TE MANATŪ WAKA
MINISTRY OF TRANSPORT

Domestic Transport Costs and Charges Study

Working Paper D5
Noise

Prepared for Te Manatū Waka Ministry of Transport (NZ)
Altissimo Consulting Ltd, in association with Ian Wallis Associates Ltd
June 2023

Contents

Appendices

Tables

Figures

Disclaimer

This Working Paper is one of a series that has been prepared as part of the New Zealand Domestic Transport Costs and Charges (DTCC) Study. A consultant team led by Ian Wallis Associates Ltd was contracted by Te Manatū Waka Ministry of Transport to carry out this Study.

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- Waka Kotahi
- Te Manatū Waka
- Peer Reviewers at the Institute of Transport Study at the University of Leeds

Research, Economics and Evaluation

The Research, Economics and Evaluation team operates within the System Performance and Governance Group of Te Manatū Waka Ministry of Transport. The team supports the Ministry's policy teams by providing the evidence base at each stage of the policy development.

The team is responsible for:

- Providing sector direction on the establishment and use of the Transport Evidence Base (see below) – including the collection, use, and sharing of data, research and analytics across the transport sector and fostering the development of sector research capabilities and ideas.
- Leading and undertaking economic analyses, appraisals and assessment including providing economic input on business cases and funding requests.
- Performing the evaluation function for Te Manatū Waka, including designing monitoring and evaluation frameworks and approaches, developing performance metrics and indicators, and designing, conducting and procuring evaluations.

The Transport Evidence Base

The Transport Evidence Base Strategy creates an environment to ensure data, information, research and evaluation play a key role in shaping the policy landscape. Good, evidence-based decisions also enhance the delivery of services provided by both the public and private sectors to support the delivery of transport outcomes and improve wellbeing and liveability in New Zealand.

The Domestic Transport Costs and Charges study aims to fill some of the research gaps identified in the 2016 Transport Domain Plan (Recommendation R6.2), which forms part of the Transport Evidence Base.

Citation

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For more information

For more information about this project and associated report, please contact: info@transport.govt.nz.

Glossary of terms and abbreviations

Term	Description
AADT	Annual Average Daily Traffic
DALY	Disability adjusted life year
dB	Decibel
DTCC	Domestic Transport Costs and Charges (this study)
MBCM	*Monetised Benefits and Costs Manual,* Waka Kotahi/NZ Transport Agency
HA	Highly annoyed
Hedonic pricing	Hedonic pricing is a model that identifies price factors according to the premise that price is determined both by internal characteristics of the good being sold and external factors affecting it.
HSD	Highly sleep disturbed
HV	Heavy vehicle
IHD	Ischemic heart disease
L_{Aeq}	A-weighted time average sound level
L_{day}	Day sound level
L_{den}	Day-evening-night sound level
L_{night}	Night sound level
QALY	Quality-adjusted life year
TOF	Transport Outcomes Framework
vpd	Vehicles per day
WHO	World Health Organisation

Executive summary

Overview

Long-term exposure to transportation noise can have detrimental effects on human health, amenity, and productivity. These effects have economic and social costs which are borne by the individual, the health system and the broader economy. The primary purpose of this working paper is to estimate the total costs of this noise exposure for different transport modes (road, rail, coastal shipping and domestic aviation) in the New Zealand context.

The paper then estimates the average exposure costs normalised by distance or movement, and disaggregates these where appropriate to assist with policy analysis. It also sets out a methodology and provides typical marginal costs reflecting the noise impacts of marginal changes in traffic volumes for typical categories of road and for rail services.

Methodology

Methods have been developed to approximate sound levels at residences from road, rail, domestic air and coastal shipping from currently available movement data.

Dose-response curves have been established to estimate the population who are suffering from high annoyance, high sleep disturbance, or increased risk of ischemic heart disease. These impacts have been expressed in terms of the number of Disability Adjusted Life Years (DALYs), based on published Disability Weights for each condition, and then monetised using the Value of Statistical Life determined in New Zealand for the social cost of vehicle crashes.

There have been limited studies in New Zealand that have monetised effects from environmental noise, and there is no standardised method. This study largely adopts the methodology detailed in the European Environmental Agency (EEA) publication Environmental noise in Europe — 2020. A more comprehensive evaluation of monetisation methods is currently being undertaken as part of Waka Kotahi's ART 19-01 - Social cost (health) of land transport noise exposure in New Zealand project. The results of this DTCC paper should be reviewed after ART 19-01 is published.

Results

A summary of the total annual and average costs caused by each mode is presented below (all costs in NZ$ 2018/19 prices, based on 4% real discount rate). Average costs are expressed on a per person (passenger) km basis for person travel and per net tonne km for freight movements: these per person km and net tonne km figures represent the total 'traffic' movements on the relevant network. Air and coastal shipping costs have not been expressed on a per km basis, as effects only occur when aircraft or ships are in or around air and seaports. Marginal costs are discussed in Chapter 5.3 of this report, but in general are 20-30% of average costs.

Source	Type	Total cost (2018/19)	Average passenger cost	Average freight costs
Road	Passenger (car etc)	$718 M	2.57 c/VKT 1.49 c/PKT	
	Freight (trucks)	$192 M		1.25 c/NTK
	Total	$910 M		
Rail	Passenger (urban)	$15 M	1.90 c/PKT	
	Freight	$58 M		1.50 c/NTK
	Total	$72 M		
Air	Passenger	$37 M	$79 / landing or take-off	
Coastal shipping	Freight	$4 M		6.81c / tonne
Total all modes		**$1,023 M**		

Limitations, future updates and potential additional areas of work

The methods adopted in this study have been designed to allow simple updates for rail and airport movement numbers, without needing extensive noise mapping. Road noise exposure has been based on detailed predictions made on behalf of Waka Kotahi, which are expected to be updated periodically.

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Chpater 1 Introduction

1.1. Study Scope and Overview

The Domestic Transport Costs and Charges (DTCC) study aims to identify all the costs associated with the domestic transport system on the wider New Zealand economy including costs (financial and non-financial) and charges borne by the transport user.

The Study is an important input to achieving a quality transport system for New Zealand that improves wellbeing and liveability. Its outputs will improve our understanding of the economic, environmental and social costs imposed by different transport modes - including road, rail and coastal shipping - and the extent to which those costs are currently offset by charges paid by transport users.

The DTCC is intended to support the wider policy framework of Te Manatū Waka, especially the Transport Outcomes Framework (TOF). The TOF seeks to make clear what government wants to achieve through the transport system under five outcome areas:

- Inclusive access,
- Economic prosperity,
- Healthy and safe people,
- Environmental sustainability, and
- Resilience and security.

Underpinning outcomes in these areas is the guiding principle of mode neutrality. In general, outputs of the DTCC study will contribute to the TOF by providing consistent methods for (1) estimating and reporting economic costs and financial charges and (2) understanding how these costs and charges vary across dimensions that are relevant to policy, such as location, mode and trip type.

Robust information on transport costs and charges is critical to establishing a sound transport policy framework. The Study itself does not address future transport policy options; but the study outputs will help inform important policy development including areas such as charging and revenue management, internalising externalities, and travel demand management.

The Study has been undertaken for Te Manatū Waka by a consultant consortium headed by Ian Wallis Associates. The Study has been divided into a number of topic areas, some of which relate to different transport modes (including road, rail, urban public transport and coastal shipping), and others to impacts or externalities (including accidents, congestion, public health, emissions, noise, biodiversity and biosecurity).

Working papers have been being prepared for each of the topic areas. Their titles, topic areas and specialist authors are listed in Appendix 2.

1.2. Costing Practices

The focus of DTCC is on NZ transport operations, economic costs, financial costs and charges for the year ending 30 June 2019 (FY 2018/19). Consistent with this focus, all economic and financial cost figures are given in NZ$2018/19 (average for the 12-month period) unless otherwise specified.

All financial costs include any taxes and charges (but exclude GST); while economic costs exclude all taxes and charges.

The DTCC economic and financial analyses comprise essentially single-year assessments of transport sector costs and charges for FY 2018/19. Capital charges have been included in these assessments, with annualised costs based on typical market depreciation rates plus an annualised charge (derived as 4% p.a., in real terms, of the optimised replacement costs of the assets involved).

1.3. Paper Scope and Structure

Long-term exposure to transport noise can have detrimental effects on human health, amenity, and productivity. These effects have costs which are borne by the individual, the health system and the broader economy. The primary purpose of this paper is to estimate the total annual economic costs of this noise exposure associated with different domestic transport modes (road, rail, coastal shipping and domestic aviation) in the New Zealand context. The paper also estimates the average and marginal exposure costs.

Previous New Zealand attempts to quantify the noise costs of surface transport have been limited primarily to road traffic using the state highway network. The 2005 STCC study used broad approximations of exposure rather than undertaking noise modelling. That study used a hedonic approach for costing noise exposure, i.e., impacts on house prices.

This current study calculates costs associated with increases in transport noise (road, rail, aircraft, coastal shipping) for the following health and well-being outcomes:

- Sleep disturbance,
- Amenity/annoyance (used interchangeably in this context),
- Increased risk of heart disease.

While these health and wellbeing effects are not in practice independent, the prevalence and costs of these effects have been calculated separately.

Full nationwide noise mapping of major transport corridors and conurbations like that performed in Europe is beyond the scope of this study. Methods have been developed to approximate sound levels at residences from rail, domestic air and coastal shipping based on currently available movement data.

Waka Kotahi NZ Transport Agency tendered a research project in 2020, ART 19-01 - Social cost (health) of land transport noise exposure in New Zealand. The key objective of that research project is to quantify the health, productivity, cognitive and hedonic costs (together, ‘social costs’) of transport noise exposure. Once published, the output of that research project should potentially supersede at least part of the noise component of the DTCC work which is covered in this paper.

Vibration effects are generally limited to people living adjacent to railways and roads in poor condition. Such properties are also subject to high noise levels and so adverse health effects would be largely overlapping. Given this, we have not undertaken any separate assessment of vibration issues and costs.

While road traffic noise is caused by motorists, they themselves do not suffer from (or bear the costs of) the noise they cause: these costs are very largely borne by people ‘external’ to those who cause the costs. Economists often refer to such costs as ‘external’ costs or an ‘externality’, and may refer to marginal external costs. In these terms, all transport- related noise costs are ‘external’ costs.

Most other environmental costs associated with road transport (e.g. local pollution, effects on biodiversity) are also external costs.

