TE MANATŪ WAKA
MINISTRY OF TRANSPORT

Domestic Transport Costs and Charges Study

Working Paper C1.1
Road Infrastructure - Marginal Cost

Prepared for Te Manatū Waka Ministry of Transport (NZ)
David Lupton & Associates Limited in association with Ian Wallis Associates Ltd
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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

AADT	Annual average daily traffic
CESA	Cumulative equivalent standard axles
EEM	Economic evaluation manual, NZ Transport Agency (now Monetised Benefits and Costs Manual, MBCM)
ESA	Equivalent standard axle
CAM	Cost allocation model
DTCC	Domestic Transport Costs and Charges (study)
dTIMS	Deighton Total Infrastructure Management System (proprietary road asset management software)
GST	Goods and services tax (currently 15%)
HCV	Heavy commercial vehicle (1= rigid, 2= multi-axle)
HDM-4	Highway Design and Maintenance model (road asset management software developed by the World Bank)
IDS	Infrastructure Decision Support (company that undertakes road asset management analysis on behalf of many local authorities and for this study)
IRI	International roughness index (measure of the quality of ride provided by the pavement)
km	kilometre
LRMC	Long run marginal costs – in this context taken to mean those costs associated with rehabilitating the pavement
MBCM	Monetised Benefits and Costs Manual (maintained by Waka Kotahi)
MCV	Medium commercial vehicle
NZ	New Zealand
NZTA	Waka Kotahi New Zealand Transport Agency
RUC	Road user charge
R^2	Regression coefficient (shows goodness of fit of data)
SMC	Social marginal cost - in this context taken to mean those costs to society without expenditure by the road agency
SN /SNC	Structural number /modified structural number - a measure of pavement strength
SRMC	Short run marginal cost – in this context the cost of repairs and maintenance
TOF	Transport Outcomes Framework
VOC	Vehicle operating costs
Waka Kotahi	Adopted name for the New Zealand Transport Agency.

Executive summary

The primary purpose of this paper is to estimate the total and average economic costs by vehicle type for the use of the NZ road infrastructure (state highways and local roads), Road infrastructure costs (attributable, joint and common costs) are allocated between road users based on the characteristics of each vehicle type. This results in fully allocated costs that reflect the assessed contribution of each vehicle type to the expenditure on road infrastructure. They are nevertheless average costs in the sense that the allocated expenditure is summed by cost category and divided by the total output in that category.

We made use of the Cost Allocation Model (CAM) maintained by The Ministry of Transport (MOT) for deriving recommended road user charges (RUC) and petrol excise duty (PED). CAM is used to allocate the expenditure of the New Zealand Transport Agency (Waka Kotahi or “WK”) which includes non-road expenditure (expenditure on public transport, railways, sea freight) as well as expenditure on roads. However, as a first step, CAM allocates all expenditure on roads to ‘cost drivers’. The rates are then adjusted so that all WK expenditure is covered. This paper is primarily concerned with the results from the first step: the allocation of road infrastructure expenditure.

The CAM process allocates financial costs relating to building and maintaining roads (Expenditure) to cost drivers – characteristics of vehicles such as axle loads that are a direct or indirect cause of road expenditure.

The main steps involved in applying the CAM process are as follows:

- Identify all government and municipal agencies that have road-related expenditure and prepare a schedule of all relevant annual costs (“schedule of costs”), disaggregated as far as possible into individual cost items. For example, cost items include patching potholes, repairing signs.
- For each cost item in the schedule of costs, identify the cost driver or the intended beneficiary group, e.g. number of equivalent standard axle-kilometres (ESA-km) or number of driver-km.
- From road use statistics and surveys etc, estimate the overall quantum of each cost driver for the relevant year- e.g. number of ESA-km or number of powered vehicle-km per year.
- Divide the cost item total by the quantum of the cost driver and aggregate by broad categories to give an average cost per unit of each cost driver for that category of expenditure.
- Use estimates of the distances travelled and the characteristics of each vehicle type to allocate all roading-related costs against vehicle types.

The five ‘cost drivers’ used in CAM to allocate road infrastructure costs are:

- Heavy vehicle-kilometres including trailers (HV)
- Gross vehicle weight-kilometres (GVW)
- Equivalent Standard Axle-kilometres (ESA)
- Passenger Car Equivalent-kilometres (PCE)
- Powered vehicle-kilometres (PV)

Table ES.1: Road cost allocation (2018/19)

All costs in $ million 2018/19	HV-km	PCE-km	GVW-km	ESA-km	PV-km	Total
Local Roads (LR):						
LR maintenance and operations	1.03	0.00	11.11	78.96	653.85	744.95
LR renewal	0.00	0.00	130.46	226.15	281.25	637.86
LR new and improved roads	2.61	103.27	2.79	47.18	267.86	423.71
State Highways (SH):						
SH maintenance and operations	0.00	16.45	7.58	42.51	349.00	415.54
SH renewal	0.00	0.00	99.43	95.51	100.41	295.36
SH new and improved roads	0.00	434.85	65.19	144.43	558.08	1,202.55
Regional improvements	0.13	3.33	76.05	0.00	101.89	181.39
Total cost ($ million)	**3.77**	**557.88**	**392.60**	**634.75**	**2,312.35**	**3,901.36**
Kilometres billion	5.25	51.91	193.63	2.69	48.68	48.68
Rate ($ per 1000 km)	**0.72**	**10.75**	**2.03**	**235.91**	**47.50**	**80.14**

Source: Ministry of Transport

Table ES.2: Average economic costs and their allocation

All costs in $ million 2018/19	HV-km	PCE-km	GVW-km	ESA-km	PV-km	Total
Local roads:						
Maintenance and operation	1.03	0.00	11.11	78.96	653.85	744.95
Renewal	0.00	0.00	130.46	226.15	281.25	637.86
Capital charge	25.47	544.41	0.00	368.38	1,521.75	2,460.00
State Highways:						
Maintenance and Operation	0.00	16.45	7.58	42.51	349.00	415.54
Renewal	0.00	0.00	99.43	95.51	100.41	295.36
Capital charge	0.14	594.98	139.25	298.43	955.19	1,988.00
Total cost ($ million)	**26.64**	**1,155.84**	**387.84**	**1,109.94**	**3,861.45**	**6,541.71**
Kilometres (billion)	5.25	51.91	193.63	2.69	48.68	48.68
Rate ($ per 1000 km)	**5.08**	**22.27**	**2.00**	**412.52**	**79.32**	**134.38**

Source: Consultant estimates

Table ES.3: Average cost comparisons by vehicle type

Vehicle type	Cost rates per thousand vehicle km (2018/19)		
	Financial cost $/1000	Economic cost $/1000	Actual charge $/1000
Motorbike	$54	$91	$33
Car	$65	$109	$66
LCV1	$65	$109	$66
LCV2	$63	$105	$66
MCV	$132	$227	$137
HCV1	$337	$571	$377
HCV2A	$393	$656	$396
HCV2B	$461	$748	$316
Bus 2 axle	$132	$225	$201
Bus 3 axle	$296	$499	$403

Chapter 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 and its impacts on the wider New Zealand economy, including costs (financial and non-financial) and charges borne by transport users.

