TE MANATŪ WAKA
MINISTRY OF TRANSPORT

Domestic Transport Costs and Charges Study

Working Paper C8
Walking and Cycling

Prepared for Te Manatū Waka Ministry of Transport (NZ)
Veitch Lister Consulting Pty Ltd, 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.

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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	Definition
Census	*New Zealand Census 2018*
DTCC	*Domestic Transport Costs and Charges*
MBCM	*Monetised Benefits and Costs Manual,* NZ Transport Agency
HES	*Household Expenditure Statistics: Year ended June 2019 Stats NZ*
HTS	*Ministry of Transport Household Travel Survey 2015-18*
HUD	*Ministry of Housing and Urban Development*
MoT	*Ministry of Transport*
NZD	*New Zealand Dollar*
ROC	*Rough Order Costs*
TOF	*Transport Outcomes Framework*
VLC	*Veitch Lister Consulting Pty Ltd*
WP	*Working Paper*

Executive summary

Overview

The Domestic Transport Costs and Charges (DTCC) study is being undertaken for Te Manatū Waka Ministry of Transport by a consultant consortium headed by Ian Wallis Associates. The DTCC Study aims to identify all the costs imposed by the domestic transport system on the wider New Zealand economy including costs (financial and non-financial) and charges borne by the transport user. Outputs of the DTCC Study will improve our understanding of current economic costs and the extent to which these costs are covered by the charges paid by transport users. Robust information on transport costs and charges can, in turn, help inform policy settings, such as the Te Manatū Waka's Transport Outcomes Framework (TOF). This Working Paper (C8) has been prepared by Veitch Lister Consulting (VLC) and focuses on the direct costs of walking and cycling.

Walking and cycling have an essential role in New Zealand's transport system. And, like many other parts of the transport system considered in the DTCC study, walking and cycling are undergoing a period of rapid change—driven by a potent combination of emerging technologies, such as electric bicycles, and evolving policy. In their recent report, for example, the New Zealand Climate Commission recommended increasing per capita use of walking and cycling nationally by 25% and 95% respectively, to help reduce carbon emissions. For these reasons, we suggest the DTCC study presents a somewhat rare and relatively timely opportunity to investigate the costs of walking and cycling in a New Zealand context.

In terms of scope, we focus on the direct costs of walking and cycling to government and users: our scope covers infrastructure costs, cycle purchase and operations/maintenance costs and user travel time costs. We also provide an assessment of the health-related benefits of walking and cycling, drawing on work undertaken in other parts of the DTCC study.. Finally we note that our findings are most relevant to other DTCC WPs that consider other passenger transport, such as private vehicles and public transport.

Questions and Challenges

In this working paper, we set out to answer the following question: What are the direct costs of walking and cycling and how do these vary with location and situation? By direct costs, we are referring to infrastructure costs imposed on government, user time costs and, in the case of cycling, cycle purchase and operating costs incurred by users. To answer this question, we must overcome several challenges that stem mostly from the limitations of our data. Perhaps most notably, our data is "backwards looking". Our demand estimates, for example, being based on 2018/19 data, do not capture the most recent growth in cycling. Our analysis is also constrained by the lack of comprehensive spatial data on walking and cycling infrastructure. To resolve these challenges, we make several assumptions. Due to the uncertainty associated with these assumptions, we recommend readers interpret our results carefully and judiciously. Specifically, we recommend this WP is considered in conjunction with the associated cost model, with which readers can gain insight into the sensitivity of our results to these assumptions.

Our Approach

We assume the direct costs of walking and cycling comprise the sum of the following four components:

- *Land costs*, that is, the estimated cost of land within the road corridor that is exclusively used to accommodate walking and cycling infrastructure.
- *Capital costs*, that is, the estimated cost of constructing and maintaining walking and cycling infrastructure in the road corridor.
- *Operating costs,* that is, the cost of purchasing and operating bicycles.[1]
- *User time costs, that reflect the behavioural/economic value of time spent walking or cycling.*

To estimate land costs, we first assess the physical extent of the walking and cycling network. For cycling, this is relatively straightforward: Waka Kotahi publish data on the length of cycle lanes. Unfortunately, similar data does not exist for walking. Instead, we assume the length of footpaths is a function of the road network. Second, to estimate of the area of land used for walking and cycling infrastructure, we multiply network length by the assumed average width. Third, we multiply the land area of each network by land prices (per square metre).