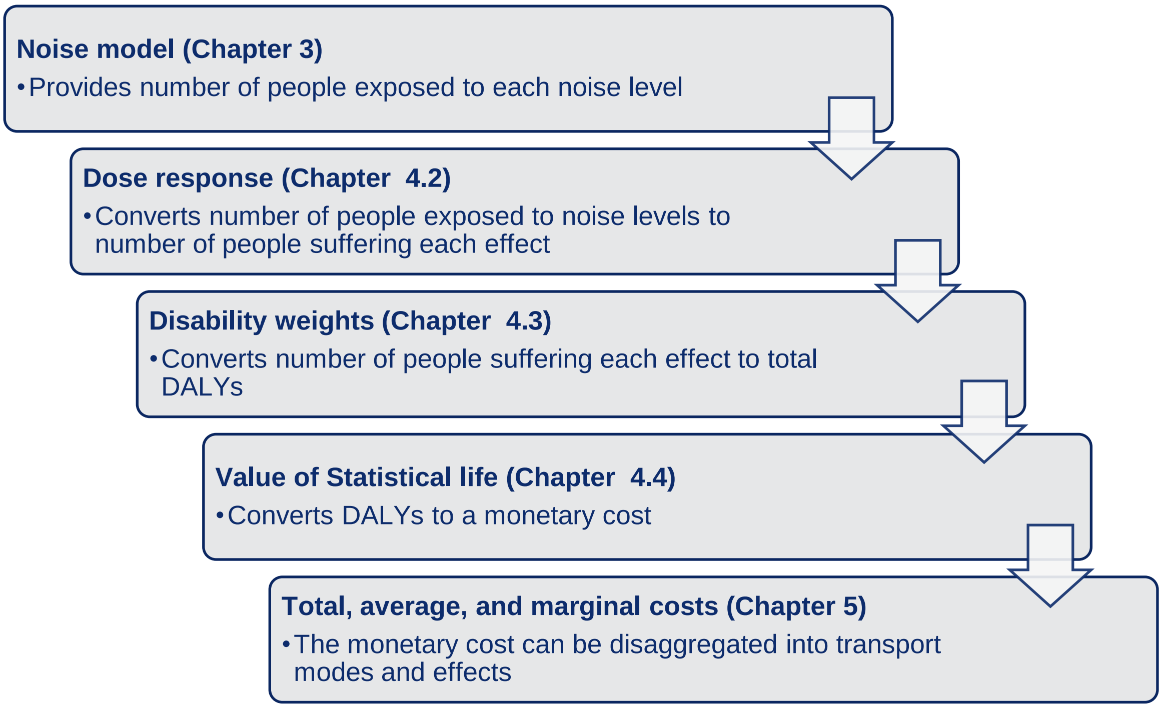
In some cases, these costs may be ‘internalised’, so that they are borne (partly or completely) by motorists. This is often done through a charge (or levy) on vehicle use or on fuel sales etc. This is currently the case (at least partially) with greenhouse gases resulting from road traffic in NZ, through a levy on fuel prices; but is not currently the case with traffic noise.

Chpater 2 Methodology

2.1 Approach

A five-step approach to the determination of total, average and marginal costs has been adopted and is presented in Figure 1. References to the appropriate report section are included.

Figure 1 Monetisation methodology



2.2 Literature review

To determine an appropriate methodology, we have reviewed approaches taken by other jurisdictions and considered their applicability to the New Zealand setting. Preference has been given to World Health Organisation publications and other government-sponsored studies, rather than primary research. To avoid duplication with the ART 19-01 - Social cost (health) of land transport noise exposure in New Zealand, an academic-style literature review has not been undertaken.

The exposure modelling in this study uses conventional methods as described in Chapter 0. Modelling of road-traffic noise has been performed (by others) following the Guide to state highway noise modelling .

The Monetised Benefits and Costs Manual (Waka Kotahi, 2021) outlines an approach to valuing road traffic noise impacts based on the findings of international (predominantly hedonic price) valuations. The change in cost associated with a change in noise exposure is valued at 1.2% of the value of properties affected per year for each dB change in noise level. This approach does not directly allow the Total Cost to be calculated.

The DTCC study has adopted a health-based approach that directly calculates the Total Cost, and is largely based on the European Environmental Agency publication Environmental noise in Europe — 2020. This methodology has the following features:

- It reflects the most recent understanding of health effects from noise,
- It uses the long-standing concept of burden of disease and disability weights, and
- It may be priced using a value of life specific to New Zealand.

The current understanding of health effects from transportation noise is summarised by the World Health Organisation in their Noise Guidelines for the European Region (2018 WHO Guidelines). The 2018 WHO Guidelines are based on a critical review of academic literature, including an evaluation of the quality of evidence prior to accepting the conclusions. With respect to transportation noise, the 2018 WHO Guidelines note there is a correlation between the following adverse effects and noise: high annoyance, sleep disturbance and ischaemic heart disease. High annoyance and sleep disturbance can be caused directly by transportation noise. In contrast, there is a baseline prevalence of ischaemic heart disease (4.9% of the population). While transportation noise may increase this prevalence, individual cases of heart disease cannot be directly attributed to transportation noise.

The prevalence of health effects from transportation noise is established through longitudinal studies, which involve repeated observations over a long period of time. These studies provide correlations between noise level and health outcomes, which are expressed as dose response curves. EEA (2018) adopts dose response curves from the following studies:

- Miedema and Oudshoorn (2001)
- Guski et al. (2017)
- Basner and McGuire (2018).

There has been little research performed specifically for the New Zealand setting, however Research Report 656 showed international dose response curves for annoyance are broadly appropriate for the local context, although the New Zealand population may be slightly more sensitive than international comparisons. Further work is currently being undertaken by Waka Kotahi on the response of communities to transport noise as part of research project ART19/27.

Each health outcome has a different impact on the quality of human life. The concept of burden of disease exists to address this. The burden of disease is expressed in terms of the Disability Adjusted Life Years (DALYs). Conceptually, one DALY is the equivalent of losing one year in good health because of either premature death or disease or disability. It is a standardised metric that allow for direct comparisons of disease burdens of different diseases and contributing factors.

In the absence of New Zealand specific values for disability weights, previous studies for the Ministry of Health have used European values, for example Stouthard et al (1997). For DTCC we have used the disability weights from EEA (2018).

To determine the value of a DALY, the Value of Statistical Life (VoSL) has been used. The methodology for determining the appropriate value is discussed in some detail in the DTCC Working Paper: Health Impacts of Active Transport.

2.3 Analysis

Large-scale strategic noise mapping is common overseas (particularly in Europe) for informing policy and quantifying health effects. While a detailed NZ-wide noise model has not been established for this project, determining noise exposure is still the most significant part of this current study. A key feature of this model is that it must be readily updatable and use broad / aggregated inputs to allow future scenarios to be modelled.

The model for each mode is therefore twofold: predictions of sound levels at individual houses based on an actual (or representative) scenario; and mapping of these results to an aggregated set of inputs available to the Ministry of Transport. While the focus of this study is on residential receivers, it is noted that noise also affects people in workplaces and other internal environments.

The modelling of noise exposure from transportation requires data in the following categories:

- Geographical – Location of houses and noise sources, local topography
- Receivers – Number of residents at each house
- Sources – Number/amount of vehicle movements, time of movements, amount of freight.

The level of information available for this study varies between each mode of transport: road, rail, air, and shipping. The best available data has been used for each mode: where reliable data is unavailable, estimates has been made to fill these gaps.

Table 1 Model inputs

Mode	Input	Model	Output
Road	Existing noise model output Underlying model relies on number of vehicles / heavy vehicles, speed, road surfaces and topography		Population exposed to noise in 5 dB bands
Rail	Aggregated freight movements in townships Number of commuter trains Distance to dwellings		
Air	Number of movements by airport / aircraft type Distance to dwellings		
Shipping	Existing Resource Management Act district plan contours Dwelling locations Tonnes per port		

Noise exposure is predicted by modelling the noise emissions from a source and evaluating the noise level at the outside of each residential dwelling. The noise within a dwelling is not typically modelled as this is heavily influenced by unknown factors such as building construction and insulation. Previous research evaluating the impact of environmental noise has also used the noise level outside residential dwellings.

The following noise indicators have been used in this study:

- L_{den} (day-evening-night noise level): the long-term average indicator designed to assess annoyance. It refers to an A-weighted average sound pressure level over all days , evenings and nights in a year, with a penalty of 5 dB applied to the evening period and 10 dB to the night period to address increased sensitivity during these periods.
- L_{night} (night noise level): the long-term average indicator designed to assess sleep disturbance. It refers to an A-weighted annual average night period of exposure.

For both metrics, day refers to 0700-1900h, evening 1900-2200h and night 2200-0700h.

The prevalence of health conditions has been calculated at each dwelling based on the noise exposure and established dose-response curves. These have been monetised using Disability Weights for each condition and the Value of Statistical Life. These have been summed to establish total costs per mode.

Average costs have been determined using total person km and net tonne km values for road and rail, and on a per movement basis for air and coastal shipping.

2.4 Key steps and assumptions

The following key steps and assumptions have been made in this study:

- Noise costs for each mode have been calculated separately.
- Domestic air travel has been evaluated independently of international air travel.
- Dose response curves and disability weights from Europe have been adopted.
- The value of a DALY has been determined based on the NZ Value of a Statistical Life (as used in the transport sector) and applying a 4% discount rate (in real terms).

2.5 Produced data

A key feature of this study is that is must be readily updateable. A spreadsheet has been provided as a supplement to this Working Paper, which takes the result of acoustics analyses in the form of population exposed to noise level bands from each of the four transportation modes and applies various constants to determine the total cost. While this does not directly facilitate updating of future traffic volumes (which is a major exercise itself) it does allow investigations of different VoSL values (either directly or through discount rates) as well as changes to disability weights.

Chpater 3 Exposure modelling

3.1 Road

Road traffic is a dominant source of noise for a large proportion of the population. For many it is a constant ‘hum’ of activity, whereas for residents close to roads there can be significant variation in the noise due to individual vehicles. This research has focused on the constant hum of noise generated by traffic on the road.

There are several mechanisms of road noise generation including: tyre-road interaction, aerodynamic noise, engine/exhaust noise and drivetrain noise.

Waka Kotahi and other Road Controlling Authorities use the One Network Road Classification (ONRC), which divides New Zealand’s main roads into six categories based on how busy they are, whether they connect to important destinations, or are the only route available. Table 2 lists the classifications relevant to this study, and AADT (annual average daily traffic) thresholds which apply. As mentioned above, these are not the sole criteria but for most roads will determine their classification.

Table 2 Determination of One Network Road Classification by AADT

Classification	Urban	Rural
National (High Volume)	>35,000 vpd	>20,000 vpd
National	>25,000 vpd	>15,000 vpd
Regional	>15,000 vpd	>10,000 vpd
Arterial	>5,000 vpd	>3,000 vpd

A breakdown of road lengths by classification and speed is provided in Table 3.

Table 3 Lengths of roads by One Network Road Classification (1000 km)

Classification	Speed	Urban	Rural	Total
National (High Volume)	>= 80 km/h	295	386	681
National		43	1,106	1,149
Regional		89	1,941	2,030
Arterial		145	2,676	2,821
National (High Volume)	< 80 km/h	186	48	234
National		76	63	139
Regional		407	115	522
Arterial		1,851	246	2,097
Total	**All speeds**	**3,092**	**6,581**	**9,673**

Figure 2 and Figure 3 shows road-km vs AADT in different bands for urban and rural areas. This has been applied to 'local roads' where the Road Controlling Authority is a Territorial Authority, rather than Waka Kotahi. All state highways have been grouped together regardless of road classification.

