adjusted VKT and fleet weighted emission factors. Key assumptions are summarised in Table 1. Adjusted emission factors were calculated as follows:

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[11] To derive fleet weighted emission factors for 2031 and 2035, VEPM was run at a nominal speed of 45km/hour with all other settings at default.

5. Emission factors were derived from VEPM for a 2035 fleet adjusted so that 30% of cars and 30% of LCVs are electric. Other categories in the car and LCV fleet were scaled so the total percentage of vehicles that are cars and LCVs was unchanged[12].

6. A scaling factor was derived for each pollutant as the ratio of the adjusted 30% EV 2035 fleet weighted emission factors/2035 fleet weighted emission factors derived in Step 3 above.

    - The scaling factor was applied to 2035 scenario 3 light duty emission factors (estimated in step 3 above)

3.5 Estimating health impacts

We used the HAPINZ 3.0 health effects model to estimate the health impacts of the base case and each scenario in 2035 by the application of scalars. Scalars were developed to adjust the HAPINZ 3.0 2016 base year as follows:

- Population was estimated for Auckland in 2035 based on StatsNZ subnational population projections for the Auckland Region[13]. A scalar of 1.2 was calculated (the ratio of the 2035 estimated population divided by the 2016 population in the HAPINZ 3.0 model).
- Total emissions of $PM_{2.5}$ and NOx were calculated for 2016 and 2035 for the base case and each scenario (as described in the previous section). Scalars were calculated as the ratio of the 2035 emissions to 2016 emissions for each pollutant and each scenario.
- Health impacts were estimated for 2035 for the base case and each scenario by applying the population scalar and the relevant emission scalars in the input sheet of the HAPINZ 3.0 health effects model.
- The HAPINZ 3.0 model allows users to adjust concentration by source or pollutant. Users cannot adjust NO_2 concentration by source because it is assumed that all NO_2 health impacts are from motor vehicles. Accordingly, the PM scalar was applied to motor vehicle PM, and the NO_2 scalar was applied to NO_2.

The application of scalars assumes that changes in motor vehicle emissions are mirrored in changes to the concentration over the same time period. While the concentration of a pollutant in ambient air does depend on emissions, it is influenced by other factors – such as meteorology, atmospheric chemistry and topography. Nonetheless this approach is a reasonable approximation and is widely used for policy analysis[14].

[12] To derive these factors VEPM was run with the adjusted fleet, for 2035, at a nominal speed of 45km/hour with all other settings at default.

[13] We assumed a linear change between StatsNZ estimated population in 2033 and 2038

[14] For example, air pollution damage costs rely on this approach. Air pollution damage costs are widely used in internationally and in NZ (in the Waka Kotahi Monetised Benefits and Costs Manual https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/).

4. Results

The overall results of modelling are summarised in Table 2, which shows estimated 2035 CO_2-e and social costs of emissions from motor vehicles in Auckland as a percentage of 2016 estimates. Estimated emissions (tonnes per annum) and health impacts (case numbers) for each scenario are summarised in the appendix and are collated in the accompanying spreadsheet. Figure 1 and Figure 2 in the appendix illustrate the results for all scenarios.

The results show that, under the **base case**:

- There is an estimated substantial reduction in harmful emissions (NOx and $PM_{2.5}$) from vehicles in Auckland between 2016 and 2035. The estimated social costs of motor vehicle air pollution reduces from $3,597 million in 2016 to $2520 million in 2035 under the base case. The estimated reduction in harmful emissions from the fleet is due to gradual retirement of old high emission vehicles and uptake of modern low-emission and zero-emission vehicles.
- There is an estimated 5% increase in greenhouse gas emissions from vehicles in Auckland between 2016 and 2035. While some improvement in fleet average CO_2-e emissions is expected over this time period, total emissions are predicted to increase due to the projected growth in VKT.

With respect to speed management interventions, the results show that:

- **Speed management approaches 1 and 2** (scenarios 1-2): there is insignificant (less than 1%) difference between the estimated emission impacts (health impacts and CO_2-e) for the base case and these scenarios.
- **Area wide speed reductions** (scenario 3): there is insignificant (less than 1%) difference between the estimated emission impacts (health impacts and CO_2-e) for the base case and area wide speed reduction. Although area wide speed reductions would affect a lot more roads compared with approaches 1 and 2, the overall impacts are similar. This is probably due to the effect of reduced speed on rural roads, which will reduce estimated emissions from these roads. This reduction in emissions from rural roads will offset estimated emission increases on urban roads to some extent in the area wide speed reduction scenario.

