The effect of speed on emissions: summary report

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Disclaimer

This report was prepared by Emission Impossible Limited, an independent consultancy specialising in air quality and vehicle emissions management[1].

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[1] For more information about Emission Impossible Limited refer to our website: www.emissionimpossible.co.nz

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Executive summary

New Zealand's road safety strategy (Road to Zero) vision is a New Zealand where no one is killed or seriously injured in road crashes. Speed is one of the determinants of whether anyone is killed, injured, or walks away unharmed from a crash. This makes speed management critical to achieving the Road to Zero vision.

Auckland is developing safe and appropriate speed limits for roads through Auckland Transport's Speed Management programme.

Reduced vehicle speeds can impact transport emissions of greenhouse gases and harmful air pollutants. This report summarises information about the effect of speed management (for safety purposes) on greenhouse gases and harmful air pollutant emissions. This report is based on three technical reports:

i. A review of information and literature about the effect of speed limits on emissions;[2]
ii. A review of literature about the effect of traffic calming measures on emissions[3].
iii. A summary of modelling undertaken to estimate the impacts of speed management in Auckland and to compare these with the potential impact of greenhouse gas emission reduction policies[4].

Key findings

It is well established that improved speed management saves lives and reduces serious injuries. Our review finds that, although changes in vehicle speed can affect emissions, **the overall impact of speed management interventions on emissions in Auckland will not be significant.**

To reduce the impacts of vehicle emissions, evidence shows that **we need to reduce reliance on cars and support people to walk, cycle and use public transport**.

Safe speeds, which make it safer to walk and cycle, will therefore be a critical part of the emission reduction pathway for Auckland and New Zealand.

[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
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 and nitrogen dioxide
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
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 of this summary report

The purpose of this report is to summarise the information available about the effects of speed management (for safety purposes) on greenhouse gases and harmful air pollutant emissions. This summary report is based on three technical reports:

i. A review of information and literature about the effect of speed limits on emissions;[5]
ii. A review of literature about the effect of traffic calming measures on emissions[6].
iii. A summary of modelling undertaken to estimate the impacts of speed management in Auckland and to compare these with the potential impact of greenhouse gas emission reduction policies[7].

1.2. Structure of this summary report

This report is structured as follows:

- **Section 2** provides **background information** on vehicle emissions and the effect of speed on emissions.
- **Section 3** summarises the findings of our literature review on the effect of **speed limits** on emissions.
- **Section 4** summarises the findings of a literature review on the effect of **traffic calming** measures on emissions and air quality.
- **Section 5** assesses the likely **overall impact** of speed management interventions on vehicle emissions in Auckland.
- **Section 6** compares the likely impact of speed management interventions on vehicle emissions in Auckland with the likely impact of key greenhouse gas emission reduction interventions.

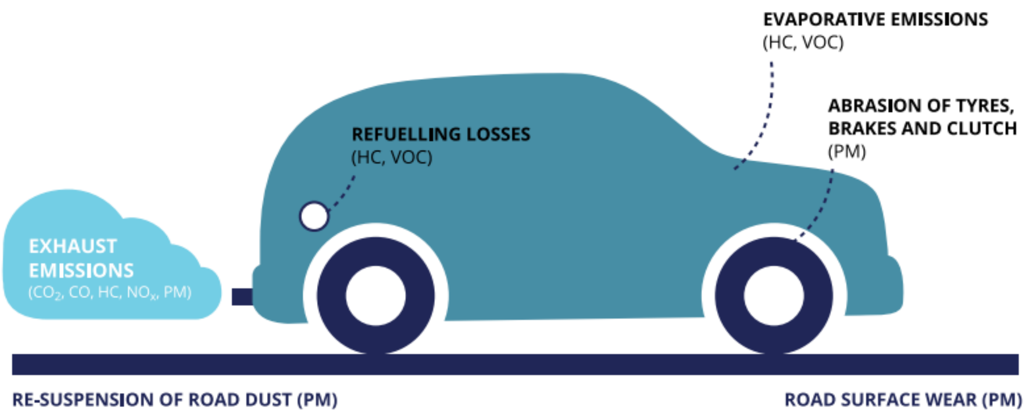
[5] Metcalfe and Boulter (2022)
[6] Gilbert and Boulter (2022)
[7] Metcalfe (2023)

2. Background

2.1. What are vehicle emissions?

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 pollutants as shown in Figure 1[8].

Figure 1: Different types of emissions from internal combustion engine vehicles. Abrasion emissions, road surface wear and re-suspension of road dust are the only 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 (most importantly tyres and brakes) 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, also known as climate pollutants, are so-called because they contribute to global warming and climate change. The most important greenhouse gases emitted by 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

[8] EEA (2016)

comparison, greenhouse gases are typically expressed as carbon dioxide equivalents (**CO_2-e**), which is the mass of CO_2 which would have the equivalent global warming impact[9].

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 micrometres (**$PM_{2.5}$**) – which arises primarily from diesel fuel combustion, brake/tyre wear and road dust.
- Nitrogen oxides (**NO_X**), in particular nitrogen dioxide (**NO_2**) – which are emitted from diesel and petrol fuel combustion.

2.2. Why do vehicle emissions matter?

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[10]. Around 90% of transport emissions are from on-road motor vehicles[11]. 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).

As shown in Figure 2, the air pollution health impacts of motor vehicle emissions in Aotearoa New Zealand are considerable. Air pollution from motor vehicles is estimated to result in 2,247 premature deaths, nearly 9,400 hospitalisations, over 13,200 cases of childhood asthma and more than 330,000 restricted activity days each year in New Zealand. These health impacts result in an estimated social cost of more than $10.5 billion[12] per year.

