Better bus fleets for New Zealand: Evaluating costs and trade-offs

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With thanks to:
Auckland Transport, Greater Wellington Regional Council, and the Energy Efficiency and Conservation Authority

Abstract:
Transport systems abound with unquantified externalities. While official guidance from the New Zealand Transport Agency recommends evaluating all impacts of vehicle operations, including noise and emissions, many are left unmeasured due to methodological difficulties. An additional challenge with bus and noise emissions is that network wide averages do not capture the site specific impacts. As a result, transport evaluations can arrive at conclusions that seem unrealistic from an on-the-ground perspective or rely instead on qualitative rather than quantitative judgements.

This paper describes an approach to measuring transport externalities that is typically left unmeasured in fleet procurement decisions– vehicle noise and emissions. It then applies this approach to an urban bus fleet, showing how GIS data and simple quantitative modelling techniques can be used to understand the impact of bus operations on urban amenity. Our approach allows us to analyse and quantify trade-offs between higher fleet costs and better outcomes on city streets.

Finally, this paper reflects upon the implications for transport agencies and bus operators. Improved evaluation methods suggest that upgrading urban bus fleets to hybrid or electric buses can bring significant long-term benefits. Although recent international experience suggests that hybrid and electric buses may not yet be ready for widespread deployment, it is recommended that agencies and operators develop strategies for incorporating them into fleets within the next decade.

Introduction

Transport agencies throughout Australasia are increasingly aware that emerging vehicle technologies will pose new opportunities and challenges for transport investment and public transport provision. Some technologies, such as hybrid and electric fuel vehicles, are available and moving towards widespread deployment, while others, such as driverless cars, are further off. These technologies promise to mitigate many of the “ills” associated with road transport, including vehicle noise and emissions and the social cost of accidents.

Transport agencies face several challenges when deciding when and how to respond to emerging technologies. First, these technologies are not yet market ready, and there is uncertainty about when they will be widely deployed. It is important to have a strategy for responding when new technologies become widely available, without committing in advance to adopting unproven technology. Second, it is often necessary to balance financial considerations with economic and environmental benefits. New vehicle technologies may be more expensive in terms of up-front purchase costs while offering long-term operating cost savings or broader benefits.

This paper presents an approach to modelling and quantifying the long-term effects of alternative fuel technologies on purchase and operating costs and environmental outcomes related to vehicle operation. It is based on recent work undertaken on behalf of Auckland Transport, as well as previous analysis for Greater Wellington Regional Council and the Energy Efficiency and Conservation Authority. While it applies this approach to the case of urban bus fleets in particular, this approach can in principle be extended to the broader vehicle fleet. It can be used to support policy and investment decisions related to the deployment of new vehicle technologies.

Strategic context for public transport provision

Transport service provision can have broad impacts on a city’s economic performance, urban outcomes, and environmental performance. This is recognised in a range of strategies and policies established by local and central governments. Taken together, these policies encourage a focus on providing an urban bus fleet that:

- Provides good value for money – NZTA rules specify a farebox recovery target of 50%, while many councils are aiming to raise public transport ridership and improve transport outcomes across the board
- Is reliable for users – bus frequency and service reliability are two key measures of service quality
- Offers good environmental performance – local and central government have set targets for a significant reduction in the greenhouse gas emissions
- Supports good urban outcomes – many councils are implementing strategies encourage improvements to amenity, especially in city centres.

There are often trade-offs between these goals. Although alternative bus technologies can offer significantly improved environmental performance and urban amenity, they are at present more costly than diesel buses and may not yet be proven for large-scale rollout. In principle, economic evaluation guidelines published by the New Zealand Transport Agency (NZTA) require these outcomes to be quantified and compared. In practice, methodologies for doing so are often underdeveloped.

A new approach to modeling outcomes from alternative bus technologies

Our methodology for evaluating the impact of alternative fuel technologies for urban bus fleets considers both costs and benefits:

- Costs include vehicle purchase costs, operation costs, and maintenance and renewal costs
- Benefits include lower greenhouse gas emissions, better local air quality in bus corridors, and lower bus noise in the major bus corridors – i.e. improved livability and environmental performance.

This evaluation takes a “whole of life” and “whole of fleet” approach – i.e. it models future fleet outcomes over an extended evaluation period. It is scenario-based – i.e. looking at multiple paths for upgrading urban bus fleets. While it does not ascribe dollar values to noise and vehicle emission outcomes, it is consistent with NZTA’s Economic Evaluation Manual (EEM) and is therefore considered fit for purpose for developing a business case for fleet upgrades.

It is important to evaluate outcomes over a longer time period, as new vehicles stay in the fleet for a long time. For example, NZTA’s urban bus fleet policy sets a maximum age of 20 years for urban buses, with a target average fleet age of 12.5 years. The “durable” nature of buses and other vehicles means that it is possible to conduct scenario-based modelling of outcomes over a 20-40 year time period, as the dates of vehicle replacement can be projected out over time.