Figure 2 Length of roads with differing levels of traffic (urban, >2000 vpd)

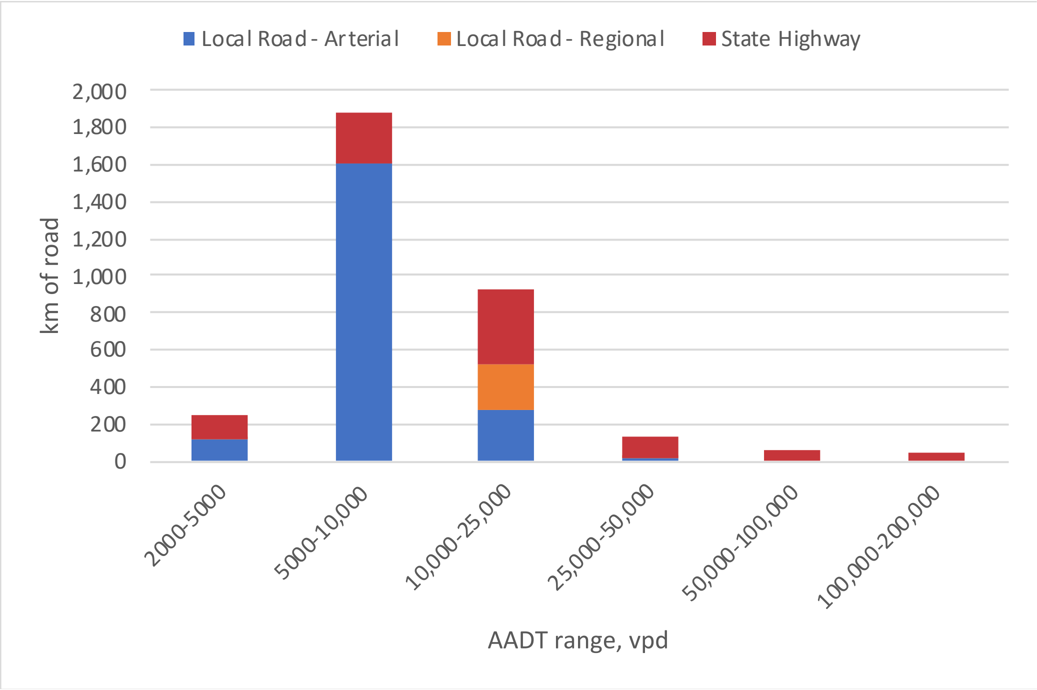
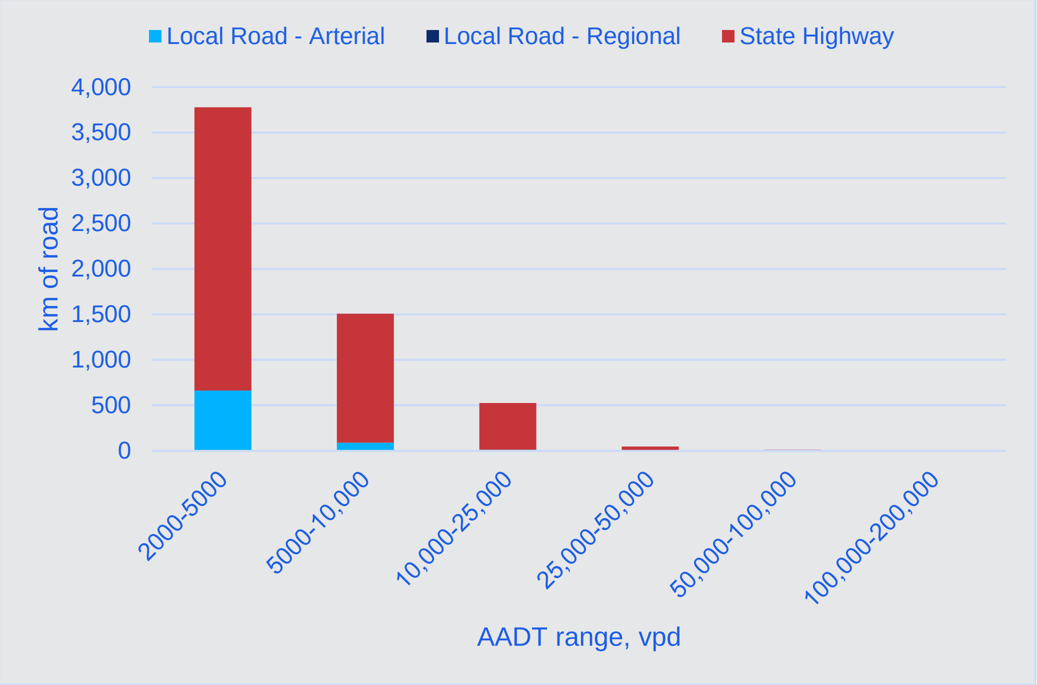


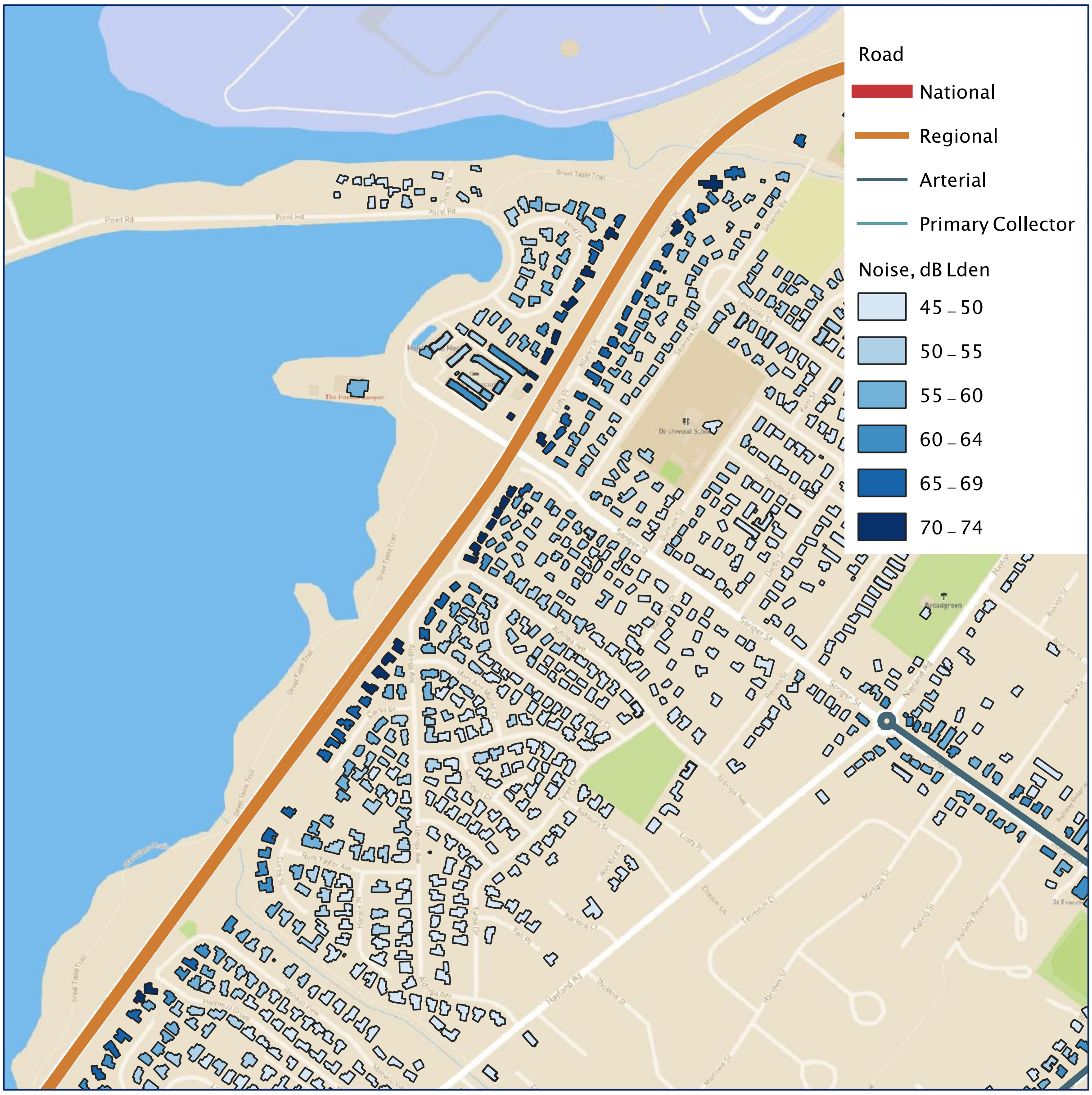
Figure 3 Length of roads with differing levels of traffic (rural, >2000 vpd)



Detailed 3-D noise modelling of arterial roads, regional roads and state highways with traffic volumes of at least 2000 vpd was performed by AECOM (2019) for Waka Kotahi. For this study the predicted sound level at each property has been analysed. The AECOM study excluded roads with traffic volumes below 2000 vpd for both practical reasons, and effects of lower volume roads are generally not significant. AECOM applied the Calculation of Road Traffic Noise (CRTN) algorithm as implemented in the noise modelling package SoundPLAN 8.0. Conversions between the reported $L_{Aeq(24h)}$ and the L_{den} / L_{night} metric have been made.

Example noise contours are presented in Figure 4 for a section of state highway in Nelson.

Figure 4 Example road noise distribution (Nelson)



3.2 Rail

Noise from rail is generated by two main mechanisms: wheel/rail interaction and locomotive engines. At high speeds the wheel/rail interaction noise increases, whereas at low speeds the locomotive engine noise is more significant.

The number of freight movements on each section of track has been estimated from aggregated annual data provided by KiwiRail on a location and area basis. Table 4 provides a high-level summary. Unlike roads, rail volumes weren't readily available on a section-by-section basis.

Table 4 Train number summary through urban areas

Location (NI)	Annual movements	Location (SI)	Annual movements
All Auckland	12,539	All Christchurch	10,221
All Wellington	5,081	All Dunedin	7,597
All Hamilton	13,600	All Invercargill	3,954
All Tauranga	14,673	All Mosgeil	3,557
All Lower Hutt	1,478		
All Palmerston North	11,657		
All New Plymouth	1,575		
All Whangarei	897		
All Whanganui	2,844		
Total North Island	**41,963**	Total South Island	**21,595**
		Total New Zealand	**63,555**

The effects of regular commuter trains have been considered (Table 5). Annual patronage numbers have been obtained from Greater Wellington and Auckland Transport publications, and number of movements have been estimated by reviewing published schedules. Long distance passenger rail services (including Scenic Rail) have not been assessed as they account for only a small proportion of total train movements.

Table 5 Metropolitan passenger patronage statistics (2018/19)

Item	Wellington	Auckland
Number of passengers (annual)	14,323,878	21,300,100
Number of trains (annual)	803,000	912,500
Number of trains (ave weekly)	2200	2500
Number of trains (ave daily)	314	357

The movement data has been used to determine a representative number of movements by day and night for each section of track (Figure 5). The sound level at each house has then been estimated based on the distance from the rail line, calculated using GIS, using an indicative sound power level, and allowing for geometric spreading: typical results are shown inFigure 6.