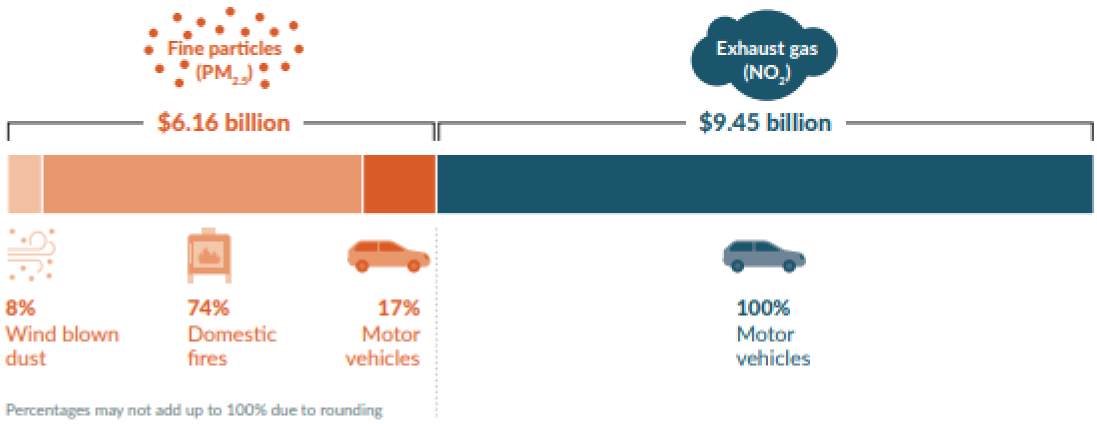
[9] This report only considers direct emissions of CO2-e from motor vehicles. Life cycle emissions from motor vehicles and transport infrastructure are not considered.

[10] MfE (2022)

[11] *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/

[12] Kuschel et al (2022)

Figure 2: Social costs of health impacts from human made air pollution. 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[13]



2.3. How do we estimate changes in vehicle emissions?

In New Zealand, we use the Waka Kotahi NZ Transport Agency (**Waka Kotahi**) Vehicle Emission Prediction Model (**VEPM**) 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 variables including for example, gradient, temperature, fuel quality, heavy vehicle load and average speed.

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 speeds less than 30km/h, VEPM emission factors will include the effects of a significant amount of stop – start driving. Conversely, at higher average speeds VEPM emission factors will be based on steadier speeds (for example, to achieve an average trip speed of 100 km/h it is necessary to be travelling at a high speed for most of the trip).

As with any model, there is some uncertainty in emission estimates from 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) and Metcalfe (2023).

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

2.4. Factors affecting vehicle emissions

The amount of greenhouse gas and harmful emissions produced by a particular vehicle depends on many factors including, for example:

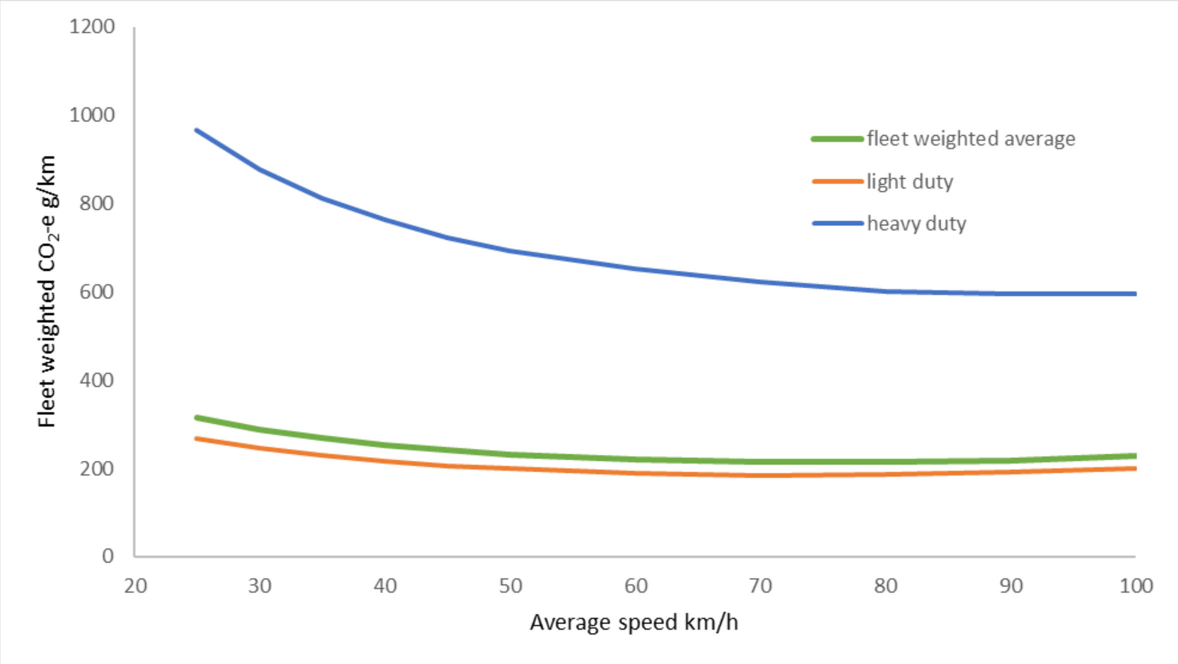
- Vehicle type:
    - fuel (e.g. petrol, diesel, hybrid, micro hybrid, electric)
    - Size and weight
    - Emission control technology (e.g. catalytic converter, diesel particulate filter)
    - Engine technology
- Vehicle maintenance (e.g. engine, emission control systems, AdBlue, tyre pressure)
- Road gradient
- Ambient temperature
- Use of auxhilary equipment such as air conditioning
- Vehicle operation (speed, acceleration, deceleration, gear, stopping and idling)
- Driving style
- Road layout
- Congestion

Effect of speed on emissions

Speed is one factor that can affect emissions. In general, harmful air pollutant and greenhouse gas emissions are lowest when a vehicle is travelling at steady speed, and emissions are increased when the amount of acceleration and deceleration is increased. This means, for example, that emissions tend to be higher in congested traffic and around intersections.

Figure 3 illustrates the effect of average speed on CO_2-e emissions predicted by VEPM (information on the model is provided in section 2.3). The emissions-speed curve has a distinctive shape, with high emission factors at low speed and somewhat higher emissions at higher speeds, with generally lower emission rates in the middle of the speed range. This is because, low average speeds generally represent stop-and-go driving, with high fuel use and emissions. However, at high speeds, higher engine loads and aerodynamic resistance can also require more fuel and generate more emissions.

Figure 3: Fleet weighted average CO_2-e predicted by the vehicle emission prediction model (VEPM 6.3) as a function of speed for 2022 (Source: Metcalfe and Boulter 2022).



Effect of vehicle type on emissions

Although average speed affects emissions, the mix of vehicle types is the most significant factor affecting average emissions from the fleet. For example, an average diesel utility vehicle (ute) in New Zealand will produce around 24 times more harmful air pollutants[14] and almost 50% more CO_2-e[15] than a small petrol car complying with the latest European (Euro 6d) emission standards.