We describe our modelling approach and key model inputs in subsequent sections.

Key insights

We find that:

- Although alternative bus technologies may not yet be ready for wide deployment, they are becoming increasingly viable. As technologies develop, they typically become more reliable and purchase prices decrease.
- At current purchase prices, we expect the cost of purchasing hybrid or electric buses to be higher than the cost to purchase diesels. Some, but not all, of these costs are expected to be recouped from fuel savings.
- However, the introduction of alternative fuels or hybrid buses is associated with significant reductions in CO2 emissions over the longer term. These emissions reductions can help urban bus fleets contribute to national and regional greenhouse gas emissions targets.
- Similarly, our fleet modeling suggests that although alternative bus technologies are more costly, they also offer significant long-term reductions in vehicle emission and noise. They are therefore highly supportive of local government strategies for improving environmental outcomes and city center vibrancy.
- While hybrid buses are already in wide deployment in some overseas cities, electric buses are less market ready and are likely to be several years off.

In summary, our analysis to date has identified long-term opportunities for transforming New Zealand’s urban bus fleets, but opportunities are limited in the short term due to recent bus purchases and the readiness of alternative technologies. The best strategy, in light of these uncertainties, may be to begin planning for a high-level fleet upgrade path while remaining flexible about timing of new bus introduction. When new bus technologies are available (and affordable), it will be necessary to ensure that an appropriate policy framework is in place and negotiate with operators.

Modelling approach – key inputs, stages, and results

The modelling approach in this report is based on work undertaken by the authors for several regional transport agencies in New Zealand as well as the Energy Efficiency and Conservation Authority. Some results have previously been published in various formats.

Overview of alternative bus technologies

We considered a number of different fuel technologies, including hydrogen fuel cells and trolleybuses, before focusing on three major technologies:

- modern diesels of Euro V and VI standards – an existing technology that is widely used in urban bus fleets
- diesel/electric hybrids powered by series or parallel systems – an emerging technology that is widely used but not fully cost-competitive with diesels
- fully-electric vehicles powered by a full-day battery, versus those that utilise induction charging – an emerging technology that is in use in a number of trials.

Table 1 provides a comparative overview of the three different technologies.

Table 1: Comparison of existing and emerging bus technologies

	Modern diesel	Diesel/Electric Hybrid	Fully-Electic
Vehicle Cost (per vehicle)	\$300,000 - \$450,000	\$600,000	\$0.9- \$1.1 million plus battery replacement
Infrastructure Cost	None	Minimal	Extensive (charging stations and/or induction pads)
Maintenance Cost	Baseline condition	Slightly higher than diesel	Lower than diesel due to fewer moving parts
Emissions	As per Euro ratings	Up to 25% less than diesel	Zero local emissions
Noise	65-77 dB	2-3 dB quieter than diesel	60-70dB
Flexibility	Complete flexibility within the existing road network	Complete flexibility within the existing road network	Overnight charging beholden to battery range; opportunity charging limited to specific routes with infrastructure
Capacity	38-100 people, depending on size/model	Slightly less than diesel due to additional battery weight	Slightly less than diesel due to additional battery weight
Reliability	High	Unproven in long-term	Unproven
Advantages	Lowest capital cost	Lower emissions Improved fuel efficiency No supporting infrastructure	Lowest noise and emissions Lower energy costs Lower maintenance costs
Disadvantages	Highest emissions Loud when accelerating	Poorer performance at higher speeds/over longer distances	Reliability unproven High infrastructure costs
Maturity of Technology	Mature	Maturing	Immature

	Modern diesel	Diesel/Electric Hybrid	Fully-Electic
Availability for New Zealand	Euro V now; Euro VI in 18-24 months	Likely in 1-2 years	Likely in 10 years

Sources: "Evaluating the impact of different bus fleet configurations" (PwC, 2014), "Powering public transport in New Zealand" (MRCagney, 2012), and discussions with bus operators and transport agencies

Identifying the costs and benefits of alternative bus technologies

Hybrid and electric bus technologies tend to be more expensive to purchase than diesel buses, while offering potential fuel savings and better environmental performance. In this section, we attempt to quantify the trade-offs involved in alternative fleet upgrade paths. Our analysis is based on principles set out in NZTA's EEM, which provides guidance on cost-benefit analysis of transport investments, including public transport investments.

Based on the EEM and relevant international experience with alternative bus technologies, we have identified various differences in the performance of different bus types. On the one hand, the cost to purchase, operate and renew different bus types will differ in the following areas:

- Bus purchase costs: Higher-quality buses and newer technologies tend to be more expensive to purchase
- Fuel costs: Buses differ in terms of fuel economy and type of fuel used; electricity tends to be cheaper than diesel fuel
- Maintenance and renewal costs: Some bus types may be more expensive to maintain and overhaul
- Fixed costs associated with introducing new technologies: Hybrid buses require battery conditioners and additional training for maintenance staff; electric buses require charging stations and additional training for maintenance staff.