To estimate capital costs, we assess the costs of existing infrastructure by multiplying the estimated length of the walking and cycling networks by rough order estimates (ROCs) per kilometre. We emphasise that our estimates of capital costs (1) reflect the cost of replacing existing infrastructure, rather than providing new infrastructure and (2) exclude the cost of land, which is considered separately as above. As such, our ROCs are typically much less than the costs of recent projects. Finally, to convert our estimates of capital costs into an annual flow measure we assume a cost of capital (4% p.a. in real terms) to which we add the costs for capital depreciation (or maintenance of the infrastructure facilities) for walking (2% p.a.) and cycling infrastructure (4% p.a.).

To estimate operating costs for cycling, we consider the annualised costs of bicycle purchase and maintenance, where we distinguish between conventional and electric bicycles to the extent allowed by our data. Bicycle purchase costs are derived from Statistics New Zealand “Household Expenditure Statistics” (HES) for the year ended June 2019: this data aligns broadly with Statistics New Zealand data on the quantities and costs of imported bicycles and e-bikes. We estimate maintenance costs for conventional bicycles by parsing information from a detailed case study. And for electric bicycles, based on industry engagement we estimate additional costs for electricity and maintenance.

To finish, we normalise, or standardise, our results per person trip and per person km using data from the MoT’s HTS.

Main Results

Costs to government

The table below summarises our estimates of the costs of existing walking and cycling infrastructure to government. We find direct economic costs to government total approximately

[1] We assume walking incurs zero user charges.

$1.5 billion, of which capital and land makes-up 16% and 84%, respectively. Approximately 89% of these costs are attributable to footpaths, with 96% of costs associated with urban areas E will incur economic resource costs to Government - total [million $ p.a.]

Location	Footpaths	Cycle paths	Total
Urban	$1,289.59	$151.41	$1,441.00
Rural	$43.00	$11.99	$54.99
Total	**$1,332.59**	**$163.41**	**$1,495.99**

In the following table, we use data on the uptake of walking and cycling from the HTS to standardise the economic resource costs to government. Specifically, we convert them into average costs per person trip and per person kilometre for walking vis-à-vis cycling in urban vis-à-vis rural areas.

Standardised economic resource costs to Government

Location	Data	Walk	Cycle
	Costs [$ m. p.a.]	$1,289.59	$151.41
	Trips [m. p.a.]	709.03	78.59
Urban	Distance [m. km p.a.]	617.83	271.71
	$ per trip	$1.82	$1.93
	$ per km	$2.09	$0.56
	Costs [$ m. p.a.]	$43.00	$11.99
	Trips [m. p.a.]	35.28	3.27
Rural	Distance [m. km p.a.]	37.64	17.53
	$ per trip	$1.22	$3.67
	$ per km	$1.14	$0.68

We estimate walking and cycling in urban areas costs on average $2.09 and $0.56 per person kilometre, respectively. In rural areas, we find lower costs for walking ($1.14 per km) but higher costs for cycling ($0.68 per km).

User operating costs

To these numbers, the following table adds our estimates of cycle operating costs, which comes to $0.30 per kilometre. Approximately two-thirds of this cost is attributable to the costs of bicycle purchase with the balance associated with bicycle maintenance.

Average direct economic costs per kilometre travelled

Location	Costs	Walk	Cycle
	Government	$2.09	$0.56
Urban	User	-	$0.30
	Total	$2.09	$0.86
	Government	$1.14	$0.68
Rural	User	-	$0.30
	Total	$1.14	$0.99

We assume ***marginal costs*** of walking are zero. For cycling, we assume marginal costs of cycling are defined by maintenance costs, which are approximately $0.13 per kilometre.

User time costs

Our assessment of travel time costs for walking and cycling is set out in appendix G. This assessment is based principally on HTS statistics for the annual amount of travel (person kms, person hrs) spent on walking/cycling, to which we have applied 'standard' values of time from the Waka Kotahi MBCM.

Based on our average value of time estimate ($11.92/hour), the total annual time costs are approximately $1800 million, comprising $1560 million for walking and $230 million for cycling.

Health benefits

Health benefits are a significant factor in many people's choice of walking and cycling relative to other (more sedentary) modes. Our assessment of health benefits to walkers/cyclists was based on the methodology developed for DTCC working paper D3: Health Impacts of Active Transport. We estimate that total annual health- related benefits (relative to other modes) amounted to about $2350 million, split $1900 million for walking, $460 million from cycling. This is a significant economic benefit associated with walking/cycling, which goes a long way to offset the longer travel times typically associated with walking and cycling compared to motorised modes.