Figure 4 and Figure 5 show NOx and CO_2-e emission factors as a function of speed for an average petrol hybrid car, petrol car, and diesel ute in the New Zealand fleet.

These comparisons show that the types of vehicles being driven on our roads can have a huge effect on emissions, which is much bigger than the relatively small effect of speed on emissions. This is especially true when we consider petrol hybrid vehicles, which have very low emissions even in stop-and-go traffic conditions, and electric cars which have no tailpipe emissions.

[14] Based on social costs of emissions quoted in Table 4 of Metcalfe and Kuschel (2022) MoT-Euro-6-modelling-final-report-4-July.pdf. (transport.govt.nz).

[15] Based on CO_2-e emission factors from VEPM 6.3 for fleet average diesel LCV compared with a small (<1400cc) petrol car.

Figure 4: Fleet weighted average NOx emission factors predicted by VEPM 6.3 as a function of speed for different vehicle types (for 2022 with all other settings at default)

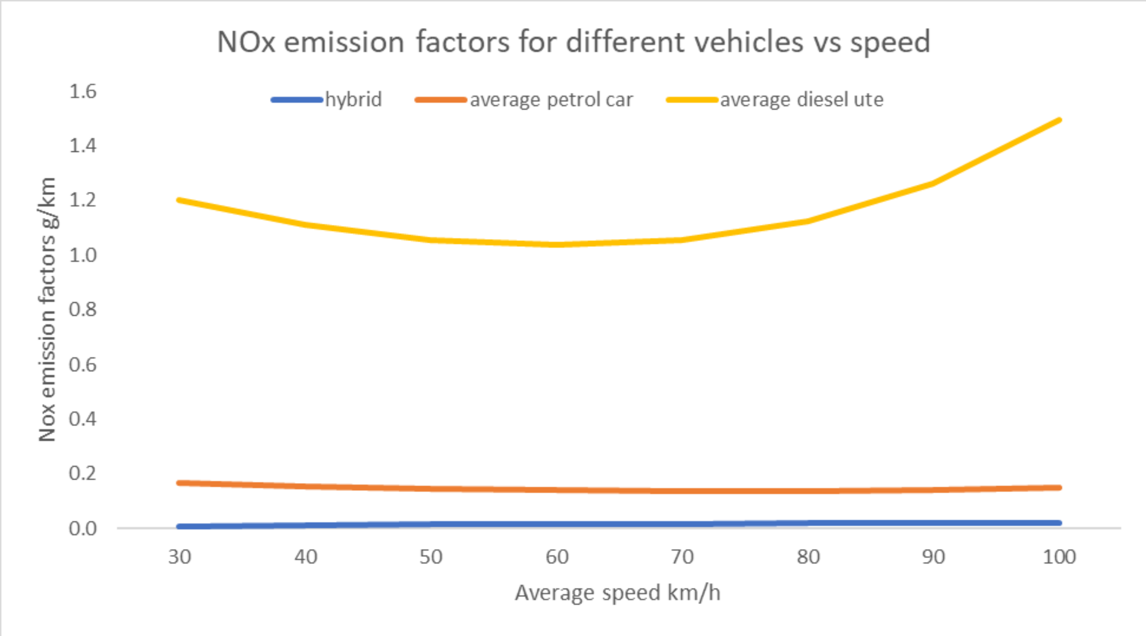
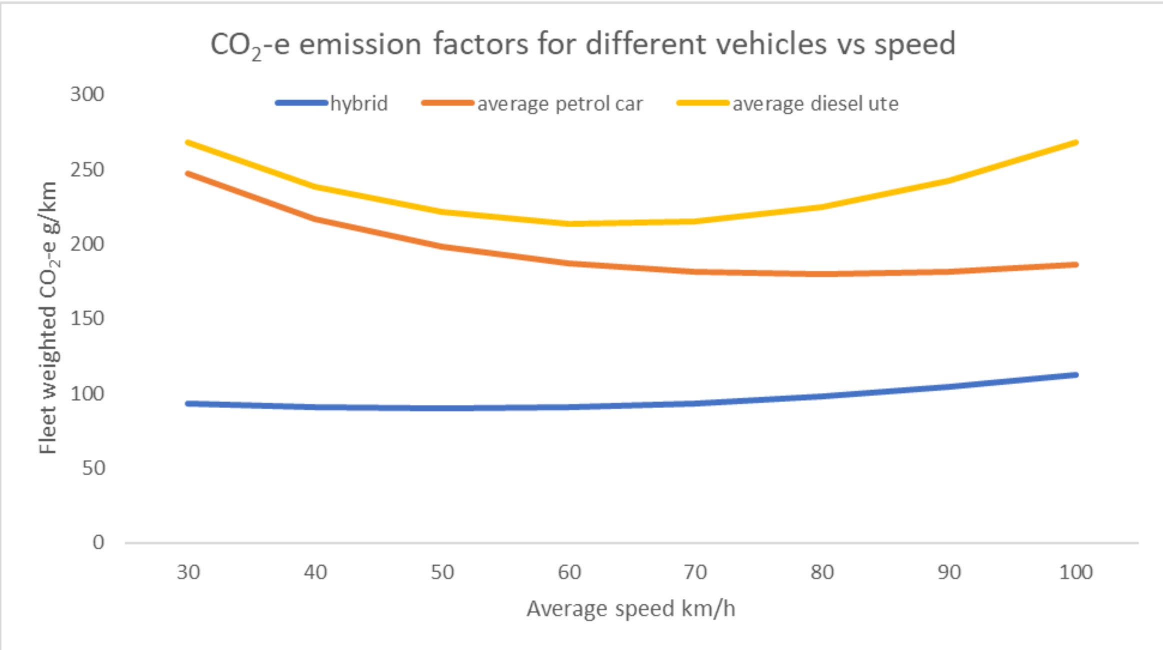


Figure 5: Fleet weighted average CO_2-e emission factors predicted by VEPM 6.3 as a function of speed for different vehicle types (for 2022 at average speed of 50 km/h with all other settings at default)



2.5. Conclusions: factors affecting emissions.

Speed is one of many factors that can affect emissions. However, the most significant factor is the types of vehicles in our fleet.

Over time, the proportion of zero-emission and low-emission hybrid vehicles in our fleet will have a big impact on average fleet emissions of greenhouse gases and harmful pollutant emissions. This will be much more important than any change in emissions due to changes in speed.