However, some costs, such as driver costs, will not vary significantly between different bus technologies.

On the other hand, alternative bus technologies offer significantly different outcomes for environmental quality and urban amenity, and, potentially, benefits for transport users. We have identified three key points of difference between alternative bus types:

- Vehicle emissions with an impact on local amenity, such as carbon monoxide (CO), un-burned hydrocarbons (HC), nitrous oxides (NOx), and particulates (PM10): Diesel buses meeting higher Euro standards perform better on emissions, while hybrids reduce emissions further as a result of their greater fuel economy
- Vehicle noise, which can have a significant effect on amenity and property values in areas with high bus movements: Diesel buses tend to be noisier than hybrid or electric buses
- Greenhouse gas emissions (CO2-equivalent emissions), which result in global environmental and social costs: Greater fuel economy reduces emissions, while electric buses' emissions are lowest due to New Zealand's renewable electricity mix.

In practice, many of these benefits are highly location-specific, which creates a challenge for evaluation. For example, bus noise is likely to only have a continuous impact in relatively dense areas which see relatively high volumes of buses.

We develop new modelling techniques, including flexible spreadsheet-based scenario modelling and noise and emissions modelling based on Generalised Transit Feed Specification (GTFS) data, GIS analysis and Python scripts, to understand the impacts of all of these factors.

A flexible, scenario-based approach

We use data on the composition and age of existing urban bus fleets to develop high-level scenarios for progressively upgrading the fleet with new vehicle technologies. Importantly, these scenarios do not envisage replacing the existing fleet *en masse* – instead, they assume that new buses will be added to the fleet incrementally when needed to replace old buses leaving service. In addition, our approach can be used to consider the impact of policy changes and contract timing. For example, transport agencies or bus operators may use the implementation of new contracts as an opportunity to renew their fleets.

The following table summarises three potential scenarios that reflect current information on the expected future market readiness of various technologies for New Zealand. We present indicative results for each of these three scenarios.

Table 2: Future fleet composition scenario definition

Scenario Name	Definition	Notes
Better diesel buses	Buses exiting the fleet are replaced by the most advanced standard for diesel buses – Euro 6 buses	This scenario reflects the most modest fleet upgrade path available
Hybrid bus introduction	Buses exiting the fleet are replaced by hybrid buses starting 2017	This scenario would allow for earlier introduction of new bus technologies
Diesel then electric	Buses entering the fleet before 2024 are replaced by Euro 5 diesel buses; starting in 2024 they will be replaced by electric buses	This scenario would move towards electric buses when they are market-ready and use diesel buses as a bridging measure

Modelling the costs of bus purchase and operations

Table 3 summarises the financial costs of alternative bus technologies, and notes how and why they might differ. It also identifies some sources of information that may assist in quantifying costs.

Transport agencies do not directly bear the costs of bus fleet operation. Instead, they contract for bus services on a six- or nine-yearly cycle – and should expect to pay the costs of purchasing, maintaining, and operating vehicles. Agencies have the option of setting quality standards for bus contracts – e.g. by requiring that operators use a specific mix of buses. If higher quality standards result in higher costs to purchase or operate buses, we would expect them to pay these costs over the life of the contract.

Table 3: Impacts of alternative bus technologies on whole-of-life costs

Cost category	Impact of bus tech	Notes / source
Bus purchase cost (fixed)	Higher-quality buses and newer technologies tend to be more expensive to purchase	MRCagney (2011) and PwC (2014) provide recent estimates; these estimates have been supplemented with a review of international evidence
Driver costs (variable)	Driver cost is likely to remain fixed unless some bus types are significantly faster on routes	MRCagney (2011) provides estimates of driver costs per hour; these have been updated to 2014 NZD using Statistics NZ wage inflation data
Fuel costs (variable)	Fuel costs vary in proportion to service-kilometres and the fuel efficiency / fuel type of buses	MRCagney (2011) and PwC (2014) provide recent estimates; these have been supplemented with a review of international evidence MBIE electricity and fuel price modelling can be used to forecast future costs
Maintenance and refurbishment costs	Maintenance costs tend to be estimated as a percentage of bus purchase costs; periodic refurbishments are likely to be estimated on a similar basis	An international literature review suggests that it is difficult to robustly estimate costs and as a result we have gathered further information from discussions with operators and agencies.

We have assumed that many costs will stay constant in real terms. This is likely to be an unrealistic assumption in light of the fact that the cost to purchase emerging technologies may fall significantly over time. However, we have incorporated projections of future energy costs, as rising diesel prices and flat electricity prices are expected to provide an incentive to adopt new fuel technologies. MBIE's forecasts of commercial diesel and electricity prices are summarised in Figure 1.