Scenarios 1 to 3 do not account for any increase in walking, cycling and other active modes as a result of speed interventions. Comparison of **scenarios 4 and 5** with the base case, demonstrates that a modest reduction (around 0.5%) in VKT would offset any estimated increase in emissions due to speed management approach 1.

The results for **scenarios 6 to 9** show that significant reductions in CO_2-e emissions and social costs of air pollution from motor vehicles in Auckland would be achieved if emission reductions targets are achieved (targets to reduce light duty VKT and increase the percentage of light duty vehicles that are EV).

Table 2: Estimated CO_2-e and social costs of motor vehicle emissions in Auckland for each scenario in 2035 as a percentage of 2016 estimates

Scenario		VKT	2035 emissions as a percentage of 2016 emissions			2035 social costs of air pollution as a percentage of 2016 social costs
N°	Description	million km/year	CO_2-e	$PM_{2.5}$	NOx	
	Base year 2016	12,664	-	-	-	-
	Base case 2035	16,396	104.9%	47.5%	57.5%	70%
1	Approach 1 2035	16,367	105.3%	47.6%	57.9%	70%
2	Approach 2 2035	16,369	105.3%	47.6%	57.9%	70%
3	Area wide 2035	16,288	105.2%	47.8%	58.1%	71%
4	Approach 1 + 0.25% VKT reduction	16,329	105.1%	47.6%	57.8%	70%
5	Approach 1 + 3.5% VKT reduction	15,837	102.5%	46.6%	56.8%	69%
6	Area wide + 20% VKT reduction	13,277	89.5%	42.0%	51.7%	63%
7	Area wide + 30% EV by 2035	16,288	89.6%	46.6%	51.2%	63%
8	Area wide + 20% VKT reduction + 30% EV by 2035	13,277	77.0%	41.0%	46.2%	57%
9	Area wide + 50% VKT reduction +30% EV by 2035	7,355	52.2%	30.1%	36.3%	45%

5. Conclusions

Key conclusions from this report are:

- Modelling undertaken by the Auckland Forecasting Centre predicts that speed reduction policies will not significantly affect vehicle emissions in Auckland.
- As with any modelling exercise, there is some uncertainty in the results. However, the modelling provides a useful estimate of the overall likely emissions impacts of speed management across Auckland.
- Modelling demonstrates that significant reductions in vehicle emissions and air pollution health impacts would be achieved if emission reductions targets are achieved (targets to reduce light duty VKT and increase the percentage of light duty vehicles that are EV).

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Appendix

Table 3: Estimated emissions and total social costs for the base case and each scenario

Scenario description	VKT (million km/year)	Emissions (tonnes per annum)			Social costs ($ million)
		CO_2-e	$PM_{2.5}$	NOx	
Base year 2016	12,664	3,318,390	714	10,715	3,597
Base case 2035	16,396	3,482,302	339	6,165	2,520
1: Approach 1 2035	16,367	3,494,099	340	6,204	2,535
2: Approach 2 2035	16,369	3,493,630	340	6,201	2,534
3: Area wide 2035	16,288	3,491,940	341	6,223	2,542
4: Approach 1 + 0.25% VKT reduction	16,329	3,487,560	340	6,195	2,531
5: Approach 1 + 3.5% VKT reduction	15,837	3,402,548	333	6,083	2,488
6: Area wide + 20% VKT reduction	13,277	2,970,279	300	5,540	2,274
7: Area wide + 30% EV by 2035	16,288	2,971,964	333	5,485	2,276
8: Area wide + 20% VKT reduction + 30% EV by 2035	13,277	2,554,298	293	4,949	2,059
9: Area wide + 50% VKT reduction +30% EV by 2035	7,355	1,732,717	215	3,895	1,626

Table 4: Estimated health impacts and social costs for the base case and each scenario