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 associated with different transport modes – including road, rail, public transport 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, in particular 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.
- Resilience and security.

Underpinning the 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 (a) estimating and reporting economic costs and financial charges; and (b) 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 in areas such as charging and revenue management, internalising externalities, and travel demand management.

The Study was undertaken for Te Manatū Waka by a consultant consortium headed by Ian Wallis Associates Ltd. 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 transport-related impacts or externalities (including accidents, congestion, public health, emissions, noise, biodiversity and biosecurity).

Working papers (25) have been prepared covering 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

Road infrastructure costs include the costs of acquiring the right-of-way; building and maintaining the pavement; providing road markings, signage, lighting and other road furniture; road and driver management and road safety administration.

This working paper is primarily concerned with road rehabilitation and maintenance costs arising from road use. In this paper we estimate social, short run and long run marginal costs. Average costs are the subject of a separate paper (C1,2: Road Infrastructure – Total and Average Costs). Road wear costs are estimated using road asset management software to estimate the change in road user costs (associated with changes in road roughness) and the change in maintenance costs consequent upon changes in road use. The software used is calibrated to reflect New Zealand road maintenance costs and conditions including the relative impact of traffic and weather on the need for road maintenance

The objective of the analysis is to determine the economic (marginal) costs associated with the marginal road user with and without a response from the road authority. The analysis was undertaken for a sample of over 6,000 NZ road sections covering both state highway and local authority roads. A total of 1,795 km of road were included, accounting for about 2% of the New Zealand road network (Table 1.1). Note that the sample was selected to include the range of road types, not to be representative.

Table 1.1: Lengths of road selected for study

Road type	Km rough	Km smooth
Rural_High Volume	145.80	623.60
Rural_low Volume	243.20	342.00
Urban_High Volume	130.00	91.20
Urban_Low Volume	182.50	36.30
Total	701.50	1093.10

Other costs relating to the use of road infrastructure are covered in other working papers. Average road agency costs relating to road use are estimated using the Ministry of Transport's Cost Allocation Model (CAM) – refer working paper C1.2. This is a well-established model that is used to allocate what are largely joint costs based on a small set of cost 'drivers' Road capacity-related costs (primarily congestion) are also considered in a separate paper (WP D.2) as are costs relating to road accidents (WP D.1).

Chapter 2 Methodology

2.1 Approach

At the margin, additional vehicles contribute to an increase in road wear. Following previous studies, we have estimated the wear cost due to the marginal vehicle in terms of additional routine maintenance expenditure, periodic maintenance and/or maintenance expenditure brought forward. However, the immediate effect of road wear is an externality imposed on other road users. The externality is the incremental vehicle operating cost (VOC) due to incremental roughness caused by incremental road use, as measured by the international roughness index (IRI) . Since the effect of road wear is almost entirely due to heavy vehicles, we calculated the costs related to a change in the number of heavy vehicles, or more precisely, in terms of the change in number of equivalent standard axles (ESA) relative to a base situation.

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect ride quality. Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and vehicle maintenance costs. The World Bank found road roughness to be a primary factor in the analyses and trade-offs involving road quality vs. user cost. The measure of roughness used, the International Roughness Index, is time-stable, transferable, and relevant, while also being readily measurable by practitioners

Pavement roughness is caused by the passage of heavy axles. The damage or road wear caused increases by the fourth power of the load on the axle but also depends on the axle configuration (single or dual tyred, tandem axles etc). The load on the pavement is measured in terms of equivalent standard axles (ESA): one ESA is a single axle with dual wheels carrying an 80 Kilonewton (kN) load.

Our analyses distinguish between the social marginal cost, the short run marginal cost and the long run marginal cost. These terms are not always used consistently by authors or between modes. For this Working Paper we have defined the terms as follows:

- The social marginal cost (SMC) is, by analogy with congestion costs, the cost imposed on other road users by the marginal user in the absence of intervention by the road owner. An increase in ESA makes the pavement rougher and increases the VOC for all subsequent vehicles-- until the next reset (rehabilitation). Hence an increase in ESA immediately after reset is relatively costly but if the increase occurs shortly before reset the total externality will be small.
- The short run marginal cost (SRMC) is the increase in maintenance expenditure required to restore the road in its original condition divided by the change in ESA. However, note that there is a time lag between the passage of the marginal vehicle and the maintenance work being undertaken, Hence, there will always be cost to other road users (ie a social marginal cost) in addition to the agency cost.
- The long run marginal cost (LRMC) is the agency increase in the cost of strengthening (rehabilitating) the pavement in response to an increases in demand.

Both the SMC and the user cost component of the SRMC are externalities. The paper only considers externalities relating to road wear. Other externalities relating to road use such as congestion, road safety related costs, environmental costs etc. are considered in other papers.

2.1.1 Short run costs

Calculation of the social marginal cost and the short run marginal cost both require estimation of the progression of road deterioration over time and the consequential increase in VOC resulting from an increase in traffic. Standard relationships exist that estimate VOC as a function of the international roughness index (IRI). A model for roughness progression is required to predict the IRI as a function of cumulative ESA. Combining the roughness progression model with the vehicle operating cost model, we can then derive the VOC as a function of cumulative ESA and estimate the change in VOC arising from a change in ESA. The total cost also depends on the volume and mix of traffic

Estimation of the increase in VOC resulting from an increase in ESA was undertaken using the Deighton Total Infrastructure Management Software (dTIMS). This is proprietary software similar to the Highway Development and Maintenance Model (HDM-4). It was chosen as the standard software for New Zealand use because its design enables the underlying algorithms to be modified to incorporate relationships that have been developed for or adapted to New Zealand conditions and other research findings. dTIMS has been calibrated for New Zealand conditions and vehicle fleet characteristics. It was applied in this study to calculate the additional costs due to a small increment in traffic, both with and without subsequent remedial maintenance. For this study, some of the dTIMS algorithms were replaced by the standard HDM-4 equations, as discussed later in this section.

The following four scenarios were run:

1. Base: Do nothing (no maintenance or renewals treatments are applied), no traffic growth
2. S1: Do nothing (no maintenance or renewals treatments are applied), 5% pa growth for MCV, HCV1, HCV2 and Bus traffic classifications
3. S2: Do maintenance (apply maintenance and renewals when maintenance thresholds are met), no traffic growth
4. S3: Do maintenance (apply maintenance and renewals when maintenance thresholds are met), 5% pa growth for MCV, HCV1, HCV2 and Bus traffic classifications.