3. Effect of speed limits on emissions

Speed limit changes are being implemented in New Zealand to improve safety outcomes and save lives. This section summarises findings of our literature review about the effects of speed limit changes on emissions[16].

3.1. Urban speed limit reductions

As discussed in the previous section, average speed models such as VEPM, typically predict higher emissions with reduction of average speed (below about 60 km/h). However, research shows that speed limit reductions in urban areas don't necessarily cause increased emissions in the real world.

The discrepancy between modelled and real-world impacts is because VEPM can't account for differences in specific driving patterns at a given average speed (as discussed in section 2.3). 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. Our review concluded that VEPM will overestimate any increase in emissions due to speed limit reductions on urban roads.

Our review found three international studies that have estimated the impacts of reducing speed limits from 50 km/h to 30 km/h in urban areas[17]. The impacts varied, from a small increase in emissions from vehicles on the affected roads (a few percent) to a 25% overall reduction, which was attributed to the combination of traffic rerouting and smoother traffic flow at the lower speed.

3.2. Speed limit reductions on motorways and rural roads

Our review found that there is a substantial amount of literature on the impacts of reducing motorway speed limits on emissions and fuel consumption[18]. The literature typically reports that reducing the speed limit from 100 km/h to 80 km/h results in a small decrease in fuel consumption (less than 10%) and associated greenhouse gas emissions.

3.3. New Zealand findings – real world fuel consumption

In New Zealand, a real-world travel time and fuel consumption investigation[19] measured the impact of speed limit changes in both urban and open road settings. The study found average fuel consumption dropped by a small amount (3-5%) when reducing the speed limit from 50 km/h to 40 km/h on urban routes and by a larger amount (14-15%) when reducing the speed limit from 100 km/h to 80 km/h on the open road. This study was for a typical petrol vehicle only and the results cannot be extrapolated to the wider fleet. However, the results support the findings reported in international literature.

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[16] The literature review is reported in full in Metcalfe and Boulter (2022)
[17] Int Panis et al. (2011), Madireddy et al. (2011), Williams (2013)
[18] Literature review is reported in section 5.3 of Metcalfe and Boulter (2022)
[19] Rowland and McLeod (2017)

3.4. Conclusions: effect of reduced speed limits on emissions

Our literature review concludes that:

- reduction of speed limits in urban areas will not significantly affect greenhouse gas emissions from vehicles on the affected roads.
- speed limit reductions in the 100 km/h to 80 km/h range will reduce greenhouse gas emissions from vehicles on the affected roads by a small amount (less than 10%).

4. Effect of traffic calming measures on emissions and air quality

This section summarises the available evidence about the effects of traffic calming on emissions and air quality[20].

Traffic calming is the use of physical measures to control vehicle speed and traffic volume, leading to improved road safety. Traffic calming measures typically involve a vertical and/or horizontal deflection of the vehicle path. Some examples are shown in Table 1.

Traffic calming measures can increase vehicle accelerations and decelerations, which can in turn increase greenhouse gas and harmful emissions. The available literature suggests that the estimated effect of traffic calming measures on emissions is complex and highly variable.

Table 1: Examples of traffic calming measures (Gilbert & Boulter, 2022).

General approach	Specific measure	Description
Vertical deflection	Road hump	Raised, rounded section of road (typically up to 100 cm high). Used to slow traffic down on approach in order to be safely navigated. Sometimes referred to as 'speed hump' in the literature.
	Speed bump	Raised areas across the road that is typically less than around 0.3 m in width and is crossed at very low speed.
	Speed cushion	Similar to road hump, but narrower to allow larger vehicles to pass unaffected. Sometimes referred to as 'speed lump' in the literature.
	Speed table	Similar to road hump, but with a longer, flat top (typically 6-9 m long). Can be combined with a pedestrian crossing, and can be used at an intersection on a minor road.
Other	Textured pavement	Often used in high pedestrian areas to indicate to drivers that they are on a shared road. This shared road system means that drivers need to have a greater awareness of their surroundings and maintain a lower speed.
	Rumble strip	Strip that is placed across the road to induce a vibration in the vehicle which alerts the driver.
Horizontal deflection	Road narrowing	Street is narrowed to reduce vehicle speed and allow more space for pedestrians, cyclers or green infrastructure.
	Chicane	Typically an S-shaped curve in the road, either produced by the road path itself or raised islands in the road. Can either be one-way or two-way.
	Pinch point	Narrowed sections of road, often made by raised boundaries which extend from the side of the road and only allows the passage of one vehicle at a time.
	Pedestrian island	A built-up section of the road separating opposing traffic. Can be used to shift the travel path or visually narrow the width of the road, inducing drivers to reduce their speed. Also provides a safer way for pedestrians to cross the road.
	Mini-roundabout	A round island at an intersection that is used to both reduce speed and organise traffic.

[20] The literature review is reported in full in Gilbert & Boulter (2022)

4.1. Effect of traffic calming measures on greenhouse gas and harmful pollutant emissions

Evidence suggests that traffic calming measures can significantly increase greenhouse gas and harmful pollutant emissions per vehicle on affected road segments (Gilbert & Boulter 2022). However, the effect will depend on the type and design of traffic calming measures. Design which encourages reduced, steady speed along the whole stretch of road (minimising the amount of vehicle acceleration and deceleration) would help to minimise the emission impacts.

Although impacts of traffic calming on emissions per vehicle on individual affected roads can be significant, the effect on overall network emissions in the affected area is likely to be small (less than 10%) because:

- Traffic calming measures tend to be implemented on low-traffic residential roads, or on isolated segments of busy roads (for example in the vicinity of schools)
- Traffic calming can lead to some reduction in overall traffic volume and some diversion of traffic (onto unaffected roads)

Gilbert & Boulter (2022) discuss several assessments which demonstrate that the area wide impact of traffic calming schemes on emissions is likely to be small. One detailed modelling study assessed the impact of area wide traffic calming to reduce speed from 50 km/h to 30 km/h across a suburb of Montreal, Canada[21]. Modelling estimated that greenhouse emissions from vehicles across the entire affected area would increase by 4% and NOx emissions would increase by 2%[22].

4.2. Effect of traffic calming measures on local air quality

Even though traffic calming measures generally result in increased emissions, evidence suggests that traffic calming is unlikely to result in poor air quality (Gilbert & Boulter 2022). Several real-world monitoring studies in cities where traffic calming has been widely implemented have found no significant impact on measured ambient air quality[23,24].