Further comments on land valuation

Finally , we draw attention to an apparent pronounced discrepancy between the land values we use in our analysis of walking and cycling and those used in WP C2 "Valuation of Road Infrastructure". Specifically, our costing methodology leads to much higher estimates for the value of land occupied by the road corridor. To understand the sensitivity of our results to this discrepancy, we also consider an alternative scenario in which we discount our estimates of land values by 85%, which serves to broadly align them with the land values used in WP C2.

The table below summarises estimated costs to government of walking and cycling facilities in this scenario, which are lower than the original scenario—especially for walking and cycling in urban areas.

Location	Data	Walk	Cycle
Urban	Costs [$ m. p.a.]	$310.10	$67.84
	$ per trip	$0.44	$0.86
	$ per km	$0.50	$0.25
Rural	Costs [$ m. p.a.]	$38.76	$11.71
	$ per trip	$1.10	$3.58
	$ per km	$1.03	$0.67

Limitations and Further Work

We note several limitations of our approach that could be addressed in further work. In terms of costs, the lack of detailed information on the physical extent of walking and cycling infrastructure in New Zealand is a major barrier to more detailed and precise analysis. We suggest further work could seek to develop comprehensive and consistent spatial data on walking and cycling infrastructure, possibly by combining open-source OSM data with road asset information held by

Councils. A lack of clarity on the value of land used by the road corridor, of which walking and cycling infrastructure comprises one part, also introduces considerable uncertainty to our results. We recommend further work should consider applying consistent land valuation methodologies between the state highway and local road networks. Our preliminary analysis raises the prospect that the latter is significantly undervalued, which—if true—may have broad ramifications, for example for local government financing. Finally, we note that the HTS data we use will not capture recent growth in cycling, which may cause us to over-estimate the standardised unit costs of cycling. We suggest that any further work should address these data limitations.

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 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 are being prepared for each of the topic areas. The 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 Overview

This WP (C8) addresses walking and cycling, where we seek to answer the following research question: What are the direct economic costs of walking and cycling? By “direct”, we are specifically referring to infrastructure costs incurred by government and operating costs incurred by users. We define walking to include all travel by foot and with mobility aids, such as canes and wheelchairs, whereas cycling covers all human-powered vehicles with pedals, including electric bicycles with pedal-assist motors.

Like other parts of the transport system, walking and especially cycling is undergoing a period of rapid change. Perhaps most notably, improvements in battery technologies have enabled rapid growth in the uptake of electric bicycles (“e-bikes”). Data from Statistics New Zealand finds imports of electric bicycles to New Zealand grew by approximately 100% and 50% in 2018 and 2019, respectively.[2] If current growth persists, then the number of electric bicycles imported to New Zealand will, on their own, surpass imports of private vehicles. At the same time, central and local government policy settings have become more supportive of walking and cycling, recognising their potential contribution to various strategic objectives.[3] Together, technology and policy seems to be supporting rapid growth in cycle numbers, especially in larger cities.[4] And looking forward, policy settings may become even more favourable. In their recently released report, for example, the New Zealand Climate Commission recommends increasing per capita use of walking and cycling nationally by 25% and 95%, respectively.

Our research into walking and cycling takes place against this backdrop of rapid change. While interesting, rapid change also presents problems for our analysis. Most fundamentally, the DTCC study is backwards-looking, in the sense we seek to understand the costs of walking and cycling as they were in the past (specifically, the 2018/19 financial year). In doing so, much of our data on usage is drawn from the MoT’s Household Travel Survey (HTS), which spans 2015—2018. For these reasons, our analysis is likely to under-estimate the current uptake of these modes, especially of cycling.

The following chapters of this WP are structured as follows: Chapter 2 summarises our methodology, Chapter 3 presents the results of our analysis, and Chapter 4 discusses limitations and further work. Appendices to this WP provide additional clarifying information.

[2] www.stuff.co.nz/dominion-post/wellington/121625298/number-of-ebike-imports-hits-record-high-could-soon-overtake-new-cars

[3] www.transport.govt.nz//assets/Uploads/Paper/GPS2021.pdf

[4] For Auckland, refer to https://at.govt.nz/media/1977266/tra_at_activemodes_publicrelease-1.pdf. For Wellington, refer to https://wellington.govt.nz/-/media/parking-roads-and-transport/parking-and-roads/cycling/files/cycleways-master-plan-103052.pdf.