Figure 5 Distribution of people within 200m of railway vs frequency of freight trains

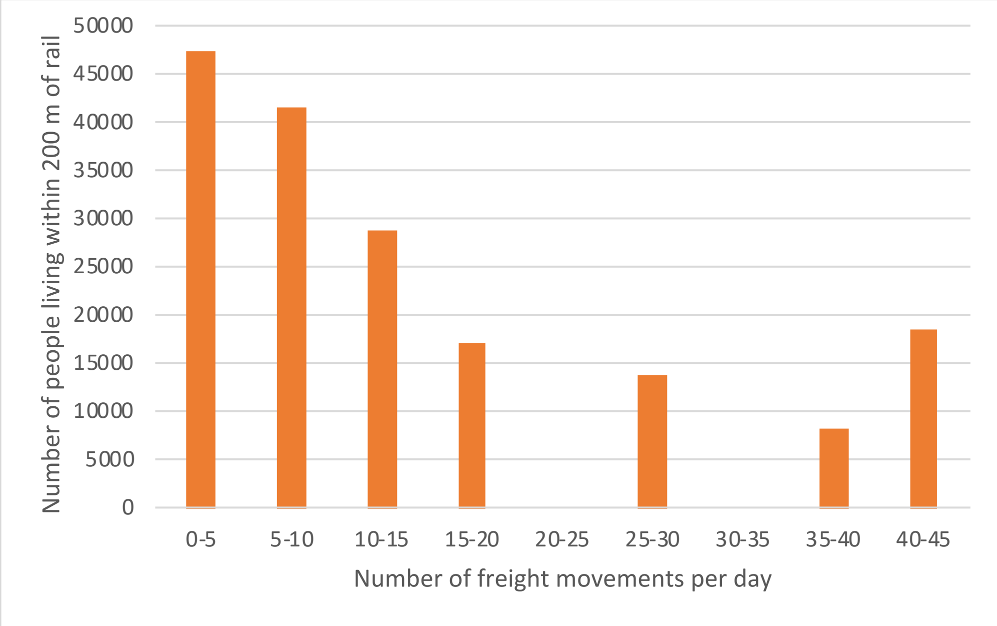
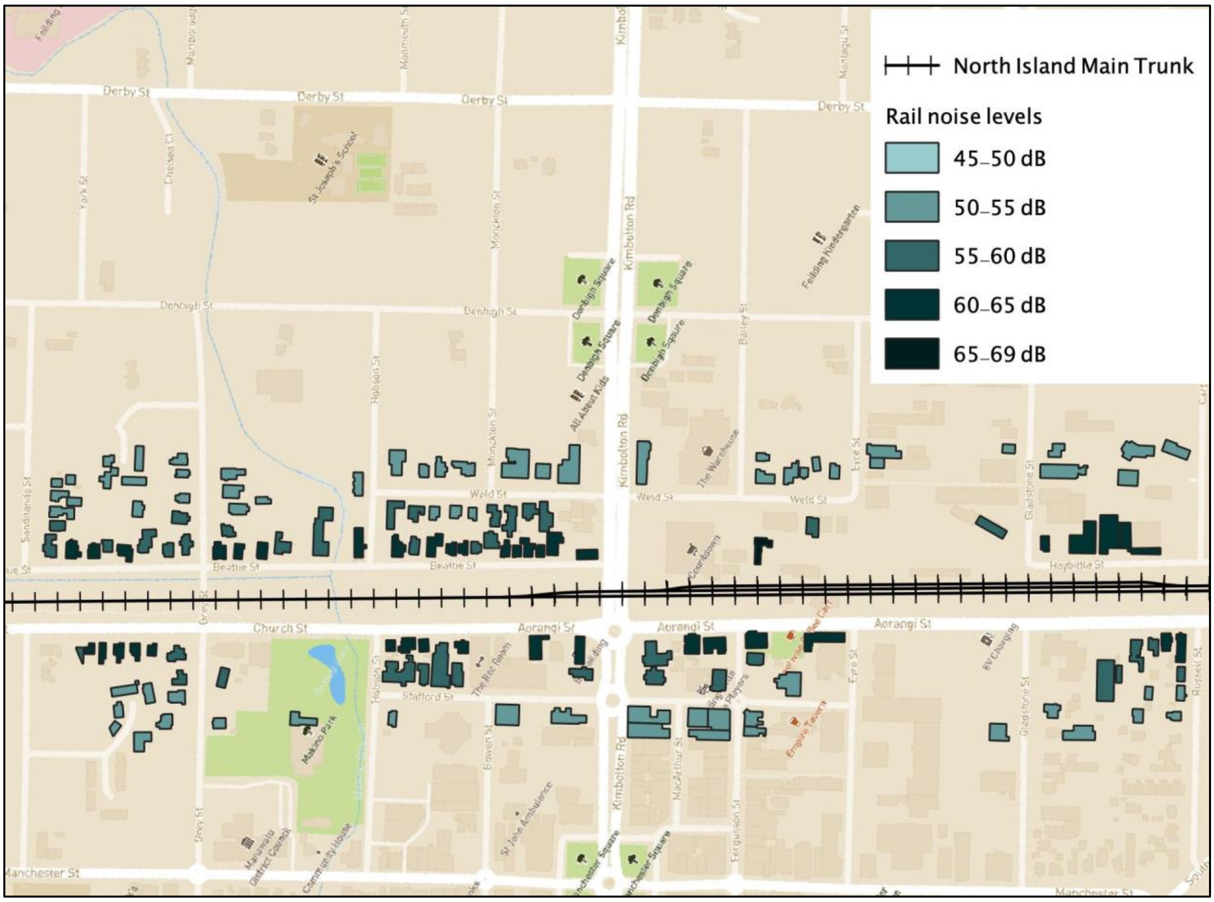


Figure 6 Example rail noise distribution, L_{den} (Fielding)



3.3 Aviation

Noise modelling is performed for most major airports in New Zealand, primarily by their respective operating companies. Modelling is used both for controlling the effects of airport activities on neighbours, as well as for land use controls to prevent the encroachment of new residential neighbours.

Typically modelling only extends to 55 dB L_{dn} whereas effects may still be significant at lower sound levels, with many people exposed to sound in those lower bands. This is evident in the dose response curves shown in Chapter 0, and confirmed in Willingness to Pay studies, for example Nellthorp et al (2007).

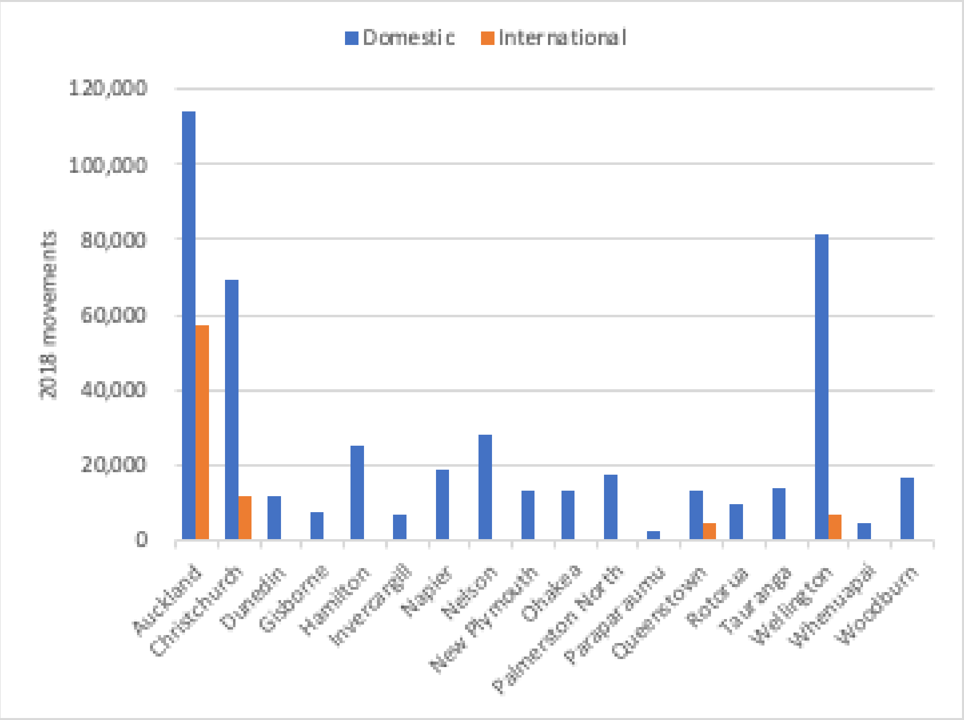
In addition, this modelling includes future airport growth, sometimes forecasting decades ahead, and including international flights. As this study required current (2018/19) exposure from domestic commercial flights only, the published contours were not appropriate to be directly used.

The location of dwellings from the building dataset used for roads has been used, and the distance from the runway end and lateral offset from the extended runway centreline determined using GIS. This assumes that all aircraft use the main runway, and ignores the effect of airports with cross-runways (e.g. Christchurch).

Annual movement numbers for each airport have been obtained from Airways (Figure 2), and the proportion of jet vs turboprop and time of day has been categorised by reviewing available timetables. A movement is considered as either a take-off or landing.

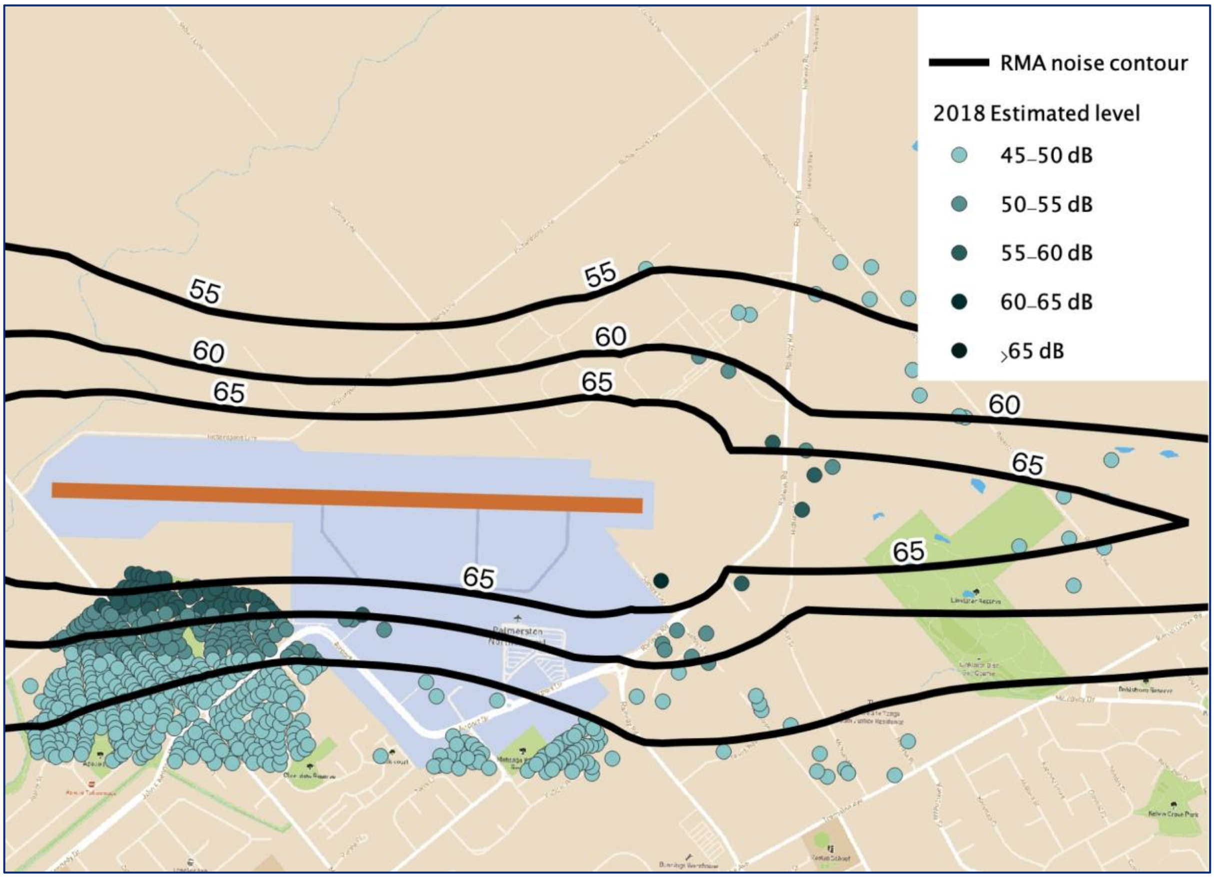
The lateral and longitudinal distance from the main runway of each major airport to dwellings has been determined in GIS. Using this distance and the number of movements for each aircraft type, sound levels at each dwelling have been calculated in GIS using published noise vs distance curves for A320 and ATR72 planes. For airports with secondary runways (for example Christchurch) this may result in some under-prediction.