Figure 1: MBIE energy price forecasts to 2030

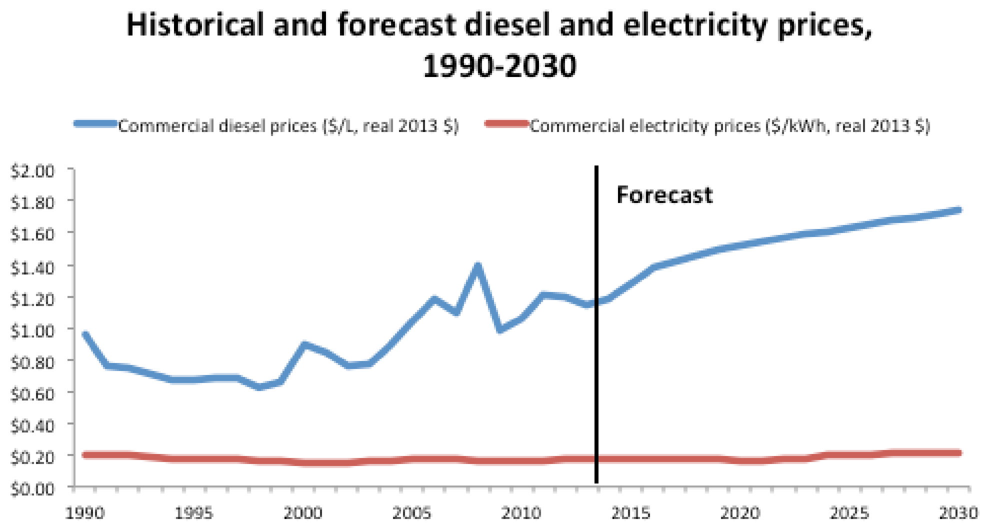


Table 4 breaks down the expected whole-of-life fleet costs under three upgrade scenarios. Costs are discounted to present value over a 40-year evaluation period using NZTA's recommended 6% discount rate. It is based on an example bus fleet of approximately 500 vehicles and an average fleet age of around 9 years. We have assumed, furthermore, that the urban bus fleet provides 21 million service-kilometres and 1 million service-hours. These values are within the typical range for a city of around half a million people.

The key finding from this analysis is that although hybrid and electric buses offer significant fuel cost savings – amounting to up to $50 million in present value terms – this is not sufficient to offset the higher purchase costs. However, this dynamic may change in the future, either due to rising fuel prices or falling costs to purchase vehicles.

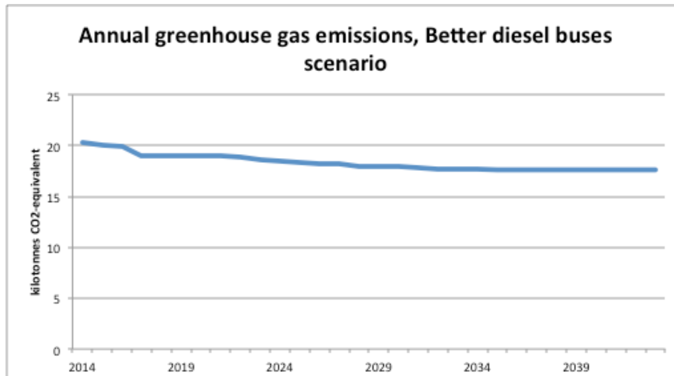
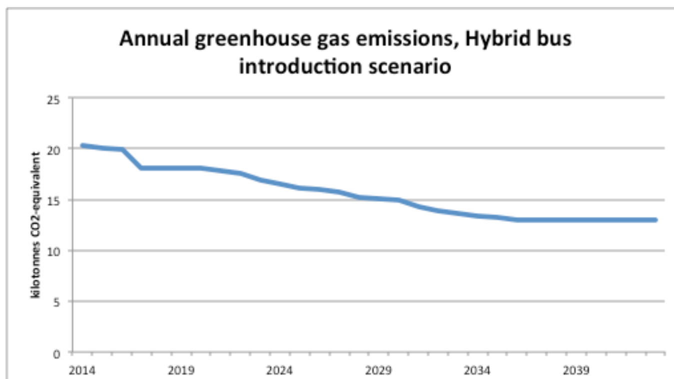
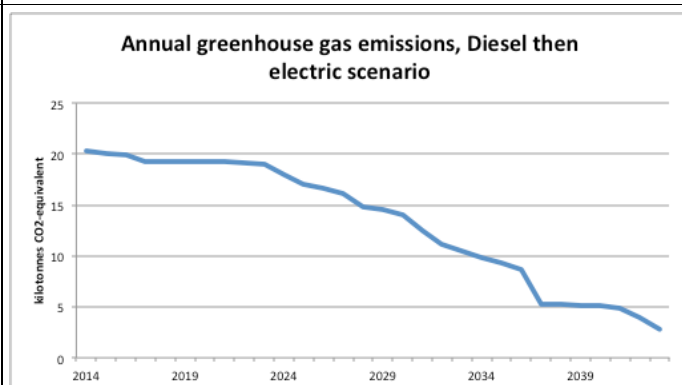
Table 4: Projected whole-of-life costs of purchasing and operating the example urban bus fleet