Chapter 2 Methodology

2.1 Research Question

The following chapters of this WP set out to answer the following research question: What are the direct economic costs of walking and cycling and how do these costs vary with location? By “direct”, we mean (1) infrastructure capital and operating/maintenance costs incurred by government and (2) operating costs incurred by users.

2.2 Challenges to our Analysis

Table 1 summarises the main elements and associated challenges for our analysis.

Table 1: Summary of elements and challenges

Element	Chapter	Challenges
Capital costs	3.2.1	To estimate the cost of existing walking and cycling infrastructure, we adopt ROC. In practice, the value of capital assets will (1) vary depending on context and (2) differ from the costs of expanding infrastructure (NB: The latter is typically much more expensive).
Land costs	3.2.2	To estimate the cost of land used for walking and cycling infrastructure, we consider land prices for adjoining properties. The resulting prices are much higher than those used in DTCC WP C2 “Valuing Road Infrastructure”. To resolve this discrepancy, we consider a scenario with lower land prices.
Network	3.2.4	To estimate the physical extent of the walking network, we use OSM data to estimate the length of the road network in urban and rural areas. We make several assumptions to estimate the physical extent (length and width) of walking infrastructure as a function of road network length.
Uptake	3.5	We use the MoT’s HTS to estimate uptake of walking and cycling. The HTS is likely to under-estimate uptake for two reasons. First, surveys typically undercount short walking trips. Second, rapid growth means cycling uptake is likely higher now than at the time of the HTS.

2.3 Data and General Assumptions

The following three data sources play a key role in our estimates of walking and cycling costs:

- *OSM data on the transport network in New Zealand*, which details the locations of transport infrastructure in New Zealand;
- *The Ministry of Housing and Urban Development (“HUD”) rateable land values 2018-19*, from which we derive estimates of land values in each location; and[5]
- *The Ministry of Transport Household Travel Survey 2017-18 (“HTS”)*, from which we derive estimates of travel demands in each location.

Where practicable, we adopt the same structure and assumptions as in other parts of the DTCC study. A key difference, however, is we assume walking and cycling are both non-congestible. In practice, this means costs are detached from levels of usage, which seems reasonable in most cases.

Unless otherwise noted, the analysis in in this paper is based on the following assumptions:

[5] HUD supplied information on rateable land values at the level of SA2s. We are, however, unable to publish values at these levels of granularity. Hence, we present average land values for urban and rural areas in each region.

- *Base price period.* All prices are expressed in NZD 2018/19 (i.e. prices typical of or averaged over the 12 months ending 30 June 19).
- *Pricing in real terms.* All prices are expressed in constant real dollar terms, i.e. excluding any inflationary components.
- *Taxes and duties.* Our estimates of economic costs exclude taxes or duties from the prices of goods and services.
- *Cost of capital / discount rate.* For infrastructure, the cost of capital equals the 4% p.a.(real) discount rate used in Waka Kotahi's Economic Evaluation Manual ("EEM"). For private purchase of bicycles, we assume the cost of capital equals 8% p.a. real.
- *Capital depreciation.* We assume capital inputs into walking and cycling infrastructure depreciate at 2% and 4% p.a., respectively, whereas bicycles depreciate at 15% p.a. Like other parts of the DTCC study, we assume land does not depreciate.

Costs are defined to include capital charges for land and infrastructure, as well as operating costs—such as bicycle purchase and maintenance costs—for users. We assume walking incurs no operating costs.

2.4 Segmentation

We present separate estimates of average costs for walking and cycling, which we break down further by urban and rural areas. For the latter, we adopt Statistics New Zealand's definitions of urban and rural areas. Walking has zero marginal costs, as it is assumed to incur zero operating costs and infrastructure is non-congestible. For cycling, in contrast, marginal costs are defined by cycle maintenance costs.

Chapter 3 Analyses and Results

3.1 Overview

We estimate the direct economic costs of walking and cycling in this chapter, in four main steps, as follows:

Chapter 3.2. Estimation of capital costs for walking and cycling infrastructure (incurred by the public sector), in two sub-sections (i) the extent of supply (route km) of walking and cycling infrastructure; and (ii) typical unit land and infrastructure costs for infrastructure supply. Multiplication of these two sets of estimates (with appropriate annualisation) provides estimates for the total economic cost of walking and cycling to government.