Figure 7 Commercial aircraft movements by airport (2018)



An example of predicted 2018 sound levels vs the published (future) contours is provided in Figure 8 Palmerston North has been used as an example of a major airport, but with no scheduled international flights. From this it can be seen that the predicted sound levels (dots) are lower than the contour lines, but also there are many affected properties that would not be included if only the published contours were used.

Figure 8 Example of air noise prediction (L_{den}) (Palmerston North) (including RMA noise contour)



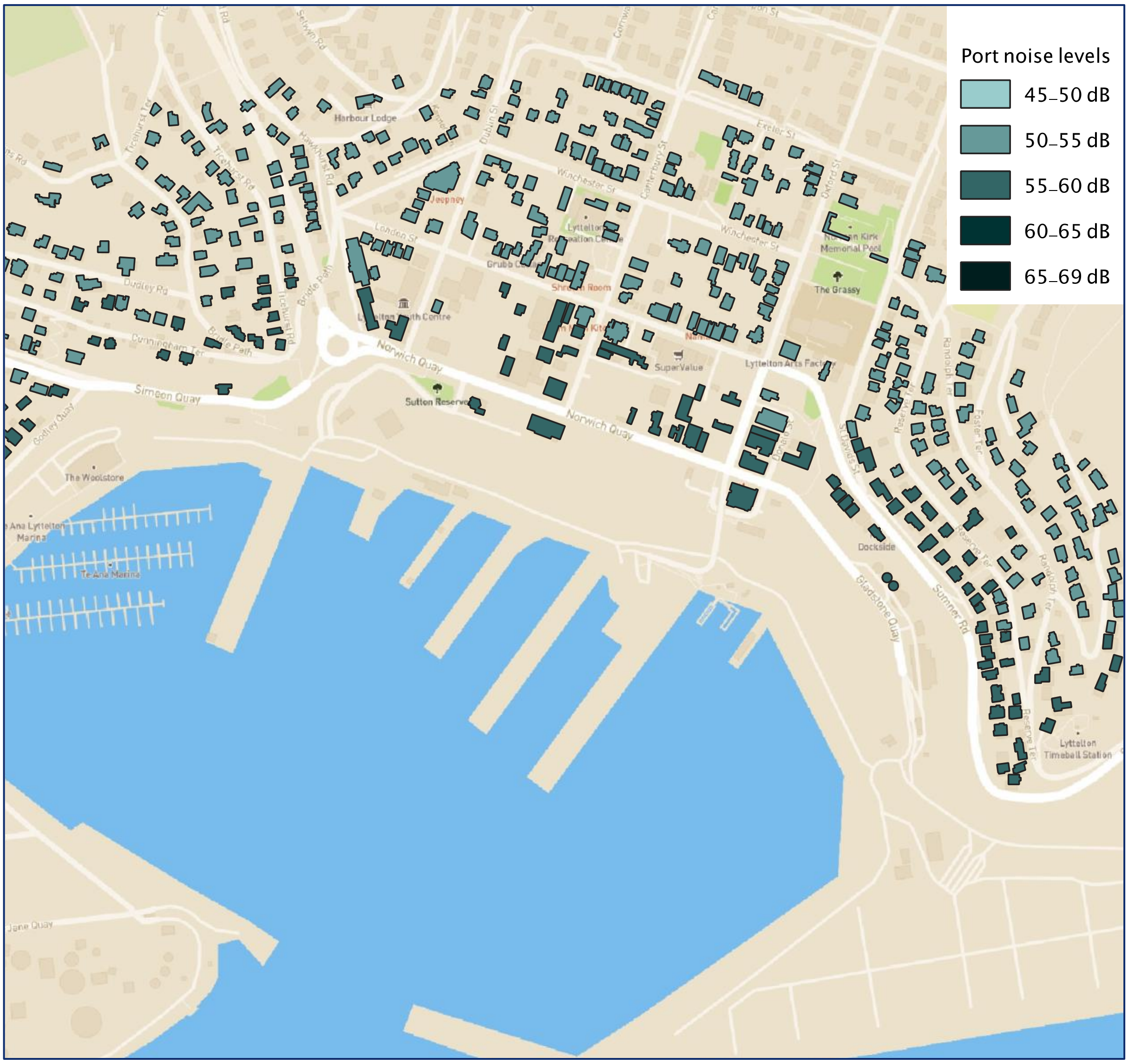
3.4 Coastal shipping

Sound levels have been predicted using the published noise contours in RMA District Plans, which represent a ‘5-day busy’ period. A significant component of port noise is typically from land- based activities, and these cannot be readily estimated from number of container movements. This also results in less ‘growth’ allowed for in the contours, unlike airports as discussed earlier.

Ships at sea are not addressed by the Resource Management Act, and have not been assessed as part of this paper. There would be negligible effect at houses on land from ships at sea.

For this project, we have taken the noise exposure at each dwelling from published contours. An example is provided in Figure 9 (for Lyttelton). As these contours include both international and domestic shipping, effects have been proportioned on a tonnage basis.

Figure 9 Example noise exposure from ports (Lyttelton)



3.5 Results - population exposure by sound level

Predicted sound levels have been summarised in 5 dB bands: these are tabulated by mode and urban / rural split in Table 6 for L_{den} and Table 7 for L_{night}, with the predicted levels also shown graphically in Figure 10 and Figure 11.

Table 6 Population exposed to sound, L_{den} (>45 dB)

	Sound level band, L_{den}				
	45-50 dB	50-55 dB	55-60 dB	60-65 dB	65-70 dB
Urban					
Air	33,879	10,362	2,748	1,142	736
Road	218,061	209,582	258,215	117,393	38,505
Rail	67,479	34,840	17,623	7,336	1,860
Coastal Shipping*	0	2,976	3,781	759	110
Rural					
Air	409	133	37	10	0
Road	22,905	32,833	31,819	17,892	5,763
Rail	5,308	3,768	2,311	697	77
Coastal Shipping	0	0	0	0	0

Note: * data not available in the 45-50 dB band. contours do not extend below 55 dB

Table 7 Population exposed to sound, L_{night} (>45 dB)

	Sound level band, L_{night}			
	45-50 dB	50-55 dB	55-60 dB	60-65 dB
Urban				
Air	393	52	0	0
Road	253,297	141,176	54,116	0
Rail	29,405	12,558	5,804	777
Coastal Shipping	3,781	759	110	0
Rural				
Air	22	1	0	0
Road	33,315	19,789	8,486	0
Rail	3,105	1,517	293	24
Coastal Shipping	0	0	0	0

Figure 10 Predicted sound levels by mode, dB L_{den}

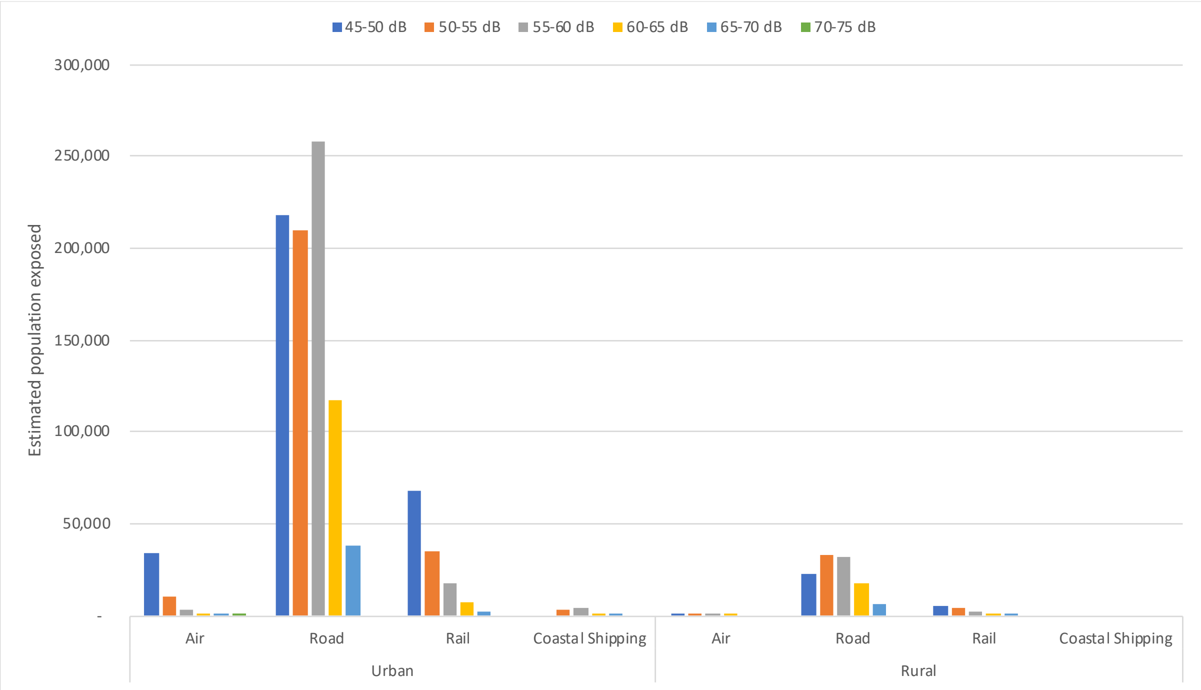
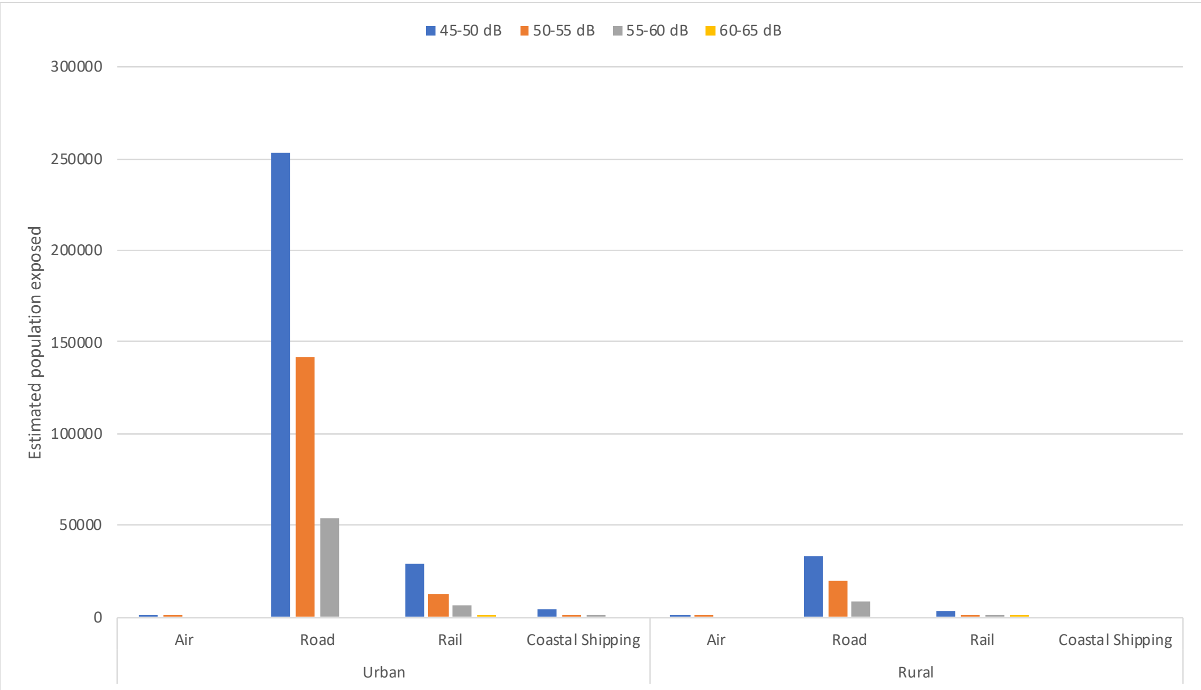


Figure 11 Predicted sound levels by mode, dB L_{night}



Chpater 4 Effects and monetisation

4.1 Introduction

The effects of transport noise on people have been extensively researched both in New Zealand and internationally. The World Health Organisation (WHO) has published several reports on the impacts of environmental noise, most recently the 2018 *Noise Guidelines for the European Region*. The conclusions of WHO (2018) been adopted by the European Environmental Agency (EEA) *Environmental noise in Europe* (2020) report, which presents a methodology for monetising health effects.