Fleet scenario	Bus purchase costs (incl. fixed costs)	Fuel costs	Bus maintenance and renewal costs	Driver costs	Total
Better diesel buses	$165.9m	$184.7m	$277.7m	$385.2m	$1013.5m
Hybrid bus introduction	$220.1m	$159.9m	$276.3m	$385.2m	$1041.5m
Diesel then electric	$256.1m	$159.1m	$285.2m	$385.2m	$1085.5m

Modelling greenhouse emissions from the urban bus fleet
We have modelled annual greenhouse gas emissions resulting from bus fleet operations over the next 40 years using information on current bus service-kilometres, estimated fuel economy of alternative bus types, and MBIE's forecasts for the future share of renewable electricity generation. These forecasts assume that the total service-kilometres operated will remain constant over time.

Table 5 presents graphs of future greenhouse gas emissions and comments on outcomes from each scenario.

Table 5: Annual forecasts for greenhouse gas emissions under three scenarios

Comments	Forecast
Upgrading the fleet with Euro 6 buses would result in incremental reductions in greenhouse gas emissions as a result of slight improvements in fuel economy.	
Transitioning the fleet to hybrid buses beginning in 2017 would result in significant reductions in greenhouse gas emissions – emissions would ultimately fall by one-third. However, the ongoing use of diesel fuel would make further reductions in emissions unlikely. This would support plans to reduce greenhouse gas emissions from transport while not fully decarbonising the bus fleet.	
Transitioning the fleet to electric buses beginning in the mid-2020s would result in relatively few emissions reductions in the short term, but over the longer term emissions would fall dramatically. By 2041, emissions would have fallen by over three-quarters. This scenario would align best with New Zealand's plans to reduce greenhouse gas emissions. Even a more conservative approach to introducing electric buses will still result in long-term benefits.	

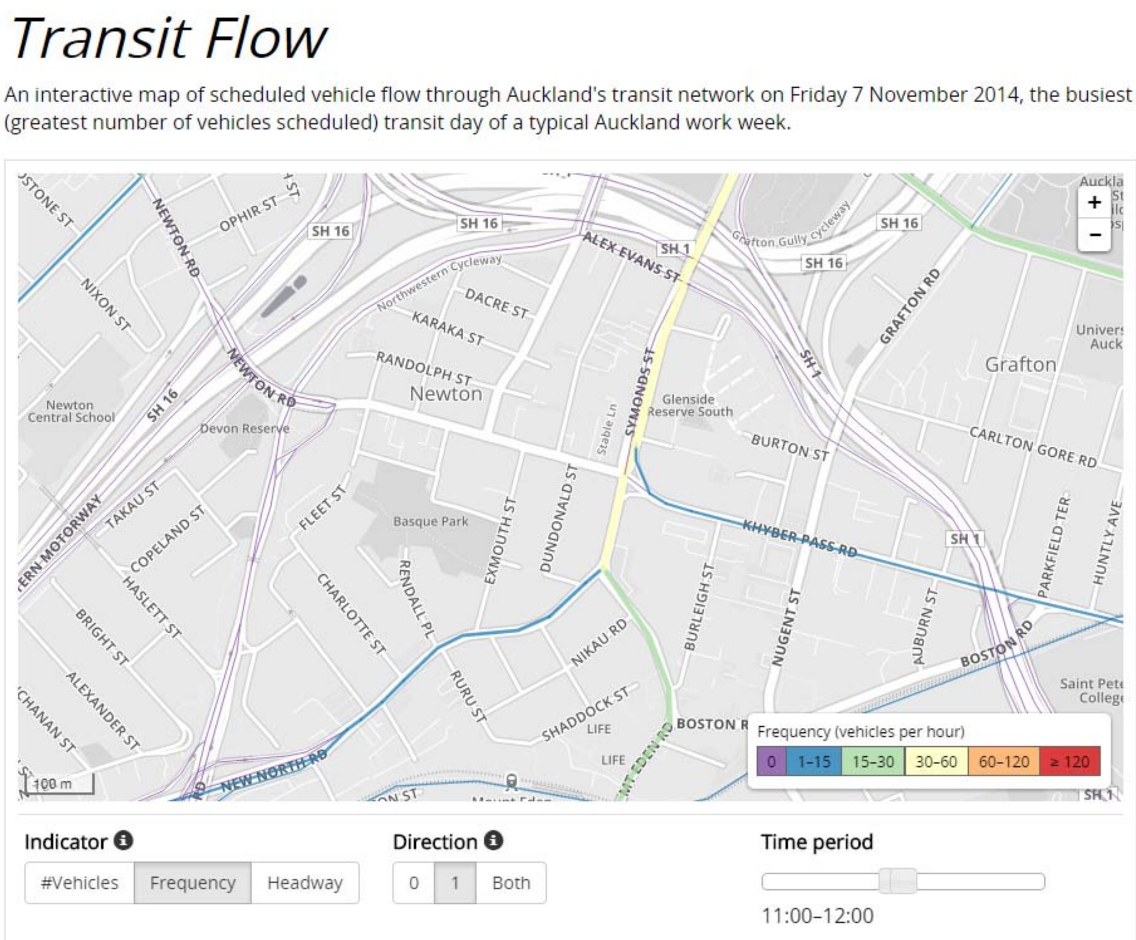
Importantly, we expect reductions in localised emissions and bus noise to follow a similar path, as reductions are driven by the introduction of alternative bus technologies.