(MCV = medium commercial vehicle; HCV = heavy commercial vehicle)

The thresholds are the trigger points. When the IRI exceeds the threshold, road maintenance activity Is initiated. The trigger points used were those currently used by Waka Kotahi for New Zealand analyses.

ROAD MANAGEMENT SOFTWARE: HDM-4 AND dTIMS

HDM-4 is a software package and associated documentation for the analysis, planning, management and appraisal of road maintenance, improvements and investment decisions. It was orginally developed by the World Bank as an expert system to assist developing countries to prepare road maintenance programs and to evaluate road improvement and rehabilitation proposals.
It has four main modules

- Pavement deterioration model that predicts the future condition of the road pavement under the expected traffic and environmental conditions. Roads deteriorate due to the combined effect of heavy traffic and age. The relative implortance of these effects depends on a number of factors including climate and pavemeent design.
- Road user costs model that estimates the vehicle operating costs and travel times based on the road geometry and pavement condition. Road user costs are affected by the age and composition of the vehicle fleet.
- Works effects model that predicts the change in condition and performance of the pavement in response to road maintenance and improvement works
- Economic analysis model that has economic algorithms to determine when to undertake works and to compare the costs and benefits of different possible actions

HDM-4 is very data-hungry software. There are three main types of parameter that are required to calibrate HDM-4 to match local conditions. These can be broadly identified as; (i) environment parameters; (ii) road user cost parameters; and (iii) pavement deterioration parameters. In addition, there are a large number of variables for each specific road. Calibration of the parameters and mesurement of the variables requires extensive pavement performance history and surveys.

dTIMS is a similar product to HDM-4. It is a commercially developed model suite aimed at developed countries. It has an open architecture compared to HDM-4 enabling the user to replace the standard algorithms based on local research and practics. dTIMS was adopted for use by the road agencies in New Zealand and has been extensively customised based on research funded by Waka Kotahi and its predecessors.

Either HDM-4 or dTIMS would have been suitable for this study. We used dTIMS because it has been callibrated for New Zealand conditions and data were available for a large sample of New Zealand roads. However the pavement deterioration model used in dTIMS is a simplified version of the HDM-4 deterioration model and does not include cumulative ESA. Cumulative ESA and pavement age are highly correlated, so New Zealand road agencies only use pavement age. Since the purpose of the analysis was to determine the impact of a change in cumulative ESA, it was necessary to implement the HDM-4 deterioration equations within the dTIMS model framework. The deterioration model parameeers were calibrated to ensure that the resulting deterioration model closely replicated the results achieved with the standard dTIMS model for New Zealand roads.

Only HCV numbers needed to be incremented as we were only interested in the number of ESA-km, not how the number was made up.

The analyses were grouped into eight road categories, being the eight combinations of:

1. Urban or Rural
2. High Volume (AADT >= 2000 vpd) or Low Volume (AADT < 2000 vpd)
3. Smooth (IRI <= 3) or Rough (IRI >3);

AADT = Annual average daily traffic., IRI = international roughness index. Vpd=vehicles per day

These groupings were chosen to enable the impact of additional traffic to be calculated based on the type of road, the volume of traffic and road condition. The analyses were undertaken for a 10-year period. Note that the road condition (smooth or rough) relates to the initial condition of the road. The outputs of the dTIMS analyses were the road condition data (primarily the IRI), the vehicle operating costs and the extent of any surfacing or pavement work in each year.

2.1.2 Long run costs

For ***long run marginal costs***, we needed to estimate the additional road pavement strength required to enable the road to carry additional heavy vehicles without an increase in IRI compared with the base case. The relationship between pavement thickness (and thus cost), pavement strength and the design life, measured by cumulative ESA (equivalent standard axles), is given by:[1]

$$IRI(t) = [IRI(0) + 725\ (1+ SNC)^{-4.99}\ .CESA(t)]e^{0.0153t} \qquad (1)$$

where:

IRI(0), IRI(t) is the international roughness index at time 0 and time t respectively
SNC is the modified structural number
CESA is cumulative ESA in millions

The exponential term accounts for time-based deterioration due to environmental factors.

Making the simplifying assumption that the ESA per year is constant, we were able to estimate a relationship between SNC and CESA of the form[2]:

$$SNC = a\ .CESA^{0.2889} \qquad (2)$$

where the value of ‘a’ depends on the initial IRI and the IRI at which the pavement is deemed to require reconstruction,

[1] See Cenek and Patrick (1991). p5.

[2] We derived equation (2) from equation (1) by using Solver in Excel to calculate the AADT values corresponding to a range of values of SN. A curve was then fitted to these data points to give Equation (2).

We used this relationship between SNC and CESA to determine the additional pavement strength to carry a 10% increase in heavy goods traffic in each of the eight road classes.

> The modified or adjusted structural number (SNC) is **widely used to define the structural capacities of various flexible pavements**. It describes in a single number, the strength of the road pavement. Pavement strength is a function of the thickness of the pavement layers (base, sub-base, etc) multiplied by a layer coefficient plus the inherent strength of the subgrade material.

2.2 Data sources and literature

The analysis used for estimating the marginal costs is based on the principles incorporated in the World Bank Highway Development and Maintenance Model (HDM-4), in particular, the road deterioration model and the vehicle operating cost model within HDM-4, but were implemented using the dTIMS modelling framework. The relationships were calibrated to New Zealand conditions taking into account road construction and maintenance methods and materials, climatic conditions and the characteristics of the NZ vehicle fleet.

The road asset database used is that maintained on behalf of the national and local road agencies for the preparation of their annual programmes. For each road section it contains details of its condition, traffic load, pavement type and age, etc.

The costs used for estimating maintenance expenditure under different scenarios are based on NZ national average costs for reseals and rehabilitation by pavement type.

An alternative approach to estimating the SRMC would be to estimate the elasticity of maintenance costs with respect to traffic volume based on historical data. Wheat (2017) undertook econometric stochastic frontier efficiency analysis of road maintenance costs for local authorities in England. This work relates the observed road maintenance costs to a number of variables including traffic volume. The relationship estimated is logarithmic and the resulting coefficients describe the elasticity of cost with respect to the variables. The cost elasticity with respect to traffic volume that Wheat calculated was 0.24, indicating that a 1% increase in traffic results in a 0.24% increase in maintenance cost. We compare this with the results from the dTIMS analysis in section 3.1.2 .

The relationship between road strength and design life is based on the work by Cenek and Patrick (1991) and the New Zealand guide to pavement structural design (NZTA 2018).