[21] Ghafgazi (2013)

[22] Ghafgazi (2013) estimated that traffic calming measures could increase emissions from vehicles on individual affected roads by up to 15% to 81%, which is comparable with estimates from other published studies.

[23] Cloke et al (1999), Boulter et al (2003), Owen (2005).

[24] 8.1 - Evaluation of the 20mph Speed Limit Roll Out.pdf (edinburgh.gov.uk)

4.3. Auckland traffic calming case study

Traffic calming is unlikely to significantly affect local air quality because, as discussed above, traffic calming measures tend to be implemented on low-traffic residential roads and can result in some diversion of traffic. Another important factor is background air quality, which is affected by emissions from the wider road network as well as other sources such as domestic fires. This means that local air quality is affected not only by nearby roads, but also by high background concentrations of pollutants, particularly in Auckland.

A case study for Auckland illustrates the effect of background air quality (Appended to this report). The case study estimates the worst-case impact of traffic calming measures at a relatively busy road in Te Atatu. We estimate that annual average NO_2 concentration could increase by up to 4%, and 24-hour PM_{10} concentration could increase by up 0.5% within 10m of traffic calming measures[25]. This is a worst-case assessment based on very conservative assumptions and methods. The actual impacts of traffic calming measures on local air quality would be lower than this estimate.

We conclude that traffic calming measures are unlikely to significantly affect local air quality in Auckland, even in the vicinity of traffic calming measures. This is consistent with findings reported in international literature.

4.4. Conclusions: effects of traffic calming measures on emissions

Evidence suggests that implementation of traffic calming generally increases emissions per vehicle on affected roads, however:

- The overall impact of traffic calming on greenhouse gas emissions, ambient air quality and air pollution health impacts of traffic calming measures across the affected area would be small (emissions are likely to increase by less than 10%).
- It is unlikely that traffic calming measures will result in poor local air quality even in the vicinity of traffic calming measures.

[25] The distance of 10m was chosen to represent the closest location where people might be exposed to pollution from the road for 24 hours. The impacts will reduce with distance from the road.

5. What is the likely overall effect of speed management on vehicle emissions in Auckland?

5.1. Overall findings of literature reviews

The literature reviews summarised in section 3 and section 4 concluded that:

- Speed limit reductions in urban areas will not significantly affect greenhouse gas emissions from vehicles on the affected roads.
- Speed limit reductions in the 100 km/h to 80 km/h range will reduce greenhouse gas emissions from vehicles on the affected roads by a small amount (less than 10%), and
- Traffic calming measures are likely to increase emissions by a small amount across affected areas.

Overall, the available evidence suggests that the impact of speed management (which will include speed limit changes and traffic calming) on greenhouse gas and harmful pollutant emissions from the Auckland regional transport network will be small.

To supplement the findings of our literature review, detailed modelling was undertaken to quantify the likely impacts of speed management in Auckland. The following section discusses the results of modelling undertaken by Auckland Transport. The modelling and results are described in more detail in the modelling summary report (Metcalfe 2023).

5.2. Auckland model estimates

The overall potential impact of speed management interventions in Auckland was estimated with the MSM model by the Auckland Forecasting Centre.

The MSM is the multi-modal (vehicles and passenger transport) travel demand model of the Auckland region. 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 VEPM (which is described in section 2.4).

The Auckland Transport model estimates that harmful air pollutants and CO_2 emissions will change by less than 1% (in 2031) due to speed changes across the network for a range of speed management scenarios.

As with any modelling exercise, there is some uncertainty in the results. However, the results from the Auckland MSM provide a useful estimate of the overall likely emissions impacts of speed management across Auckland (Metcalfe 2023). The modelling results support the overall conclusion from our literature reviews - that the overall impact of speed management on greenhouse gas and harmful pollutant emissions from the regional transport network in Auckland will be small.

5.3. Conclusion: overall impact of speed management measures on emissions in Auckland

Although speed management can affect emissions, the overall impact in Auckland is expected to be small (possibly an overall increase or decrease of around 1%).

6. How do we reduce vehicle emissions?

To achieve emission reduction targets, extensive analysis from central government[26] and Auckland Council[27] shows that we need to reduce vehicle travel and increase the proportion of zero emission and low emission vehicles in the fleet.

6.1. Estimated future CO_2-e emissions and health impacts

We have used emission estimates from the Auckland MSM model to estimate future CO_2-e emissions and air pollution health impacts for a range of scenarios (Metcalfe 2023).

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):

- **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.
- **Increase the proportion of light duty vehicles that are electric to 30% in 2035**. This is the ERP target for Aotearoa New Zealand.

We estimated CO_2-e emissions and social costs of motor vehicle air pollution health impacts in Auckland for the following scenarios:

- **Base case 2016:** This is the base case from HAPINZ 3.0
- **Base case 2035:** This is based on business as usual projections from the Auckland MSM model
- **Area wide speed reductions:** This scenario assumes speed reductions to 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.
- **Area wide speed reductions with 20% reduction in (VKT) and 30% EV:** This scenario assumes that targets from the New Zealand emission reduction plan for reduction of light duty vehicle kilometres travelled (VKT) and uptake of light duty electric vehicles are achieved.

Figure 6 illustrates the estimated social costs of motor vehicle emissions in Auckland for each scenario. The results estimate that:

- **Base case 2016:** HAPINZ 3.0 (Kuschel et al 2022) estimates the air pollution health impacts of motor vehicle emissions in Auckland as approximately $3.6 billion in 2016
- **Base case 2035:** The social costs of motor vehicle emissions in Auckland reduce to approximately $2.5 billion by 2035 under a base case projection. This reduction in health impacts is in spite of an estimated 29% increase in vehicle kilometres travelled between 2016 and 2035. Reduced impacts are due to gradual replacement of older vehicles in the fleet with new low and zero emission vehicles.

[26] MfE (2022)
[27] Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan (aucklandcouncil.govt.nz)

- **Area wide speed reductions:** Social costs of motor vehicle emissions are less than 1% higher than the social costs of motor vehicle emissions under the base case (without any speed interventions).
- **Area wide speed reductions with 20% reduction in light duty VKT and 30% light duty EV by 2035.** Social costs of motor vehicle emissions in Auckland would reduce to approximately $2.1 billion if these national level transport targets are achieved in Auckland.