The following broad categories of adverse health effects have been considered in our study:

- Annoyance
- Sleep disturbance
- Cardiovascular effects.

These effects have different thresholds for onset, with the thresholds for health and sleep effects being summarised in Table 8 below. Port noise was not included in this EEA report.

Table 8 Thresholds for effects (WHO 2018)

Mode	Adverse health effects	Adverse effects on sleep
Road	53 dB L_{den}	45 dB L_{night}
Rail	54 dB L_{den}	44 dB L_{night}
Air	45 dB L_{den}	40 dB L_{night}

To provide a total cost for all transport and each different mode the methodology shown in is used. The exposure modelling described in Chapter 3 is used to provide the number of people exposed to each noise level. The dose response curves presented in Chapter 4.2 are used to calculate the number of people suffering from annoyance, sleep disturbance, and cardiovascular effects. This is achieved by multiplying the number of people in each noise band by the proportion of the population that will be affected based on the dose response curve.

The number of people suffering from each of the three effects is then multiplied by the relevant disability weighting. This yields the DALYs lost associated with each effect, which can then be converted into a monetary cost based on the selected “Value of Life” metric. These total costs are disaggregated into the following cost measures for each mode of transport:

- Total cost
- Cost of annoyance
- Cost of sleep disturbance
- Cost of ischemic heart disease (IHD) and associated mortality.

4.2 Dose response curves

The relationship between the prevalence of effects and environmental noise exposure on a population is typically expressed as a dose response curve. EEA (2020) collated dose response curves from several research projects. The dose response curves for each mode of transport are presented in Figure 12 to Figure 15. The dose response curves for annoyance and sleep disturbance are an absolute percentage of the population affected. The dose response curves for Ischemic Heart Disease (IHD) are the increase over baseline.

It should be noted that dose-response curves for annoyance and sleep disturbance often do not reach 0%. This is because there is typically a small percentage of the population that will report annoyance or sleep disturbance in the absence of significant environmental noise.

These dose response curves are derived using statistical methods that rely on sufficiently large proportions of the population being exposed to the noise levels of interest. In most studies there are insufficiently large populations exposed to high environmental noise levels. This results in uncertainty in the accuracy of the dose-response curves at high environmental noise levels. Locations close to sources are affected by uncertainties in geometry, and therefore predicted sound levels over 65 dB L_{den} may not be accurate. To address this, all predicted sound levels have been capped at 65 dB L_{den}.

Figure 12 Dose-response curves for road traffic noise

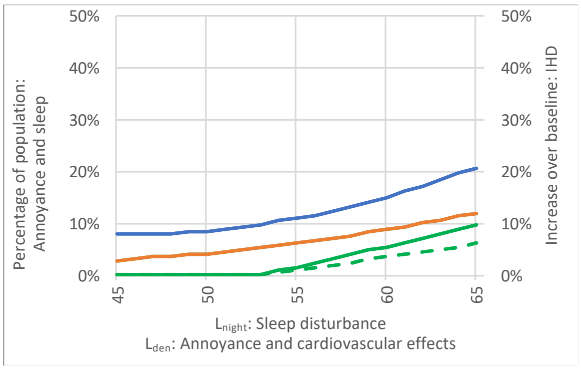


Figure 13 Dose-response curves for rail noise

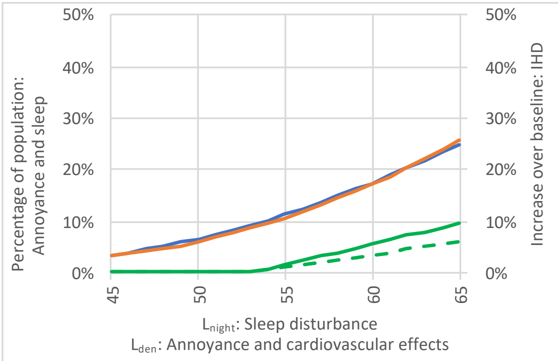


Figure 14 Dose-response curves for aircraft noise

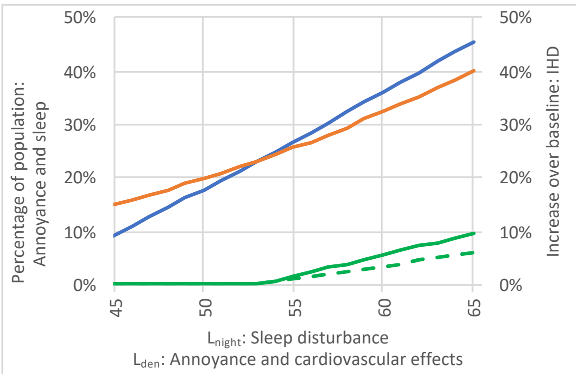
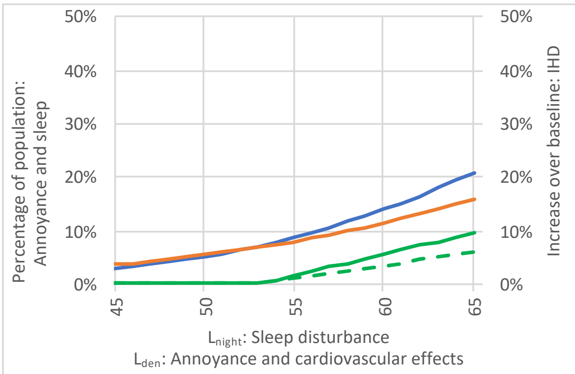


Figure 15 Dose-response curves for coastal shipping noise



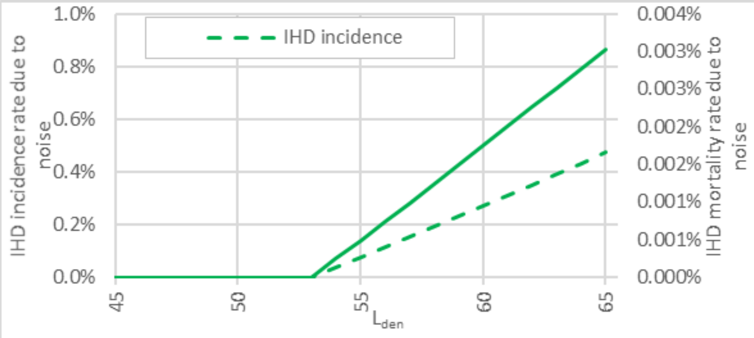
Highly Annoyed — Sleep Disturbance — IHD incidence (increase) — IHD mortality (increase)

The increase in IHD conditions over baseline is converted to the actual incidence rate based on the actual rates of IHD incidence and mortality in New Zealand. Incidence and mortality data is shown below (Ministry of Health, 2019):

- IHD incidence – 4.9% in 2017
- IHD mortality – 0.05% in 2017.

The absolute IHD incidence and mortality effects due to environmental noise are shown in , combining the dose response curves with prevalence. While the numbers are relatively small, the effects are significant.

Figure 16 Dose-response curve for IHD incidence and mortality increase



4.3 Disability weights

The European Environment Agency (2010) *Good practice guide on noise exposure and potential health effect* provides a method for determining DALYs for different health conditions, using published Disability Weights. A disability weight[1] is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death) (WHO 2014). Disability weights are widely used, and the WHO publishes a comprehensive list of disability weights for wide range of diseases and injuries. A subset of disability weightings that apply to the conditions investigated in this report are provided in Table 9.

Table 9 Disability Weights for different health conditions

Effect	Disability weight
Ischaemic heart disease	0.35
Sleep disturbance	0.07
Annoyance	0.02

4.4 Value of statistical life

One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.[2]

[1] WHO (2004) Global burden of disease 2004 update: disability weights for diseases and conditions
[2] https://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

The value of a DALY has been derived based on the Value of Statistical Life (VoSL) determined for the NZ transport sector from previous market research studies[3]. See the DTCC *Health Impacts of Active Transport* Working Paper for details on how this has been determined.

Table 10 Determination of the value of a DALY (2018/19)[4]

	Health sector discount rate	Transport sector discount rates			
	3.5%	3%	4%	5%	6%
DALY/QALY	$194,139	$178,278	$210,605	$245,184	$281,667

4.5 Results

The estimated number of people suffering from different health outcomes has been determined by applying the noise exposure (Table 6 and Table 7with the dose response curves. The results are presented in Table 11.

Applying the disability weights (Table 9) to this exposure data (Table 11) results in the figures for burden of disease (expressed in DALYs) in Table 12.

Application of the figure for the value of a DALY from Table 10 (at 4% discount rate) to the Table 12 DALY numbers then results in the monetised burden of disease estimates in Table 13.

[3] The current NZ VoSL is currently the subject of further market research in NZ, which is expected to lead to establishment of a new VoSL value for use throughout the transport sector. The current NZ VoSL has been applied in other DTCC topic areas (including transport accidents, public health impacts).
[4] The values given in this table are the annualised equivalents of the NZ VoSL value. They represent the value of one life year lost (without adjustment for quality factors).

Table 11 Estimated population suffering from various health outcomes due to environmental noise

Location	Source	High annoyance	High sleep disturbance	IHD	Premature mortality
Urban	Road	98,840	19,407	1,010	6
	Rail	10,105	1,305	60	0
	Air	8,098	74	14	0
	Coastal shipping	763	45	7	0
Rural	Road	16,741	3,266	171	1
	Rail	840	132	4	0
	Air	89	4	0	0
	Coastal shipping	0	2	0	0
	Total	**135,476**	**24,235**	**1,266**	**7**

Table 12 Burden of disease (DALYs) due to environmental noise

Location	Source	High annoyance	High sleep disturbance	IHD	Premature mortality	Total
Urban	Road	1,977	1,359	353	7	3,695
	Rail	202	91	21	0	315
	Air	162	5	5	0	172
	Coastal shipping	15	3	3	0	21
Rural	Road	335	229	60	1	624
	Rail	17	9	2	0	28
	Air	2	0	0	0	2
	Coastal shipping	0	0	0	0	0
	Total	**2,710**	**1,696**	**444**	**8**	**4,857**

Table 13 Burden of disease ($million pa) due to environmental noise (based on discount rate of 4%pa)

Location	Source	High annoyance	High sleep disturbance	IHD	Premature mortality	Total
Urban	Road	416.3	286.1	74.4	1.4	778.2
	Rail	42.5	19.2	4.4	0.1	66.2
	Air	34.2	1.1	1.1	0.0	36.3
	Coastal shipping	3.3	0.7	0.5	0.0	4.4
Rural	Road	70.5	48.1	12.6	0.2	131.5
	Rail	3.5	2.0	0.3	0.0	5.8
	Air	0.3	0.1	0.0	0.0	0.4
	Coastal shipping	0.0	0.0	0.0	0.0	0.0
	Total	**570.6**	**357.3**	**93.4**	**1.7**	**1,023.0**

Chpater 5 Costs

5.1 Total noise costs

Total costs allow comparisons with other effects / externalities, and between modes.