	HAPINZ 3.0 ESTIMATES (MOTOR VEHICLES ONLY)										
	2016	2035	2035 scenario								
	base case		1	2	3	4	5	6	7	8	9
Cases per year due to annual $PM_{2.5}$											
Premature mortality (all adults)	79	45	45	45	45	45	44	40	44	39	28
Cardiovascular hospitalisations*	189	107	108	108	108	108	105	95	105	93	68
Respiratory hospitalisations*	164	93	94	94	94	94	92	83	92	81	59
Restricted activity days*	153,014	86,572	86,909	86,885	87,262	86,777	85,060	76,678	85,003	74,871	54,940
Cases per year due to annual NO_2											
Premature mortality (all adults)	685	490	493	493	495	493	484	443	439	398	317
Cardiovascular hospitalisations*	757	531	534	534	536	533	524	478	474	429	339
Respiratory hospitalisations*	2,747	1,995	2,006	2,006	2,012	2,004	1,970	1,807	1,790	1,627	1,298
Asthma prevalence (0-18 yrs)	6,144	4,446	4,472	4,470	4,485	4,466	4,392	4,026	3,988	3,622	2,888
Social costs per year due to both $PM_{2.5}$ and NO_2											
Social cost ($ million)	3,597	2,520	2,535	2,534	2,542	2,531	2,488	2,274	2,276	2,059	1,626

*all ages

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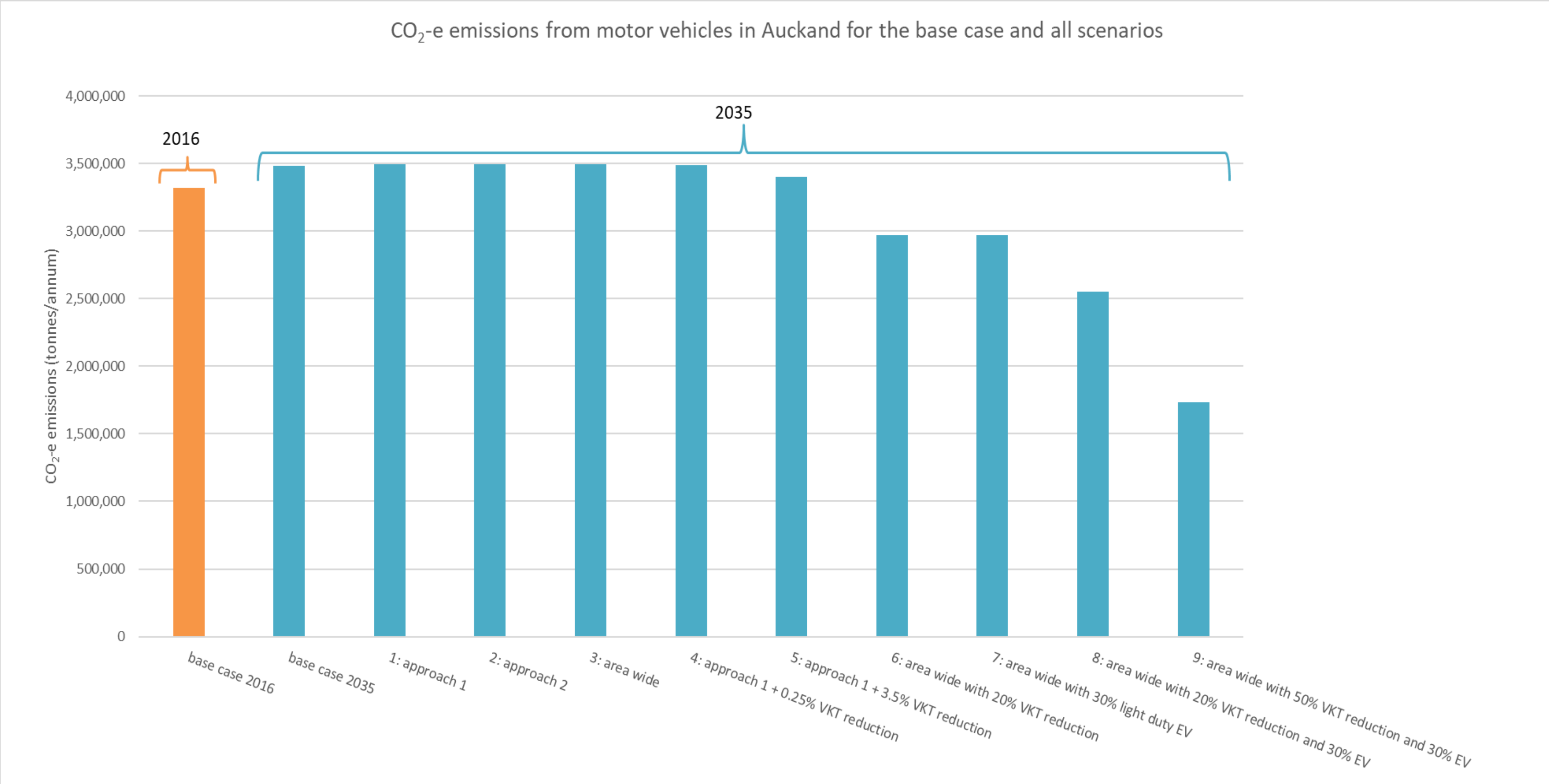