2.3 Analyses

2.3.1 Short run costs

The two measures of short run costs – the Social Marginal Cost and the Short Run Marginal Cost, were estimated using dTIMS. The steps involved in the dTIMS analysis were as follows:

1. Collate data set from recent analysis of State Highway and Local Authority road networks.
2. Research the HDM4 roughness model and determine the most appropriate way to incorporate it into the NZ IDS dTIMS template and calibrate the new roughness model and code the changes into the template.
3. Modify dTIMS to include Vehicle Operating Costs (VOC) from the Waka Kotahi Monetised Benefits and Costs Manual (MBCM).
4. Run scenarios using different traffic and loading growth rates.

5 Analyse the data
6 Report the estimated social and short run marginal costs.

2.3.1.1 Data Set

A sample of 6,631 New Zealand road sections was used. These sections were already available in a dTIMS database used by the analyst to undertake work for Waka Kotahi and local authorities . The sections were grouped into eight categories based on whether they were rural or urban, rough or smooth, high or low traffic. The analysis was undertaken for 10 years. Table 2.1 shows the average values within each of the eight categories.

The samples were selected to represent each of the eight categories, not to be representative of roads in New Zealand The analysis was undertaken for each individual road section and the results were then aggregated.

Table 2.1: Budgeted Road Expenditure by work category (2018/19)

Analysis Group	Number	Average AADT	Average Length (km)	Average IRI	Average Pavement Age	Average Surface Age
All	6631	4184	0.3	3.5	36	9.0
Rural_HighVolume_Rough	486	5725	0.3	3.7	31	6.6
Rural_HighVolume_Smooth	1559	7736	0.4	2.1	31	7.1
Rural_LowVolume_Rough	608	924	0.4	4.0	35	7.7
Rural_LowVolume_Smooth	684	1179	0.5	2.3	33	8.8
Urban_HighVolume_Rough	650	7983	0.2	4.3	40	8.6
Urban_HighVolume_Smooth	456	11712	0.3	2.4	33	7.7
Urban_LowVolume_Rough	1825	452	0.1	4.9	43	11.8
Urban_LowVolume_Smooth	363	493	0.2	2.6	30	11.0

Source: Infrastructure Decision Support

2.3.1.2 HDM-4 Roughness Model

The current dTIMS template utilises a simplified model to predict roughness progression based on pavement age, known as the Cenek Model. Since pavement age is highly correlated with cumulative ESA, pavement age is used as a proxy for CESA in the Cenek model. This is a useful approximation for the usual use of the model to prepare maintenance programs for Waka Kotahi and local authorities. For this analysis, we needed to compare scenarios with different CESA profiles over time. For the purpose of this study, the Cenek deterioration model was replaced by a slightly modified HDM-4 roughness deterioration model[3], This was based on prior experience by Cenek and others with the model and its sensitivities.

[3] This ability to change the deterioration model within dTIMS is the reason it was chosen rather than HDM-4.

Figure 2-1 shows the results of the calibration of the HDM-4 model, showing the dTIMS deterioration curve (in blue), the standard HDM-4 deterioration curve (red) and the HDM-4 curve calibrated to closely fit the dTIMS curve (grey). A close fit of the grey curve to the blue dTIMS curve gives assurance that the model is correctly reflecting New Zealand conditions.

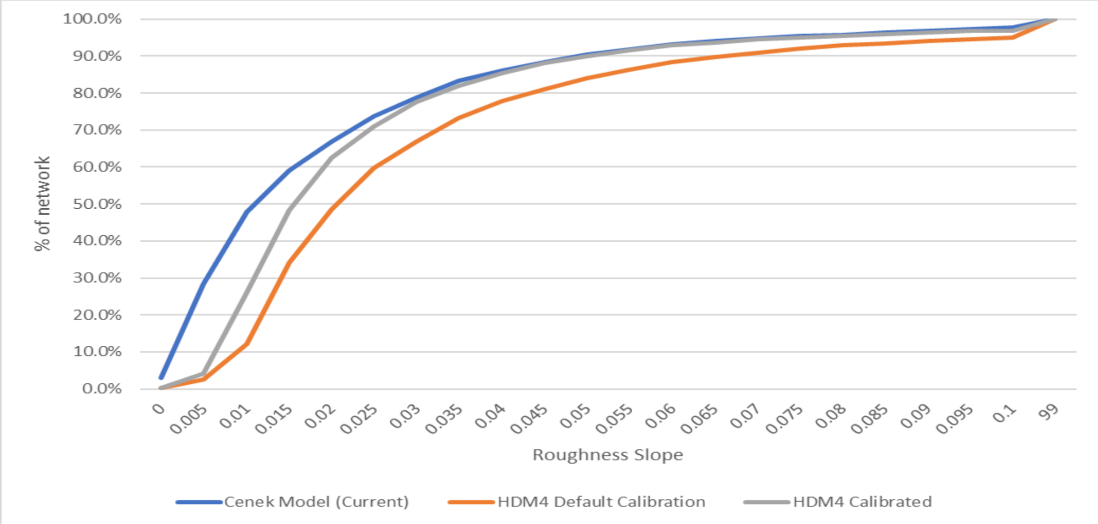

Figure 2-1: Calibration of roughness model

2.3.1.3 Vehicle Operating Cost Model

The relationship between IRI and vehicle operating costs (VOC) depends on the characteristics of each vehicle. Relationships specifically developed for NZ were used. These relationships are based on research undertaken for Waka Kotahi New Zealand Transport Agency (Waka Kotahi) and are given in Table A5.12 of the Monetised Benefit and Cost Manual (MBCM) and are shown as Figure 2-2. Note that the "Y" axis is the contribution of roughness (as measured on the "X" axis in IRI) to total VOC (measured in cents per km). Figure 2-2 is clearly a linear approximation, and in particular implies that IRI less than 2.5 has no effect on roughness-related costs.