The total cost for each mode (based on Table 13) is presented in Table 14, for each of the discount rates listed in Table 10. As expected, it is seen that the estimates of total noise costs are reasonably sensitive to the discount rate chosen. For the remainder of this report, the costs based on a transport sector discount rate of 4% have been used. This gives results approximately 8% higher than use of the health sector rate of 3.5%.

Table 14 Total noise costs ($M) by mode, for different discount rates (2018/19)

Source	Health sector discount rate	Transport discount rates			
	3.50%	3%	4%	5%	6%
Road	838.6	770.1	**909.7**	1,059.1	1,216.6
Rail	66.4	61.0	**72.1**	83.9	96.4
Air	33.9	31.1	**36.8**	42.8	49.2
Coastal shipping	4.1	3.8	**4.4**	5.2	5.9
Total - all modes	943.0	866.0	**1,023.0**	1,190.9	1,368.2

5.1.1 Road

The Handbook on the external costs of transport in Europe (CE Delft, 2019, Table 34) has 9 different vehicle categories with associated weighting. Consideration has been given to including the various categories to allow direct comparison, however for the reasons stated below the authors consider that more nuanced data could potentially lead to false conclusions:

- Motorbikes: there is not an evidence base to support assigning costs from long-term health effects on short term events, which typically are more prevalent in the day.
- Active modes (walking / cycling): these are not represented in the input noise model, and do not generate significant noise
- Buses: again these are daytime uses only, whereas modelled sound levels are 24-hour averages
- Heavy vehicles by weight class: there is insufficient evidence to support this in New Zealand. In many cases, higher capacity (eg. 40-50 tonne) vehicles may be significantly more modern than 10-20 tonne trucks and have lower noise levels.
- Electric / hybrid vehicles: at highway speeds, vehicle noise is predominately generated by aerodynamic noise and the road-tyre interaction, so is largely independent of the power source.

Other than fleet composition and number of vehicle movements, the factors that affect the average cost the most are housing/population density and speeds. Rather than developing weighting factors for each of these factors, the average costs have been directly calculated for a number of categories in terms of network classification, speed, and urban/rural split.

A breakdown of Total Costs vs road classification and speed categories is provided in Table 15, and a split between passenger and freight movements is provided in Table 16.

Table 15 Total costs ($M) by road type (2018/19)

Classification	Speed	Urban	Rural	Total
National (High Volume)	>= 80 km/h	75	7	82
National		6	11	17
Regional		17	15	32
Arterial		12	27	38
National (High Volume)	< 80 km/h	44	1	45
National		14	3	18
Regional		108	3	111
Arterial		506	13	520
Other		20	27	47
Total	**All speeds**	**802**	**108**	**910**

Table 16 Total costs ($M) by vehicle type for road transport (2018/19)

Classification	Urban	Rural	Total
Passenger	626	92	718
Freight	152	39	192
Total	**778**	**131**	**910**

5.1.2 Rail

The total cost for rail transport apportioned between freight and passenger is detailed in Table 17. The proportions have been determined from the difference in exposure at each receiver.

Table 17 Total costs ($M) by vehicle type for rail transport (2018/19)

Classification	Urban	Rural	Total
Passenger (urban)	14.4	0.1	14.5
Freight	52.1	5.8	57.9
Total	**66.5**	**5.8**	**72.4**

5.2 Average noise costs

5.2.1 Introduction

As set out in Chapter 5.1, total costs have been calculated based on the noise effects experienced by those receiving noise (Chapter 3 and 4), rather than directly on an emissions basis. As the DTCC Study requires average costs to be presented – i.e., costs on a per movement or distance-travelled basis – the total cost at all relevant receivers is summed, assigned to a source (road / rail / air / port) and then normalised as appropriate.

5.2.2 Road

The average costs for road transport have been calculated using the following metrics.

- Passenger - vehicle kilometre travelled (VKT) and passenger kilometre travelled (PKT)
- Freight – net tonne kilometre transported (NTK).

The noise modelling set out in Chapter 3.1 contains road segments with traffic attributes such as the AADT and percentage of heavy vehicles, as well as the length of the segment, and the ONRC Classification. The total cost of noise effects for that road segment has been determined using a GIS query to assign the cost of all receivers closest to that road. While the noise exposure at a receiver may be influenced by multiple roads, the cost has only been assigned to the closest road. Where the model includes separate carriageways (noted by an Increasing or Decreasing ID), these have been aggregated into a single road segment. This assignment of total costs to a road segment allows the average cost to be calculated.

A breakdown of NZ annual VKT, PKT and NTK data by road class is provided in Table 18. These values have been calculated directly from the traffic volumes and road segment lengths used in the noise model (Table 6). The results differ from the figures published by Waka Kotahi and Ministry of Transport that have been calculated using Warrant of Fitness / Certificate of Fitness statistics, which include all classes of roads and capture all journeys. Noise from low volume roads has been excluded from the noise model as a practical consideration, and in general these would not result in significant noise effects.

NTK has been calculated using the heavy vehicle percentage for each road segment and the average freight loading.

The most significant segments are high speed National (High Volume) and low speed Arterial roads, as one would expect.

Table 18 Road transport movements by road class (millions per year, 2018/19)

	Speed	Urban			Rural			Total		
		VKT	PKT	NTK	VKT	PKT	NTK	VKT	PKT	NTK
National (High Volume)	>= 80 km/h	4,451	7,656	2,476	1,825	3,140	2,476	6,277	10,796	4,952
National		209	360	141	2,081	3,579	3,036	2,290	3,939	3,177
Regional		420	723	268	2,578	4,434	3,242	2,998	5,157	3,510
Arterial		387	665	227	2,422	4,166	2,496	2,809	4,831	2,723
National (High Volume)	< 80 km/h	1,057	1,819	742	221	380	263	1,278	2,198	1,004
National		311	534	256	148	254	175	458	788	432
Regional		1,890	3,250	1,046	2,578	4,434	351	4,468	7,684	1,397
Arterial		4,620	7,946	2,245	335	576	252	4,955	8,522	2,498
Total	**All speeds**	**13,345**	**22,953**	**7,401**	**12,187**	**20,962**	**12,291**	**25,532**	**43,916**	**19,692**

Weighting factors can be applied to reflect the fact that different classes of vehicles result in proportionally higher levels of effects[5]. For our analysis, a heavy vehicle has been considered equivalent to 4 light vehicles[6].Table 19 determines the average road transport costs on a national basis.

Table 19 National average costs for road transport, all areas (2018/19)

Vehicle type	Value
Light (passenger) vehicles (VKT)	26,492 M
Heavy vehicles (VKT)	2,230 M
Light vehicle equivalent (VKT)	35,412 M
Cost per light vehicle equivalent	2.57 c/VKT

The average costs for road transport have been determined on a per vehicle kilometre basis, using the VKT summary provided by Waka Kotahi, and the average vehicle occupancy from the New Zealand Household Travel Survey. The basis for these calculations is presented in Table 20 and Table 21.

Table 20 Determination of average costs for road transport (passenger)

Vehicle type	Value
Light vehicle cost (cents / VKT)	2.57 c/VKT
Occupancy rate (person / vehicle)	1.72
Light vehicle cost (cents / PKT)	1.49 c/PKT

[5] The previous STCC study used a 1:5 weighting.
[6] Using the Calculation of Road Traffic Noise algorithm, a road with 100% heavy vehicles is approximately 6 dB louder than a road with 0% heavy vehicles. This equates to increasing the number of light vehicles by a factor of 4.

Table 21 Determination of average costs for road transport (freight)

Vehicle type	Value
Heavy vehicle cost (cents / VKT)	10.28 c/VKT
Average payload rate[7] (tonnes / vehicle)	8.2
Heavy vehicle cost (cents /net tonne km)	1.25 c/NTK

Table 22 provides disaggregated average costs by speed and ONRC road category for each of VKT, PKT and NTK. Significant variations can be seen: the highest values are for arterial speed-limited roads, the lowest values being for national non-limited speed roads, with the latter's values typically being around one-twelfth of the former's values.

Table 22 Average costs by road class (2018/19)

Classification	Speed	Urban			Rural			Total		
		c/VKT	c/PKT	c/NTK	c/VKT	c/PKT	c/NTK	c/VKT	c/PKT	c/NTK
National (high vol)	>= 80 km/h	1.34	0.78	0.66	0.30	0.17	0.15	1.04	0.61	0.51
National		2.33	1.36	1.14	0.44	0.25	0.21	0.61	0.36	0.30
Regional		3.25	1.89	1.58	0.45	0.26	0.22	0.84	0.49	0.41
Arterial		2.41	1.40	1.18	0.88	0.51	0.43	1.09	0.64	0.53
National (high vol)	< 80 km/h	3.34	1.94	1.63	0.36	0.21	0.17	2.82	1.64	1.38
National		3.66	2.13	1.79	1.87	1.09	0.91	3.08	1.79	1.50
Regional		4.58	2.66	2.23	0.10	0.06	0.05	2.00	1.16	0.97
Arterial		8.77	5.10	4.28	3.16	1.84	1.54	8.39	4.88	4.09
Total	**All speeds**	4.81	2.80	2.35	0.71	0.41	0.34	2.85	1.66	1.39

5.2.3 Rail

The average costs for rail freight transport have been expressed on a per net tonne km basis, using the 2018 totals from the Ministry of Transport FIGS report. The basis for these calculations is presented in Table 23.

Table 23 Determination of average costs for rail freight transport (per net tonne km)

Parameter	Value
Cost ($M)	57.9
Number of net tonne km (M)	3856.6
Cost per net tonne km (c)	1.50 c/NTK

[7] Ministry of Transport (2018) Vehicle Statistics Table 11.1 & 11.2

Average costs for passenger rail (urban commuter) have been determined using annual movement numbers, as shown in Table 24.

Table 24 Determination of average costs for urban rail passenger movements

Parameter	Value
Cost ($M)	14.5
Number of passenger trips (M)	35.6
Cost per passenger trip ($)	0.41
Average passenger trip length (km)	21.5
Number of passenger km (M)	765.5
Cost per passenger km (c)	1.90 c/PKm

5.2.4 Air

The average costs for air transport have been determined on a per movement (landing or take-off / LTO) basis. The results are presented in Table 25.

Table 25 Determination of average costs for air transport

Parameter	Value
Cost ($million)	36.837
Number of movements pa	468,489
Cost per movement ($)	$78.63

5.2.5 Coastal shipping

The split of noise effects from domestic vs international shipping has been done on a per tonne basis, as shown in Table 26 and Table 27.

Table 26 Split between domestic and international shipping

Parameter	Value
Domestic tonnage (mill tonnes)	4.3
International tonnage (mill tonnes)	66
Domestic fraction (%)	6.5%

Table 27 Determination of average costs for coastal shipping

Parameter	Value
Total cost ($M)	4.45 M
Domestic cost ($M)	0.29 M
Domestic cost per tonne (c)	6.81

5.2.6 Summary of average noise costs by mode

Table 28 provides a summary of average noise costs by mode drawn from this section. It should be noted that these costs are averaged across all domestic travel by the stated mode, whether directly affected by noise or not.