Figure 3: estimated CO_2-e emissions from motor vehicles in Auckland for the base case and each scenario

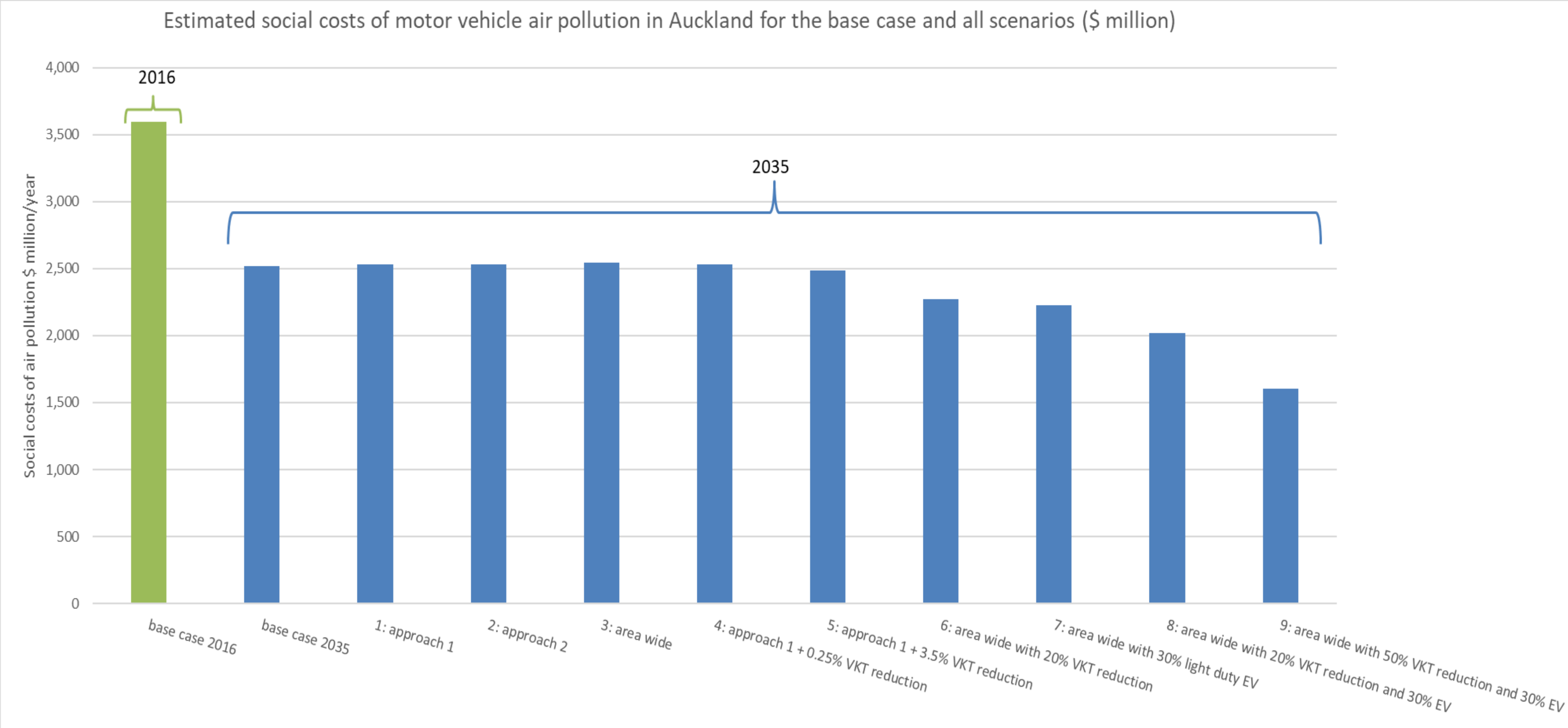

Figure 4: estimated social costs of motor vehicle air pollution in Auckland for the base case and each scenario