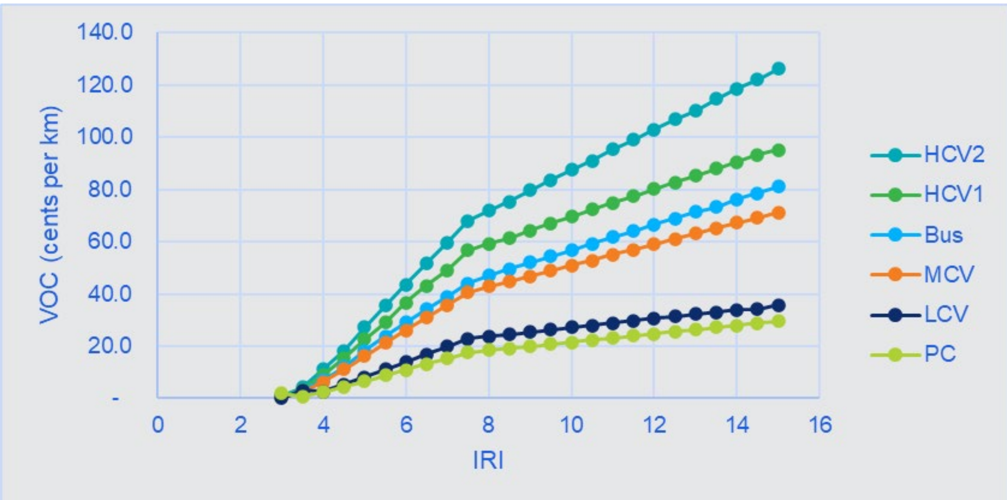

Figure 2-2: Contribution of roughness to the VOC vs IRI

Source MBCM table A5.12

While this approximation may be acceptable for normal use, it led to some issues for our analysis. Further work on this aspect is suggested in Section 4.2.

The effect of additional heavy vehicles is to increase the roughness of the road pavement (IRI) and thus to increase vehicle operating costs for all vehicles. To illustrate, the net effect of a 5%pa increase in vehicles per year on the average cost per vehicle-km for all other vehicles on the road is illustrated by Figure 2-3, which compares the average VOC with and without the 5% per annum increase in traffic volumes for HCV2, high volume rough surface.

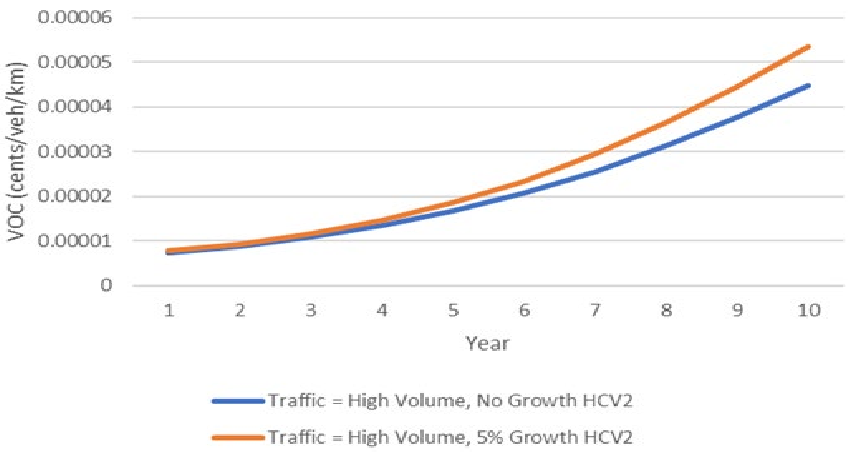

Figure 2-3: Effect of additional heavy vehicles: high traffic volume

While 5% was chosen as an appropriate increment for testing, further analysis to determine the sensitivity of the results to this choice is recommended (Section 4.2).

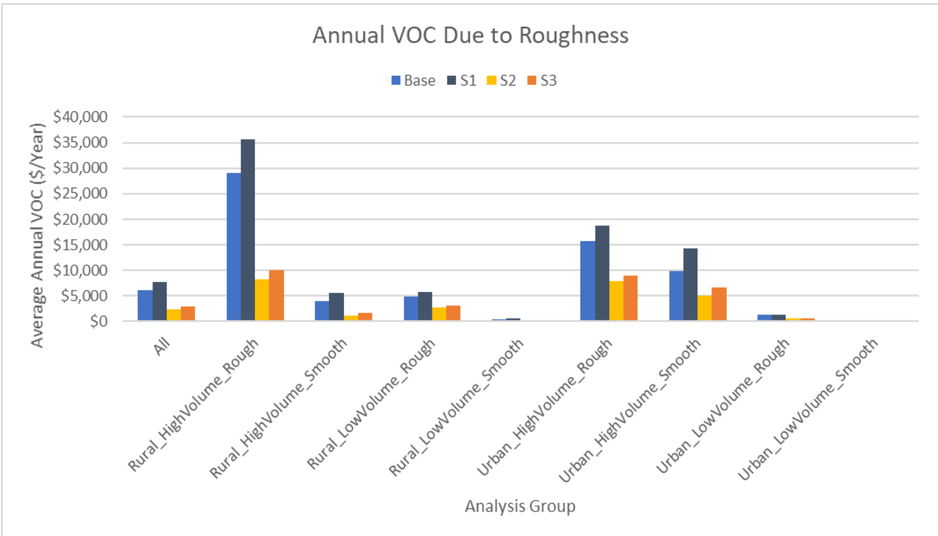

Figure 2-4: Total VOC due to roughness by road type (year 10)

Base, S1, S2, S3 as defined in Section 2.1.1.

Figure 2-4 below shows the average annual contribution to VOC due to roughness at year 10 of the analysis period for each scenario, in terms of absolute values. This shows that rough, rural and high volume roads have higher annual VOC, which is as expected given the relationship between these variables. Note that for roads with IRI < 2.5 the contribution of roughness to VOC is specified in MBCM to be zero.

The dTIMS model suite contains a vehicle operating cost module (based on the original HDM-4 model) that predicts changes in both vehicle operating costs and changes in travel time. While the vehicle operating cost module is universal in application and has been calibrated to reflect New Zealand conditions, use of the module to predict changes in travel times was considered but not pursued for the following reasons:

- HDM-4 was originally developed by the World Bank for use in developing countries,in the context of significant reductions in speeds due to poor maintenance e.g. when vehicles have to slow down to crawling speeds to avoid potholes. The model is relatively insensitive to the condition changes of the size contemplated in this study.
- The travel time model is significantly data-hungry and there is no data for the variables used in the model nor in the native databases in NZ because NZ roads are not as a rule allowed to deteriorate sufficiently for the effect on speeds to be measurable.

The analysis therefore did not include any estimate of the effect of road deterioration on vehicle speeds. This is a reasonable approach for small variations from existing conditions.

2.3.1.4 Analysis

Data from the individual road sections was aggregated into analysis groups by year and by scenario. As an example, Table 2.2 shows the data for the category Rural, High Volume Rough roads. The right-hand column calculates the additional VOC for all traffic in the year when the ESA increase occurred divided by the cumulative additional ESA-km.