Chapter 3.3. Estimation of unit capital/operating/maintenance costs for bicycles, to derive total annualised costs for bicycle owners/users: the corresponding costs for walkers are taken as zero (ignoring the very small costs for shoe leather etc)

Chapter 3.4. Travel time costs for walking and cycling, based on typical average speeds and 'standard' values of travel time used in economic appraisal (MBCM).

Chapter 3.5. Health benefits associated with walking/cycling (relative to sedentary modes). These benefits primarily accrue to those people who walk/cycle, through their improved health and fitness. A small component of these benefits accrues as cost savings to the health sector. H,

Notwithstanding the intuition underpinning our approach, all three steps are somewhat complex. In the first step, complexity is introduced by the need to capture variation in unit costs, specifically land prices, between urban and rural locations. In the second step, complexity is introduced by the lack of comprehensive and consistent information on the extent of the walking and cycling network. And in the third and final step, complexity is introduced by somewhat limited data. Due to this complexity, we note that relatively high levels of uncertainty are attached to our estimates.

3.2 Walking and cycling infrastructure - capital costs

In the first step of our analysis, we estimate unit costs based on the value of the resources used to provide walking and cycling infrastructure. We consider two cost components, namely: (1) infrastructure *capital* costs and (2) *land costs*. Infrastructure costs are assumed the same in all locations whereas land costs vary between locations. We emphasise that these unit costs are designed to capture the average cost of existing walking and cycling infrastructure. That is, our unit costs are not designed to reflect the costs of expanding existing infrastructure, especially where such expansions involve retrofitting existing road corridors. We expect the latter to incur significantly higher costs than we adopt here. In the following sub-chapter, we estimate each cost component and then present total unit costs for urban and rural locations.

3.2.1 Infrastructure costs

We worked with ViaStrada—who also contributed to the DTCC study—to develop the following ROCs for walking and cycling infrastructure:

- *Footpaths* are costed at $53 per sqm in both urban and rural areas, which covers installed material costs for a concrete path (NB: Use of bitumen will likely incur lower costs).

Assuming an average footpath width of 1.2m, we estimate an average installed cost of $63,600 per km.[6]

- *Cycleways* are assumed to be split 50:50 between unidirectional on-road and separated cycleways, which are estimated to cost $105,000/km and $438,700/km, respectively, yielding an average ROC of $271,850 per km.

These ROCs seek to capture average capital costs, which can vary between locations depending on geographical and physical constraints. We emphasise again these ROCs represent the average cost of constructing existing walking and cycling infrastructure. We expect these ROCs will be lower than costs associated with new walking and cycling projects for two main reasons: First, efforts to expand the existing network often involve retrofitting walking and cycling infrastructure to existing corridors, which can be expensive; and second, these ROCs exclude the cost of land, which we quantify separately in the section below. On average, we find land accounts for approximately 84% of total unit costs.

To annualise these capital costs, we assume a cost of capital of 4% p.a. real (as adopted throughout DTCC and consistent with Waka Kotahi's MBCM). To account for capital depreciation and/or maintenance, we assume rates of 2% p.a. and 4% p.a. of capital values for walking and cycling infrastructure, respectively. These depreciation rates imply walking and cycling facilities require complete renewal every 50- and 25-years, respectively. Table 2 summarises the capital costs for footpaths and cycle paths that result from these assumptions. On this basis, we find annual capital costs of $3,816 and $21,748 per km p.a. for footpaths and cycle paths, respectively.

Table 2: Capital costs for footpaths and cycle paths

Capital costs	Footpaths	Cycle paths
ROCs [$ per km]	$63,600	$271,850
Cost annualisation	6.0%	8.0%
Capital cost [$ per km p.a.]	$3,816	$21,748

3.2.2 Land costs

Land prices are estimated using data from HUD, which aggregates the rateable value of land for all properties (residential and commercial) at the SA2 level. Using this data, we estimate average land prices (2018/19) of $10.44/sqm and $673.06/sqm in rural and urban areas, respectively. We convert this price into a land cost per km of infrastructure, assuming average widths of 1.2m and 1.5m for footpaths and cycle paths, respectively. To finish, we assume a capital cost of 4% p.a. to arrive at an annualised cost measure (NB: We assume land does not depreciate). Table 3 summarises resulting land costs per kilometre for footpaths and cycle paths in urban and rural areas.