Figure 6: Estimated social costs of motor vehicle emissions in Auckland for 4 key scenarios (Metcalfe 2023)

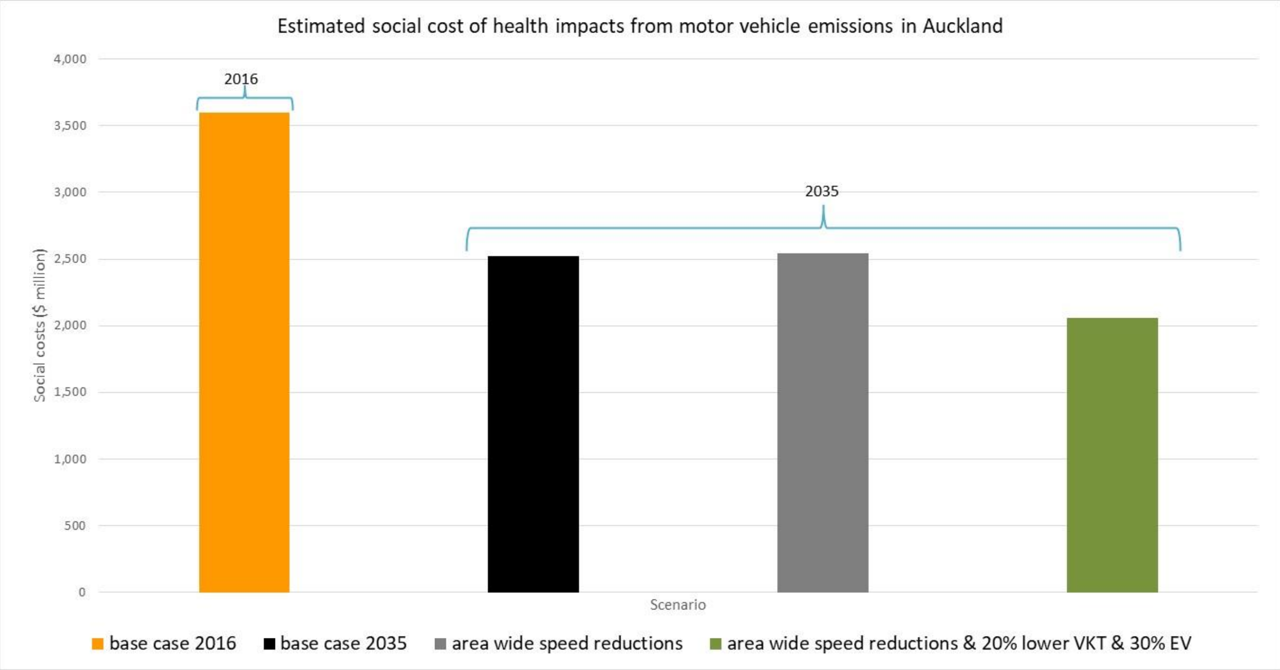
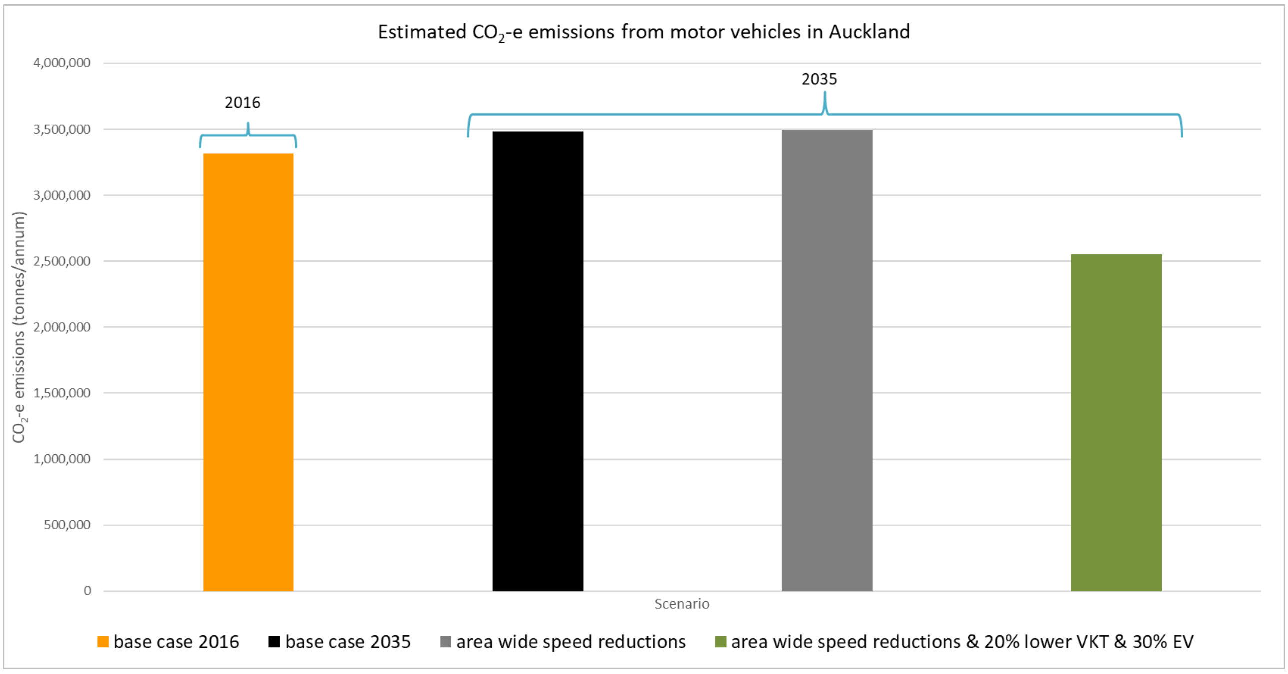


Figure 7 illustrates the estimated CO_2-e emissions from motor vehicles in Auckland for each scenario. The results show that:

- **Base case 2035:** 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.
- **Area wide speed reductions:** Overall CO_2-e emissions from motor vehicles in Auckland with area wide speed reductions would be 0.3% higher than CO_2-e emissions from motor vehicle emissions under the base case (without any speed interventions). This is not a significant difference.
- **Area wide speed reductions with 20% reduction in light duty VKT and 30% light duty EV by 2035:** CO_2-e emissions from motor vehicles in Auckland would be around 27% lower than the base case in 2035 if these national level transport targets are achieved in Auckland. As discussed above, the target to reduce VKT by 20% (compared to the 2035 baseline) 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. The Auckland Council Emission Reduction Plan includes a target to reduce VKT by 50% 2030 compared to 2019, which would substantially reduce motor vehicle emissions and social costs compared to this scenario.