Emissions with a localised impact

We have modelled localised emissions from bus fleet operations along a single corridor in the city centre. In order to do so, we have used Generalised Transit Feed Specification (GTFS) data on urban bus fleets, which allows us to identify the timing and location of bus movements during a typical weekday, in conjunction with data on the expected emissions from different types of buses.

We model emissions at a particular point, rather than across the whole network, as the impacts of vehicle emissions on human health and urban amenity are highly site-specific. In New Zealand's main cities, some city centre streets can attract over 1,000 daily bus movements. They tend to be close to major concentrations of employment and, increasingly, residential populations. These streets are therefore likely to be areas where bus emissions have a significant impact on urban outcomes. Figure 2 displays outputs from MRCagney's proprietary GTFS Explorer, which enables easy visualisation and analysis of bus volumes throughout the network.

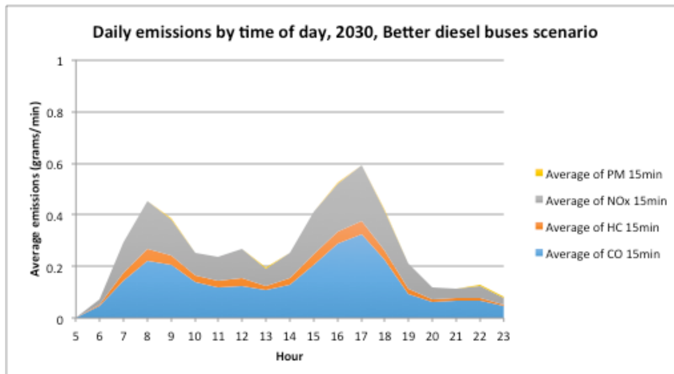
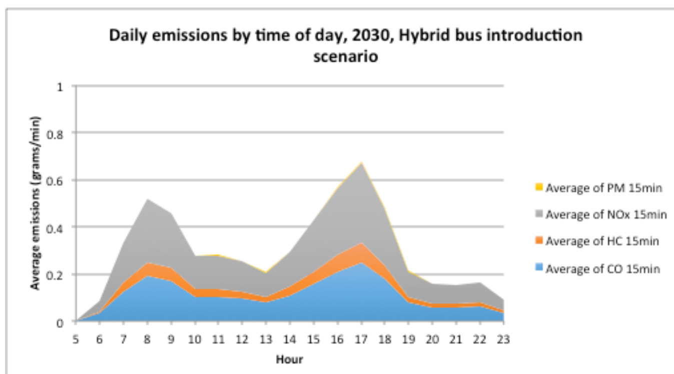
Figure 2: Sample outputs from MRCagney's GTFS Explorer



Our modelling approach allows us to identify the expected timing of emissions throughout the average weekday. This can be used to support analysis of the timing of exposure to emissions, the concentration of emissions in the local environment throughout the day[1], and the severity of exposure to emissions[2].

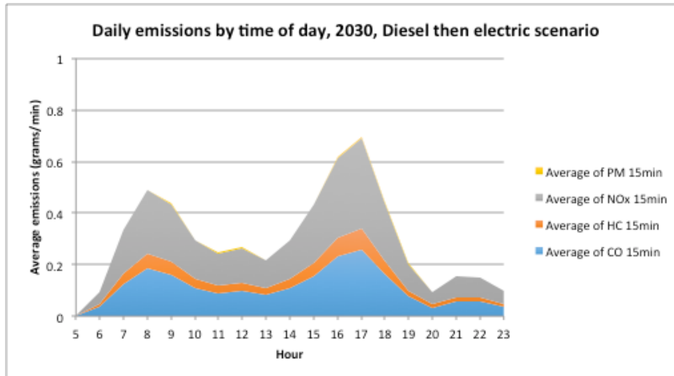
Table 6 presents graphs of bus emissions on an important city centre bus corridor, broken down by time of day and comments on outcomes from each scenario. In order to smooth out variations, we have averaged grams emitted per minute over the course of whole hours.