Table 2.2 ESA-km and VOC for Rural High Volume Rough roads

Scenario:	Base	S1	Base	S1	Incremental
Variable	ESA	ESA	VOC	VOC	VOC per
	Sum	Sum	Sum	Sum	ESA
Year	ESA-km	ESA-km	$/Year	$/Year	$/km
1	221,450	221,450	1,286,728	1,286,728	
2	221,450	232,522	1,400,611	1,425,097	2.21
3	221,450	243,595	1,523,103	1,580,340	1.72
4	221,450	254,667	1,747,442	1,853,092	1.59
5	221,450	265,740	2,019,368	2,191,991	1.56
6	221,450	276,812	2,332,964	2,594,942	1.58
7	221,450	287,885	2,674,635	3,048,557	1.61
8	221,450	298,957	3,045,692	3,565,573	1.68
9	221,450	310,030	3,450,843	4,136,778	1.72
10	221,450	321,102	3,877,074	4,747,011	1.75

Source: consultant analysis

Base – no maintenance, no growth

S1 – no maintenance, 5%pa growth in HCV

Table 2.3 shows the incremental VOC per ESA for each year for all eight road categories.

Table 2.3: VOC – dollars per incremental ESA-km by road type

Year	Rural				Urban			
	High volume		Low volume		High volume		Low volume	
	Rough	Smooth	Rough	Smooth	Rough	Smooth	Rough	Smooth
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.21	0.20	3.19	0.22	1.95	0.47	3.19	0.15
3	1.72	0.19	2.26	0.20	1.47	0.62	2.45	0.13
4	1.59	0.23	1.84	0.19	1.19	0.80	2.09	0.12
5	1.56	0.29	1.60	0.20	1.31	0.99	1.85	0.12
6	1.58	0.39	1.46	0.21	1.28	1.24	1.56	0.13
7	1.61	0.53	1.36	0.23	1.21	1.41	1.47	0.14
8	1.68	0.68	1.31	0.25	1.24	1.57	1.41	0.14
9	1.72	0.85	1.27	0.28	1.22	1.72	1.36	0.15
10	1.75	1.02	1.22	0.30	1.22	1.85	1.21	0.16

Source: consultant analysis
Base – no maintenance, no growth
S1 – no maintenance, 5% growth in HCV

These results are shown graphically in Figure 2-5.There appears to be little difference in the cost progression between urban and rural road sections despite the difference in pavement type – rural roads being mostly chip seal while urban roads are primarily asphaltic concrete. Perhaps more surprising, there is also little difference based on traffic volume. This is presumably because high volume roads are typically designed for a longer ESA life and therefore additional ESA have a lesser impact on the VOC per vehicle – but this is multiplied by more vehicles.

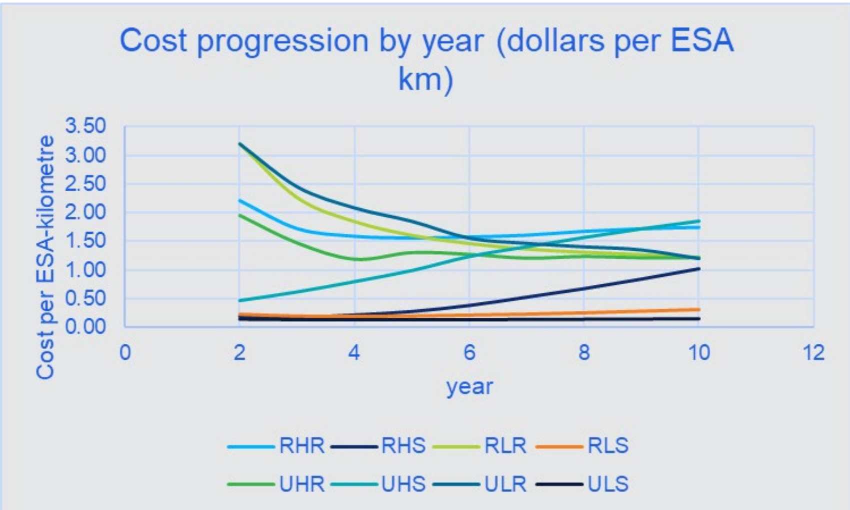

Figure 2-5: Cost progression by year by road category

The most significant difference in VOC per ESA is between roads that are smooth and roads that are rough.

This is most noticeable for the high volume-smooth roads (green and orange lines in Figure 2-5) because these roads transition from smooth to rough over the analysis period. They start in year 2 with a very low cost per ESA along with the other smooth roads, but over time, the number of sections that are rough increases and the ratio consequently also increases until in year 10 it is up with the rough roads.

In the analysis we excluded roads that had IRI < 2.5 in year 1. The reason for this is that the MBCM explicitly rules out VOC benefits for IRI <2.5. This is in line with standard engineering understanding – it means that for those roads, the effect of additional ESA is taken as zero.

2.3.1.4 Estimation of the Social Marginal Cost

The calculation above took the additional vehicle operating cost in each year and divided it by the accumulated additional ESA. This assumes that the effect of the additional ESA is cumulative. But it also means that the effect would continue even if the additional ESA were temporary. We therefore need to multiply the additional ESA by the length of time until the road condition is restored. This depends on the renewals policy of the road agency.

2.3.1.5 Estimation of Short Run Marginal Cost

Scenarios S2 and S3 correspond to the base scenario and scenario S1 discussed above but with condition-responsive maintenance sufficient to maintain the road in its current condition. Comparing S3 with S2 shows the additional maintenance costs required to restore the road's condition in the face of additional ESA – in other words it enables an estimate of the short run marginal cost (SRMC). Note that because there is a lag between the road wear and the remedial treatment, there is still an externality cost in addition to the additional maintenance cost.

The vehicle operating costs (VOC) in column four (S2 VOC) and column five (S3 VOC) fluctuate from year to year. This is because while the initial condition of all the roads in the sample is 'rough', and the overall trend will be for their condition to deteriorate, so the VOC would rise, some roads will be repaired during the ten-year period. As roads are repaired, the VOC on those roads will reduce.

Table 2.4: ESA-km and VOC for Rural High Volume Rough roads

Scenario:	S2	S3	S2	S3	Externality	Maintenance
Variable	ESA	ESA	VOC	VOC	VOC per	$ per
	Sum	Sum	Sum	Sum	ESA	ESA
Year	ESA-km	ESA-km	$/Year	$/Year	$/ESA-km	$/ESA-km
1	221,450	221,450	1,286,728	1,286,728		
2	221,450	232,522	1,313,492	1,335,839	2.02	0.00
3	221,450	243,595	1,000,993	1,041,704	1.23	0.00
4	221,450	254,667	1,121,813	1,195,262	1.11	0.00
5	221,450	265,740	1,170,610	1,280,084	0.99	0.00
6	221,450	276,812	1,104,444	1,238,664	0.81	0.95
7	221,450	287,885	1,014,344	1,152,761	0.60	2.81
8	221,450	298,957	999,554	1,171,498	0.55	-2.33
9	221,450	310,030	1,049,317	1,285,689	0.59	4.64
10	221,450	321,102	1,104,079	1,345,984	0.49	-4.26

Source: consultant estimates

S2= maintenance, no growth; S3 = maintenance, 5% growth

Table 2.4 shows (column 7) that for rural high-volume rough roads, the main effect of the extra ESA is to bring some maintenance costs forward by a year (the cost is higher in years 7 and 9 but lower in the following year). A similar effect is observable with all road categories. However, the average impact over 10 years is markedly different by road category. This can be seen in Table 2.5. Urban roads are more expensive to maintain, being generally wider and often constructed in asphalt concrete.