Figure 7: Estimated CO2-e emissions from motor vehicles in Auckland for 4 key scenarios (Metcalfe 2023)



6.2. Conclusions: how do we reduce vehicle emissions and air pollution health impacts in Auckland?

To achieve significant reductions in vehicle emissions and air pollution health impacts we need to increase the proportion of zero emission vehicles in the fleet and reduce vehicle travel. This means that we need to increase the share of trips undertaken by walking, cycling and public transport.

Speed reduction, which makes it safer to walk and cycle, is a critical part of our emission reduction pathway for Auckland and New Zealand.

7. Conclusions

This section collates conclusions from previous sections of the report.

Factors affecting emissions.

Speed is one of many factors that can affect emissions. However, the most significant factor is the types of vehicles in our fleet.

Over time, the proportion of zero-emission and low-emission hybrid vehicles in our fleet will have a big impact on average fleet emissions of greenhouse gases and harmful pollutant emissions. This will be much more important than any change in emissions due to changes in speed.

Effect of reduced speed limits on emissions

Our literature review concludes that:

- Reduction of speed limits in urban areas will not significantly affect greenhouse gas emissions from vehicles on the affected roads.
- Speed limit reductions in the 100 km/h to 80 km/h range will reduce greenhouse gas emissions from vehicles on the affected roads by a small amount (less than 10%).

Effect of traffic calming measures on emissions

Evidence suggests that implementation of traffic calming generally increases emissions per vehicle on affected roads, however:

- The overall impact of traffic calming on greenhouse gas emissions, ambient air quality and air pollution health impacts of traffic calming measures across the affected area would be small (emissions are likely to increase by less than 10%).
- It is unlikely that traffic calming measures will result in poor local air quality even in the vicinity of traffic calming measures.

Overall impact of speed management measures on emissions in Auckland

Taking into account findings from our literature reviews, as well as the results of a detailed modelling study for Auckland, we conclude that, although speed management can affect emissions, the overall impact in Auckland is expected to be small (possibly an overall increase or decrease of around 1%).

How do we reduce vehicle emissions and air pollution health impacts in Auckland?

To achieve significant reductions in vehicle emissions and air pollution health impacts we need to increase the proportion of zero emission vehicles in the fleet and reduce vehicle travel. This means that we need to increase the share of trips undertaken by walking, cycling and public transport.

Speed reduction, which makes it safer to walk and cycle, is a critical part of our emission reduction pathway for Auckland and New Zealand.

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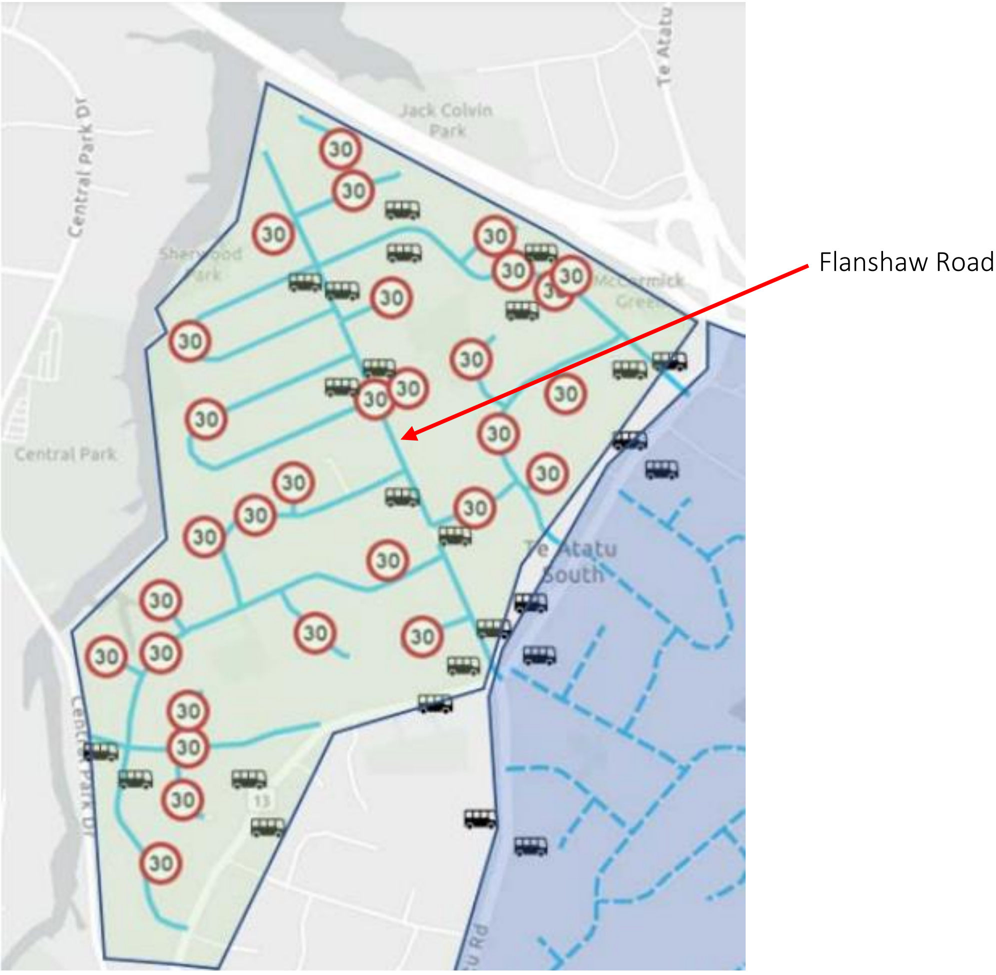
Appendix: Auckland traffic calming case study

CASE STUDY: Potential local air quality impacts of traffic calming measures in Te Atatu South
Description: Auckland Transport introduced speed calming measures and speed limit reductions across a Te Atatu South neighbourhood (shown below). Measures included speed bumps, speed tables and signage[28]. We estimated the worst-case impact to local air quality of localised emission increases in the vicinity of traffic calming measures on Flanshaw Road, which is the busiest road in the affected area. This means that Flanshaw Road is the worst-case location within the affected area (in terms of air quality risk). We have not estimated the impact of the traffic calming measures on overall air quality across the area. The overall effect is likely to be small, as discussed previously. 
Method: We used the Waka Kotahi air quality screening model to estimate air quality impacts. The model is briefly described as follows.