Table 6: Bus emissions on a major bus corridor, broken down by time of day, 2030

Comments	Forecast
Upgrading the fleet to Euro 6 standard would result in a lower path for localised emissions in the short term. Our analysis suggests that peaks in emissions will closely follow peaks in vehicle movements. Emissions are higher in the afternoon and evening peak, which is a significant concern given the fact that pedestrian movements in the area are also likely to be higher during this time.	
Interestingly, upgrading the fleet to hybrid buses will not necessarily lower aggregate emissions relative to a Euro 6 upgrade path. However, as this graph shows, carbon monoxide emissions are expected to be significantly lower under this scenario. This analysis does not consider the fact that parallel hybrids could be run under battery power in the city centre – which could result in considerably better environmental performance in this area.	

[1] Different types of emissions tend to dissipate at different rates, depending upon local environmental conditions. More persistent emissions can have an impact on health over a longer period.

[2] Impacts on human health depend upon concentration of emissions and duration of exposure. Consequently, estimating these impacts would require additional information on pedestrian volumes on and around city centre streets, etc.

<table>
<tr><th>Comments</th><th>Forecast</th></tr>
<tr><td>Upgrading the fleet to electric buses would deliver slower reductions in emissions by 2030, due to the fact that electric bus introduction would only begin in 2024.
However, this graph shows that by 2030, the electric bus upgrade path would roughly match outcomes from the hybrid bus scenario. Over the longer term, gains are expected to be significantly greater.</td><td>
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Bus noise

We have modelled noise arising from bus fleet operations along a major city centre bus corridor. In order to do so, we have used Generalised Transit Feed Specification (GTFS) data, which allows us to identify the timing and location of bus movements during a typical weekday, in conjunction with data on noise from different types of buses[3].

We model bus noise on a particular high-traffic corridor, rather than across the whole network, as the impacts of vehicle noise on urban amenity are highly site-specific, and vary depending upon the density of development and the use of noise insulation.

Our modelling approach allows us to identify the expected noise level throughout the day. We measure average noise during particular periods using a measure, LAeq, that averages noise across time[4]. It is important to understand that noise levels are reported in decibels, which use a logarithmic scale. As a result, small numerical differences in decibel values actually correspond to large differences in noisiness. A three decibel increase in noise levels actually corresponds to a doubling in sound power. As a result, even a one decibel difference in LAeq can have a quite significant impact on local amenity.

[3] Available data on bus noise provides an indicative range from minimum noise (idling or cruising at moderate speed) to maximum noise (typically experienced while accelerating away from stops). We have not attempted to model bus speed change cycles. We note that the selected site contains one signalised intersection and no bus stops, meaning that a range of bus noise outcomes may be experienced.

[4] This approach does rely upon some simplifying assumptions. We use GTFS data to identify the number of buses passing through the 100 metre study area at one-minute intervals between 6am and midnight. We have assumed that all buses present in the study area are simultaneously audible by an observer standing on the curb. This is a slightly unrealistic simplification, as it does not explicitly consider the way that noise travels through air. However, it is reasonable in light of the fact that buses will often "platoon" together through this corridor.

We then calculate noise from bus operations at a point in time using the equation below is used to add together noise from multiple sources, e.g. from two buses on the street at the same point in time. While we have not explicitly incorporated information on general traffic noise, we would expect this to simply raise the level of noise experienced under all bus fleet scenarios.

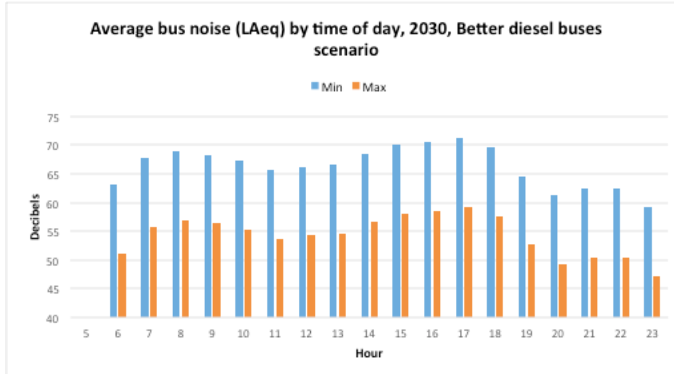
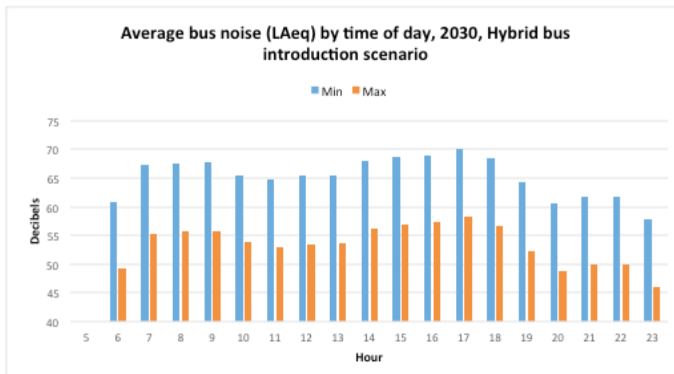
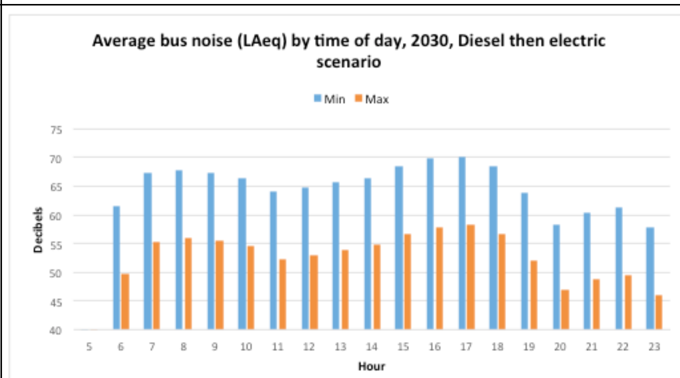
$$LAeq(n) = 10 * \frac{\log(\sum_{i=1}^{k} 10^{Li/10})}{\log(10)}$$