Table 28 Summary of average noise costs by mode

Mode	Person travel	Freight travel
Road	2.57 c/VKT or 1.49 c/PKT	1.25 c/NTK
Rail	1.90 c/PKT*	1.50 c/NTK
Air (passenger)	$79/LTO	N/A
Shipping (domestic)	N/A	6.81c / tonne

*Urban passenger

5.3 Marginal costs

Marginal costs reflect the costs of additional movements over the existing baseline, ie they represent the incremental cost of any single journey. They may be calculated using the following formula, for a given *q* movements:

Marginal Cost (q) = Total Cost (q+1) – Total Cost (q)

Two competing factors affect the Marginal Cost in a given scenario:

- The higher the existing noise level, dose response curves result in a higher $/dB increase.
- The logarithmic relationship between noise levels and number of movements results in a lesser change in dB/movement for higher existing traffic volumes.

Similar to the Average Costs, the Marginal Costs are significantly influenced by the density of dwellings and their distance from the source. For this reason, it is useful to express the Marginal Cost as a proportion of the Average Cost.

Marginal costs have been calculated only for road and rail modes, for which Total and Average costs have been calculated in terms of person or tonne km movements.

The following marginal cost estimates all relate to Short Run Marginal Cost (SRMC) situations only, ie they are based on the cost impacts of marginal increases in vehicles, trains etc using the existing network and infrastructure. We have not attempted any estimates of Long Run Marginal Costs (LRMC), which would apply to situations where additional travel volumes were catered for by network and/or infrastructure expansion.

5.3.1 Road

Marginal Costs have been calculated for each road segment, and aggregated values are presented in Table 29. For passenger vehicles, the Marginal Cost is 20-30% of the Average Cost, depending on the existing traffic volumes. For heavy vehicles, for the same section of road, the ratio of Marginal Cost to Average Cost is 3 percentage points higher than for passenger vehicles.

Table 29 Marginal cost rates for road transport

Classification	Speed	Urban			Rural		
		c/VKT	c/PKT	c/NTK	c/VKT	c/PKT	c/NTK
National (High Volume)	>= 80 km/h	0.32	0.21	0.15	0.07	0.05	0.03
National		0.58	0.37	0.27	0.12	0.08	0.05
Regional		0.81	0.52	0.38	0.12	0.08	0.06
Arterial		0.65	0.42	0.30	0.26	0.16	0.12
National (High Volume)	< 80 km/h	0.83	0.53	0.39	0.09	0.06	0.04
National		0.92	0.59	0.43	0.49	0.31	0.23
Regional		1.14	0.73	0.53	0.03	0.02	0.01
Arterial		2.28	1.46	1.06	0.92	0.59	0.43
Total	**All speeds**	**1.20**	**0.77**	**0.56**	**0.18**	**0.26**	**0.07**

We have considered how the uptake of public transport could be considered for road users – that is, people replacing car journeys by taking buses. In the case where passengers can be accommodated without changes to the bus timetables (ie using the existing capacity), then the benefit would be the Marginal Cost for cars on a VKT basis.

More generally, if additional bus capacity is added to meet increased patronage:

- P_{bus} is the number of additional passengers before an additional bus is required. This is different to the average bus occupancy.
- P_{car} is the average passenger car vehicle occupancy (1.56)

On the basis that 1 bus = 4 car equivalents of noise, the emissions per additional bus passenger is:

$$MC_{bus}(PKT) = \frac{4}{P_{bus}} MC_{car}(VKT)$$

Taking into consideration the average car passenger vehicle occupancy, this can be rewritten as:

$$MC_{bus}(PKT) = \frac{4\ P_{car}}{P_{bus}} MC_{car}(PKT)$$

Therefore, the net change in noise costs of transferring one passenger from a car to a bus is:

$$MC_{PT}(PKT) = MC_{bus}(PKT) - MC_{car}(PKT)$$

$$= MC_{car}(PKT) * \left(\frac{4\ P_{car}}{P_{bus}} - 1\right)$$

On this basis, the marginal benefit of mode shift from passenger cars to buses is 69% of the PKT rate (assuming P_{bus} = 20).

5.3.2 Rail

Marginal Costs for rail mode are presented in Table 30. For freight movements, the Marginal Cost rates (per NTK) are on average 88% of the Average Costs, although there is variation around the country depending on the existing movement numbers. These estimates will also depend on the time of day, as an additional night-time movement will have higher costs than day-time movements. For passenger movements, the Marginal Cost rates (per PKT) average some 40% of the Average Costs.

Table 30 Marginal costs for rail transport

Parameter	Value
Freight	1.32 c/NTK
Passenger (urban rail)	0.77 c/PKT

Chpater 6 Conclusions

6.1 Comparisons with similar work

A summary of how the average noise cost results in this paper for road and rail (passenger and freight) modes compare with relevant overseas studies is provided in Table 31 below. More details of the overseas studies summarised here are presented in Appendix 3.

In most of the overseas studies, rail freight has considerably lower average costs (per NTK) than road freight; whereas the DTCC study finds somewhat lower costs for road freight. This is likely to be a limitation of the DTCC study whereby road-traffic noise effects are assessed in totality and pro-rated between passenger and freight (with one truck taken as equivalent to 4 cars in terms of noise impacts[8]). An alternative methodology looking at road freight in isolation and looking directly at effects from heavy vehicle movements at night (for example) may produce a different result.

Table 31 Summary comparison of average costs with other studies (NZD equivalent)

	Road - passenger (c / PKT)	Rail – urban passenger ($ / PKT)	Road - freight (c / NTK)	Rail – freight ($/ NTK)
DTCC	1.65	1.9	1.19	1.50
Europe[1]	1.056		2.095	0.704
Australia [2]	0.742	0.954	4.346	0.954

[1] CE Delft (2019). Handbook on the external costs of transport. Report prepared for the European Commission.

[2] ATAP (2020). Australian Transport Assessment and Planning Guidelines, Report PV5: Environmental Parameter Values (draft for public consultation).

6.2 Strengths, limitations and potential additional areas of work

This paper applies a health-based estimate of the noise costs arising from the use of the NZ domestic transport network. This approach provides a significant improvement over the approach adopted in previous studies in NZ which have only applied a hedonic pricing approach.

The methods adopted in this paper have been designed to allow relatively simple updates for rail and airport numbers. Road noise exposure has been based on predictions made on behalf of Waka Kotahi, which are expected to be updated periodically.

The methodology and findings of this paper should be reviewed following the completion of the Waka Kotahi research project *ART 19-01: Social cost (health) of land transport noise*

[8] This is the weighting used by the Calculation of Road Traffic Noise model

exposure in New Zealand. In addition, before undertaking any further work, the authors recommend that the output formats and disaggregation categories be reviewed with stakeholders to ensure data is in the most useful format. It may be useful to develop a number of case studies.

Specific sources of uncertainty and potential future work for each mode are detailed in Table 32.

The analysis considers the costs from exposure to multiple noise sources on the same population independently; and does not consider the effect of existing noise from non-transport sources.

The extent of sensitivity analysis has been limited to considering the value of the DALY based on different discount rates.

Table 32 Sources of uncertainty and potential future work

Mode	Sources of uncertainty	Scale of uncertainty	Potential future work
Road	Predictions are reliant on large-scale modelling where it is not practical for all inputs to be manually verified This includes identification of residential dwellings	Predictions likely to be within 2-3 dB $L_{Aeq(24h)}$ for most receivers (based on known accuracy of CRTN) Missing or incorrectly identified receivers estimated as less than 5%	Include updated noise modelling from Waka Kotahi
Rail	Train movements not available for individual rail sections Night-time rail movements not directly assessed, and relationships between $L_{Aeq(24h)}$ and L_{den}/L_{night} less certain than for road Receivers from road model adopted	Large scale errors likely due to approximation measures for rail movements.	Review noise modelling approach from ART19-01
Air	Flight paths not directly modelled Cross-runways not considered Freight and international passenger movements not considered Receivers from road model adopted	For most receivers with exposure > 55 dB L_{den}, predicted sound levels are likely to be within 5 dB. Greater uncertainty for receivers with lower noise exposure	Liaise with airport companies / Airways to obtain and use annual noise contours (noting that these include international movements)
Sea	Port noise model also includes land-based noise sources within ports (eg dry dock maintenance, container handling). Pro-rata assignment of total noise to domestic activity	Total noise levels likely to be within 5 dB	Given limited scale of effect and ability to assign to domestic transport only, any future work should be regarded as of low priority.

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Appendix 2 : Listing of DTCC Working Papers

The table below lists the Working Papers prepared as part of the DTCC Study, together with the consultants responsible for their preparation.

Ref	Topic/Working Paper title	Principal Consultants	Affiliation
MODAL TOPICS			
C1.1	Road Infrastructure – Marginal Costs	David Lupton	David Lupton & Associates
C1.2	Road Infrastructure – Total & Average Costs		
C2	Valuation of the Road Network	Richard Paling	Richard Paling Consulting
C3	Road Expenditure & Funding Overview		
C4	Road Vehicle Ownership & Use Charges		
C5	Motor Vehicle Operating Costs		
C6	Long-distance Coaches	David Lupton	David Lupton & Associates
C7	Car Parking	Stuart Donovan	Veitch Lister Consulting
C8	Walking & Cycling		
C9	Taxis & Ride-hailing		
C10	Micro-mobility		
C11.2	Rail Regulation	Murray King	Murray King & Francis Small Consultancy
C11.3	Rail Investment		
C11.4	Rail Funding		
C11.5	Rail Operating Costs		
C11.6	Rail Safety		
C12	Urban Public Transport	Ian Wallis & Adam Lawrence	Ian Wallis Associates
C14	Coastal Shipping	Chris Stone	Rockpoint Corporate Finance
C15	Cook Strait Ferries		
SOCIAL AND ENVIRONMENTAL IMPACT TOPICS			
D1	Costs of Road Transport Accidents	Glen Koorey	ViaStrada
D2	Road Congestion Costs	David Lupton	David Lupton & Associates
D3	Health Impacts of Active Transport	Anja Misdrak & Ed Randal	University of Otago (Wellington)
D4	Air Quality & Greenhouse Gas Emissions	Gerda Kuschel	Emission Impossible
D5	Noise	Michael Smith	Altissimo Consulting
D6	Biodiversity & Biosecurity	Stephen Fuller	Boffa Miskell

Note:

The above listing incorporates a number of variations from the initial listing and scope of the DTCC Working Papers as set out in the DTCC Scoping Report (May 2020).

Appendix 3 : Comparisons with other studies

A summary of average noise cost rates from other studies is presented below, followed by a summary of the DTCC values derived in this paper.

Study	Local currency	NZD
Road - passenger (c / pkm)		
DTCC	1.65	1.65
Handbook on cost of externalities Europe (2019) (euro cents)	0.6	1.06
STCC (2005)	0.75	0.75
Austroads (2012/2014) (AUD)	0.7	0.74
Road - freight (c / tkm)		
DTCC	1.19	1.19
Europe	1.2	2.09
Austroads	4.1	4.35
Rail – passenger (c/pkm)		
DTCC	1.90	1.90
Europe		
Austroads	0.9	0.95
Rail – freight (c/tkm)		
DTCC	1.50	1.50
Europe	0.4	0.70
Austroads	0.9	0.95
Air (per LTO)		
DTCC	37	37
Europe	275	484
Germany (daytime)	26	45.8

Mode	Person travel	Freight travel
Road	2.57 c/VKT 1.49 c/PKT	1.25 c/NTK
Rail	1.90 c/PKT*	1.50 c/NTK
Air	$79 / LTO	
Shipping (domestic)	n.a	6.81c / tonne

Domestic Transport Costs and Charges Study

Working paper D5

Noise

transport.govt.nz

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