The externality costs (ie vehicle operating costs imposed on other users) are generally of the same pattern but lower than Table 2.3 which compares S1 with the base scenario (the no maintenance case).

Table 2.5: Additional cost (dollars per ESA-km)

	Maintenance		Externality	
Road category	rough	smooth	rough	smooth
Rural_High volume	0.20	0.48	0.93	0.25
Rural_Low volume	0.96	0.19	1.33	0.19
Urban_High volume	6.31	2.16	0.49	0.71
Urban_Low volume	6.54	2.39	1.12	0.14

Note: average costs over 10 years

2.3.2 Long run marginal costs

Whereas the SRMC measures the cost of repairing the road, the long run marginal cost (LRMC) is the cost of building a stronger road. There are diseconomies of scale in the short run – road wear being generally taken to increase with the fourth power of the axle load, so a 10% increase in axle load would increase road wear by 46% - but there are large economies of scale in the provision of road pavement life. Using equation (2) (section 2.1), it can be seen that an increase in pavement thickness of 12% is sufficient to cater for the 46% increase in ESA due to the increased axle load.

Because of the non-linear nature of the responses, the marginal cost depends on the current heavy traffic on the road. It also depends on whether the marginal demand is met by increasing the load on each truck or by increasing the number of trucks. The increase in pavement thickness that would be sufficient to cater for a 10% increase in truck numbers is 3% compared to the 12% above for an increase in axle load. The LRMC has been calculated by considering a 10% increase in the cumulative ESA in each of the road categories and then estimating the structural number (SN) required to provide a 10 year pavement life with and without additional ESA (SN and SN+ in Table 2.7)

Road rehabilitation costs for state highways and municipal roads[4] were used to estimate the additional cost resulting from the need to construct pavement with higher SN. Reconstruction costs are reported in dollars per square metre and vary considerably between local authorities. We assumed that the variation was in part due to differences in traffic levels and thus required pavement depth. Table 2.6 shows the estimated cost for road rehabilitation by the main road types. The assumed SN is the pavement strength that would be required, based on equation (2), to provide a ten-year life with a heavy traffic load equal to the average load for the sample. On this assumption, the rehabilitation cost per unit of strength (SN) is reasonably consistent at around $30,000 per kilometre per metre of width.

Table 2.6: Cost of renewals by road type

	width m	$/km	Assumed SN	cost/SN/km
Rural high	10	1,083,000	4.1	266,617
rural low	7.5	812,250	3.2	253,698
urban high	15	2,093,775	4.1	514,450
urban low	7.5	559,388	2.4	236,139

Source: Consultant estimate based on state highway and local authority data

Table 2.7 calculates the LRMC for each road type. The first four columns reproduce the average characteristics of the roads in the sample. Equation (2) is used to calculate the SN required to carry the cumulative standard axles (CESA). The next column (SN+ trucks) is the SN required to carry a 10% greater CESA due to more trucks. The LRMC is expressed as dollars per ESA. SN+ tons is the SN required if the extra ESA arise due to higher axle weights, The associated LRMC is expressed as dollars per ton. The marginal costs per ton are higher than the marginal cost per ESA by a factor of 4.2, the ratio arising due to the fourth power relationship between axle load and ESA.

[4] Based on unofficial data provided by Waka Kotahl and IDS

Table 2.7: Calculation of LRMC

Analysis Group	number	Average AADT	Length (km)	CESA	SN	SN+ trucks	LRMC/ ESA $	SN+ tons/axle	LRMC/ Ton $
Rural_HighVolume_Rough	486	5725	0.3	1.7	0.47	0.49	0.16	0.53	0.68
Rural_HighVolume_Smooth	1559	7736	0.4	2.4	0.53	0.54	0.13	0.59	0.53
Rural_LowVolume_Rough	608	924	0.4	0.3	0.29	0.29	0.71	0.32	2.95
Rural_LowVolume_Smooth	684	1179	0.5	0.4	0.31	0.32	0.56	0.35	2.34
Urban_HighVolume_Rough	650	7983	0.2	1.1	0.42	0.43	0.43	0.47	1.80
Urban_HighVolume_Smooth	456	11712	0.3	2.2	0.51	0.53	0.26	0.57	1.09
Urban_LowVolume_Rough	1825	452	0.1	0.0	0.16	0.17	3.66	0.18	15.27
Urban_LowVolume_Smooth	363	493	0.2	0.0	0.17	0.17	3.32	0.19	13.85

Source: consultant calculations

Chapter 3 Results, commentary and conclusions

3.1 Results and commentary

3.1.1 Social marginal cost

Possible responses to deterioration in the road surface due to wear range from doing nothing, through minor patching or reseals to full pavement reconstruction. The social marginal cost as defined in section 2.1.1 is calculated by estimating the additional cost incurred by all other road users resulting from a marginal increase in heavy vehicles in the absence of a response by the road agency. It is thus the externality due to road wear in the absence of any mitigation measures[5].

Table 2.3 showed the estimated increase in aggregate vehicle operating costs as a result of an increase in ESA in the year in which the increase in ESA occurred – ie the immediate impact. However, the increase in cost will continue until the road condition is reset by resurfacing or rehabilitation SMC therefor depends on the intervention policy adopted by the road agency. Current practice in New Zealand is for roads to be maintained to a high standard, so that we can assume a maximum of five years between resets or an average time of 2.5 years from the passage of the marginal ESA and the reset. Table 3.1 summarises Table 2.3 showing the increase per year without any road agency intervention averaged over 10 years.

Table 3.1: Social Marginal Cost (dollars per additional ESA-km) per year until reset

	Rough	Smooth
Rural_High Volume	1.71	0.49
Rural_Low Volume	1.72	0.23
Urban_High Volume	1.34	1.19
Urban_Low Volume	1.84	0.14

Source: consultant estimates

3.1.2 Short run marginal cost

The SRMC is usually defined as the additional road agency cost per additional ESA. Intervention by the road agency may take the form of additional patching or reseals or could involve bringing the date for major work forward. We used the same dTIMS application as used by most New Zealand road agencies to calculate the increase in road agency cost. dTIMS is designed to select the optimum intervention based on the road condition.