[28] Research Report 701 Safety interventions and their contribution to mode shift (nzta.govt.nz)

Waka Kotahi air quality screening model: The Waka Kotahi air quality screening model (nzta.govt.nz) for estimating air quality near roadways combines the contribution of the road together with the background air quality to arrive at a cumulative concentration.

Background air quality is the level of pollution from all sources excluding the road being assessed. This includes the wider road network as well as other sources such as domestic fires.

The screening model is designed to provide a conservative (worst-case) assessment of air quality risk from a single road for two key transport-related air pollutants – particulate matter (PM_{10}) and nitrogen dioxide (NO_2).

The road contribution to PM_{10} concentrations is calculated using emission factors, which take into consideration the assessment year, the average speed, the amount of traffic and the proportion of heavy vehicles. For NO_2 concentrations, the road contribution is based on a general dispersion algorithm, which is only dependent on the amount of traffic. Background air quality data (excluding nearby roads) are provided for every location in New Zealand (by census area unit).

The method followed two key steps:

Step 1. Estimate worst-case air quality risk for Flanshaw Road without considering localised impacts of traffic calming measures. The air quality risk was estimated using the Waka Kotahi air quality screening model.

Step 2: Make a worst-case assumption that air quality risk for Flanshaw Road in the vicinity of traffic calming measures could be up to 100% higher than the risk estimated in Step 1.

Estimation of impacts at Flanshaw Road.

Step 1: Estimate worst-case air quality risk for Flanshaw Road without considering localised impacts of traffic calming measures.

We assume that neighbouring houses are the closest (worst-case) locations where people might be exposed for significant time. The closest houses are approximately 10m from the road edge.

Screening tool input data:

- Background air quality for the Wakeling Census Area Unit[29].
- Traffic: 3,121 AADT. 5% heavy[30]
- Vehicle speed: 30km/hour
- Distance to receptor: 10m
- Assessment year: 2022

Screening tool results:

PM_{10} 24hr average:

- Road contribution: 0.2µg/m^3
- Background air quality: 43.6µg/m^3
- Cumulative contributions: 43.8µg/m^3

[29] 13.1µg/m^3 annual average NO_2 and 43.6 µg/m^3 24 hour PM_{10} Background air quality | Waka Kotahi NZ Transport Agency (nzta.govt.nz)
[30] Traffic count, May 4 2021: Auckland Transport Open GIS Data (arcgis.com)

NO_2 annual average:

- Road contribution: 0.5µg/m³
- Background air quality: 13.1µg/m³

Cumulative contributions: 13.6µg/m³

Step 2: Estimate worst case air quality risk in the vicinity of traffic calming measures on Flanshaw Road:

Although traffic calming generally results in increased harmful emissions per vehicle, there is little consensus on the size of the effect (Gilbert and Boulter, 2022). For the purposes of this case study, we make a conservative (worst case) assumption that harmful emissions could potentially increase by up to 100% from vehicles in the vicinity of a speed bump or speed table[31].

Under this worst-case assumption, the worst-case air quality risk for Flanshaw Road quality could be 100% higher in the immediate vicinity of traffic calming measures (compared with the risk without considering localised impacts of traffic calming measures estimated in Step 1).

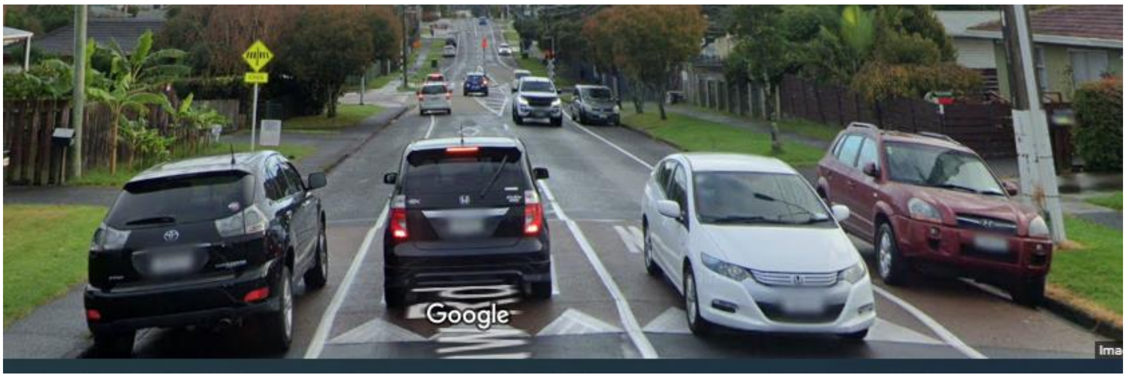
Based on these assumptions, the worst-case contribution of emissions from a local road in the Te Atatu South case study area, within 10m of traffic calming measures, would be:

PM_{10} 24hr average:

- Road contribution: 0.4µg/m³ (100% higher than the contribution estimated in Step 1)
- Background air quality: 43.6µg/m³
- Cumulative contributions: 44.0 µg/m³

NO_2 annual average:

- Road contribution: 1.0µg/m³ (100% higher than the contribution estimated in Step 1)
- Background air quality: 13.1µg/m³
- Cumulative contributions: 14.1µg/m³



Flanshaw Road, Te Atatu. Google maps image captured May 2022 ©2023 google

[31] Gilbert and Boulter (2022) summarise findings from literature (Table 4.1 of the report). Setting aside results reported by Daham et al (2005) which assumed aggressive driving behavior, and Ribeiro (2015) which only equipped on vehicle with a low-cost hand held monitor, the effect of speed humps, bumps and cushions ranged from a 22% decrease in NOx emissions through to a 110% increase in NOx emissions.

Findings: The screening assessment shows that the worst-case contribution of Flanshaw Road to local air quality is small compared with background air quality, even within 10m of the road edge.

Based on worst-case assumptions, we estimate that annual average NO_2 concentration could increase by up to 4% and 24 hour PM_{10} concentration could increase by up 0.5% within 10m of traffic calming measures.

The distance of 10m was chosen to represent the closest location where people might be exposed to pollution from the road for 24 hours. The impacts will reduce with distance from the road.

This is a worst-case assessment. The actual impacts of traffic calming measures on local air quality would be lower than this estimate and would not be significant.