where n = time of day (in one-minute slices); i = index of buses on the street at time n; k = total number of buses on street at time n; Li = noise produced by bus i; and LAeq(n) = total cumulative volume of all buses on street at time n. (This equation was sourced from http://noisemeters.com/apps/db-calculator.asp.)

After calculating bus noise at all points in time, we calculate the average noise levels (LAeq, or "equivalent continuous sound level") over the 18 hour period in which buses are operating. NZTA recommends using this approach as it provides a single, easily comparable estimate of noise levels. However, it is important to understand that this approach may not provide a clear indication of peaks and troughs in noise levels.

With that in mind, Table 7 presents graphs of city centre bus noise broken down by time of day and comments on outcomes from each scenario.

Table 7: Bus noise on a major bus corridor, broken down by time of day, 2030

Comments	Forecast
Introducing Euro 6 buses is expected to bring few reductions in noise relative to the current fleet as diesel buses tend to be comparably noisy. As this graph shows, noise levels vary throughout the day, with the highest noise levels reported in the afternoon and evening peak. The wide range between minimum and maximum sound levels provides an indication of the range of outcomes experienced on the street at a point in time depending upon bus speed change cycles.	
Introducing hybrid buses is expected to result in an average one decibel reduction in bus noise relative to the Do-Minimum scenario. This reduction appears to be slightly greater during the AM peak period and midday period, with slightly smaller reductions in the afternoon and evening peak. Once again, this analysis does not factor in the option for parallel hybrids to run on battery power in the city centre, which would result in further noise reductions.	
Introducing electric buses starting in 2024 is expected to reduce average bus noise by approximately one decibel relative to the Do-Minimum scenario. Noise reductions are likely to be greater in the AM peak and midday period, and in the evening. Reductions in bus noise after 2030 are likely to be even significant as more relatively quiet electric buses enter the fleet. By 2041, bus noise is expected to be five to seven decibels lower than it would be under the Do-Minimum scenario.	

Conclusions

This paper has described and presented a flexible approach to understanding and quantifying the trade-offs involved in new vehicle technologies. This approach is efficient to implement, as it relies upon scenario-based spreadsheet modelling, GTFS data, and Python scripts. It can easily be extended to additional cities across New Zealand and Australia providing that information on the composition and age of the existing urban bus fleet is available.

We find that introducing new fuel technologies to urban bus fleets can have both costs and benefits. At current purchase prices, we expect the cost of purchasing hybrid or electric buses to be higher than the cost to purchase diesels. Some, but not all, of these costs are expected to be recouped from fuel savings. However, these added costs may be justifiable in light of the fact that alternative bus technologies are expected to deliver significant reductions in emissions and vehicle noise over the long run. They are therefore highly supportive of strategies for improving environmental outcomes and city centre vibrancy.

In summary, our analysis has identified long-term opportunities for transforming New Zealand's urban bus fleets. The best strategy, in light of uncertainty around the readiness of new bus technologies, may be to begin planning for a high-level fleet upgrade path while remaining flexible about timing of new bus introduction. When new bus technologies are available (and affordable), it will be necessary to ensure that an appropriate policy framework is in place and negotiate with operators.

Future work

Our analysis to date has identified some opportunities for improving our modelling approach and expanding it to other aspects of the transport system. This may include:

- Refining our range of scenarios to account for the potential impact of public transport contracting processes. For example, we may seek to account for the timing and duration of new contracts under New Zealand's Public Transport Operating Model (PTOM).
- Testing the application of this model to other vehicle types. For example, this model could readily be adapted to analyse truck fleets or corporate car fleets, provided that some data on vehicle movements was available.
- Refining our analysis of vehicle noise by including additional information on car traffic on main bus corridors and incorporating more detailed information on vehicle noise and speed change cycles.
- Integrating the model with data on population, employment, and other land uses around main bus corridors. This information may assist in analysing the impacts of vehicle noise and emissions on human health, land values, and other urban outcomes.

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Acknowledgements
Auckland Transport, Greater Wellington Regional Council, and the Energy Efficiency and Conservation Authority