This is shown as the agency cost in Table 3.2 below. However, it is inevitable that the road will go for some time between interventions and thus that there will be some impact on other users between the time the wear is incurred and the repair takes place. Hence our definition (in section 2.1.1) includes this externality. This is shown in Table 3.2. Interpretation of the table would depend on the policy issue under consideration. In some instances (such as determining whether users as a whole pay the costs of providing the facility), only the restoration cost (i.e. agency cost) is of

[5] Other externalities are considered in separate papers.

relevance. However, for other questions such as the optimum time for intervention, the externality will need to be included in the consideration.

The agency costs in Table 3.2 imply an elasticity of maintenance costs with respect to ESA-km that varies from 0.01 for rural roads to 0.83 for urban high volume rough roads. The value for high volume smooth urban roads is 0.22. Although this value is close to the value found by Wheat (2017) for English local authorities (0.24), the value calculated by Wheat was the elasticity with respect to total traffic volume rather than ESA and therefore are not directly comparable.

Table 3.2: v Short Run Marginal Cost (dollars per ESA-km)

	Agency cost		Externality	
	Rough	Smooth	Rough	Smooth
Rural_High Volume	0.20	0.48	0.93	0.25
Rural_Low Volume	0.96	0.19	1.33	0.19
Urban_High Volume	6.31	2.16	0.49	0.71
Urban_Low Volume	6.54	2.39	1.12	0.14

Source: consultant estimates

3.1.3 Long run marginal cost

The long run marginal cost as defined in section 2.1.2 is the additional rehabilitation cost required to cater for an additional ESA-kilometre. There are significant returns to scale in pavement construction. One consequence of this is that the LRMC for high volume roads is much lower than for low volume roads (Table 3.3).

Table 3.3: Long Run Marginal Cost (dollars per ESA-km)

	Reconstruction cost	
	Rough	Smooth
Rural_HighVolume	0.16	0.13
Rural_lowVolume	0.71	0.56
Urban_HighVolume	0.43	0.26
Urban_LowVolume	3.66	3.32

Source: consultant estimates

3.1.4 Commentary

Comparison of the SRMC and the SMC is effectively comparing the cost with and without intervention, If we assume five years between pavement restoration – ie an average time to restoration of 2.5 years, then the SMC is 2.5 times the figures in Table 3.1 and are generally a lot higher than the SRMC. This implies that over any medium-term time horizon, conducting optimised maintenance minimises total costs to society.

Both the SMC and the SRMC are significantly lower for roads that are in smooth condition. The only exception is the restoration cost for rural high-volume roads where dTIMS predicts that early rehabilitation is warranted with or without additional ESA and the primary effect of the additional ESA is to bring the rehabilitation forward one year.

The LRMC are consistently lower than either the SMC or the SRMC. This implies that the cost to society is lowest if additional vehicles are catered for at the reconstruction stage.

A linear regression of the Road User Charges (including GST) for rigid 2 and 3 axle trucks against the ESA gives the equation

RUC ($/1000 km) = 122 + 99 * ESA r2 = 0.88I (3)

This is a charge of $0.086 per ESA-km (excluding GST)[6]. The short run marginal costs shown in Table 3.2 are all higher than the RUC per marginal ESA. They are closest for smooth high volume rural roads.

The result that smooth roads are cheaper to maintain, have lower externalities and have costs closer to the RUC charge appears to support the current maintenance strategies adopted by the road agencies.

3.2 Conclusions

New Zealand roads are generally kept to a high standard (ie low IRI): 28% of our sample have IRI less than 2.5, where according to MBCM, small changes in IRI have no effect on vehicle operating costs and thus the SMC is zero. Our analysis shows that the SMC and SRMC for smooth roads are generally significantly lower that for rough roads, while for rural roads, the SMC and SRMC are broadly of the same order. This appears to support (in broad terms) current maintenance standards.

The marginal costs are in all cases higher than the estimated RUC. This is particularly true for urban roads where heavy vehicles are a smaller proportion of the total traffic stream and have a disproportionate effect on the costs borne by other vehicles and on restoration costs.

Our analyses have applied dTIMS to a large (6,000 road links) sample of New Zealand roads, enabling us to draw some general conclusions that could inform both inter-modal and intra-modal discussions. However, both the response of pavements to axle load and the relationship between pavement life and pavement strength are highly non-linear, so the results for the eight categories of road studied depend heavily on the average of the road sections in the samples. Decisions relating to individual roads are always going to be best made by running dTIMS with that road's specific features.

[6] =99/1.15 dollars per 1000 km or $0.086 per km excluding gst.

Chapter 4 Limitations and future updates

4.1 Any limitations and exclusions

The MBCM sets the effect of roughness for roads with IRI <2.5 to zero. It is not clear from Figure 2-2 whether this is a genuine effect or a convenient approximation. For our analysis, we have assumed that it is that latter. Hence these roads were excluded. This resulted in overstating the value of the SMC calculated (by a factor of about 2), but not the overall conclusion that the marginal cost for smooth roads is significantly lower than that for rough roads.

As can be seen from Figure 2-5, even if the initial impact of heavy traffic on these roads is zero, over time the effect of the heavy traffic will be to increase roughness and eventually cause additional VOC and/or trigger road maintenance,

We also followed New Zealand practice of ignoring any impact on travel time. Again, this is a reasonable assumption provided we are only considering marginal changes from current conditions. If roads were to be left in a deteriorated condition for an extended length of time, the effect on vehicles speeds would become a consideration.

The non-linear nature of the responses to axle loading and pavement strength results in the calculated SMC, SRMC and LRMC taking a very wide range of values across the eight road types. It is possible to draw conclusions from comparisons between road types and between the three measures for each road type, but it would be difficult to draw conclusions for any inter-modal comparisons.

4.2 Potential areas for further work

The finding that the marginal cost for heavy vehicles exceeds the RUC suggests that the current method of setting RUC based on CAM may result in trucks bearing a lower proportion of road costs than the marginal costs they impose on the road system. (This would be less of an issue if CAM was changed to use a return on capital approach rather than the current PAYGO approach to setting recommended charge rates).

Leading on from the previous section, further work on the issue of roads with IRI <2.5 appears warranted: this would particularly be the case if a marginal cost approach (such as Ramsey pricing) were to be pursued to modify CAM for use in setting road user charges.

As noted above, the wide range in values of the measures makes cross-mode comparisons difficult. Further work is needed to develop measures that enable more meaningful comparisons.

Appendix 1 Bibliography

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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).

Domestic Transport Costs and Charges Study

Working Paper C1.1

Road Infrastructure – Marginal Cost

transport.govt.nz

ISBN 978-1-99-117849-7

Te Kāwanatanga o Aotearoa
New Zealand Government