[6] Footpaths in older suburban areas will often be only 1m wide, whereas footpaths in newer and / or more central areas tend to be wider. In the absence of more detailed data, we consider 1.2m to be a reasonable average.

Table 3: Urban and rural land values

Location	Price	Land cost per km		Land cost per km p.a.	
	[$ per sqm]	Footpaths	Cycle paths	Footpaths	Cycle paths
Urban	$673.06	$807,672	$1,009,590	$32,307	$40,384
Rural	$10.44	$12,528	$15,660	$501	$626

3.2.3 Unit costs

Table 4 summarises total unit costs for footpaths and cycle paths in urban and rural areas, which are simply the sum of the relevant infrastructure and land costs presented in Chapters 3.2.1 and 3.2.2, respectively.

Table 4: Unit costs for footpaths and cycle paths

Location	Unit costs [$ p.a. per km]	
	Footpaths	Cycle paths
Urban	$36,123	$62,132
Rural	$4,317	$22,374

3.2.4 Infrastructure Supply

We now estimate the supply of walking and cycling infrastructure. For the latter, we use Waka Kotahi's estimates for the length of cycleways in 2018/19, which reports urban (2,437km) and rural (536km).[7] For walking, we have no reliable data and instead estimate network length using OSM data as follows:[8]

- First, we estimate a total road network length of 120,000km, which is split approximately 83% and 17% between rural and urban locations, respectively; and
- Second, we estimate the length of the pedestrian network by multiplying:
  - The urban road network length by 1.75;[9] and
  - The rural road network length by 0.10.[10]

Table 5 summarises our estimates of the supply of footpaths and cycle infrastructure.

Table 5: Length of footpath and cycle networks [all distances in kilometres]

Location	Footpaths	Cycle paths
Urban	35,700	2,437
Rural	9,960	536

[7] www.nzta.govt.nz/planning-and-investment/learning-and-resources/transport-data/data-and-tools/

[8] https://wiki.openstreetmap.org/wiki/Downloading data

[9] We note our estimate of road network length includes state highways, which rarely provide footpaths.

[10] This draws on reported numbers from Ashburton Council, which we assume are typical for rural areas.

3.3 User Operational Costs (Cycling)

Operational costs of cycling include the costs of bicycle purchase and maintenance. To understand bicycle purchase costs, we can draw on two independent sources of administrative data:

- Statistics New Zealand's Household Expenditure Statistics (HES) for June 2019 indicates the average household spends $1.20 per week on the "Purchase of bicycles" (sampling error 26.4%), or $62.40 per household p.a. From the HTS, we estimate 0.75 bicycles per household, which implies the average household spends $62.40 / 0.75 = $83.20 per bicycle p.a.
- Statistics New Zealand's publishes data on the quantities and prices of imported bicycles. From 2017 to 2019, we estimate an average imported price of $342 and $1,169 for bicycles and electric bicycles, respectively. If we apply a 40% mark-up, then we find average prices for distributed bicycles and electric bicycles of $479 and $1,637, or a volume-weighted price of $617 per bicycle.[11] Assuming 10% p.a. depreciation yields an annual cost of $61.70 per bicycle p.a.

Promisingly, both the HES data and administrative data lead to broadly similar estimates, especially when considering the sampling error associated with the former. In terms of bicycle maintenance costs, the best local data we find comes by way of a detailed case study, which we detail below.[12]

Case study: Bicycle maintenance costs

The Cycle Action Network (CAN) website documents a case study of bicycle operating costs. For the ten-year period starting in 1996, John maintained detailed records of all bicycle repairs and associated expenses incurred in cycling 100,000km on the same bicycle. Most repairs were undertaken by himself and involved purchasing various materials, including a new frame, derailleurs, bottom brackets, pedals, chains, clusters and chainrings, and 16 tyres. In total, John spent $4,168 on repairs in this ten-year period. We note that maintenance costs appear proportional to the distance travelled: $1,100 $1,014, $1,036, and $1,018 for each consecutive 25,000 km travelled. Using this data, we can estimate maintenance costs of 4.17 cents/km (NB: This excludes bicycle purchase costs). To these costs we allow for the cost of time spent on repairs, which we estimate adds 100% to the maintenance costs. Finally, these figures relate to the ten-year period from 1996 to 2005, with a mid-point of 2001. Inflation indices from the Reserve Bank for the

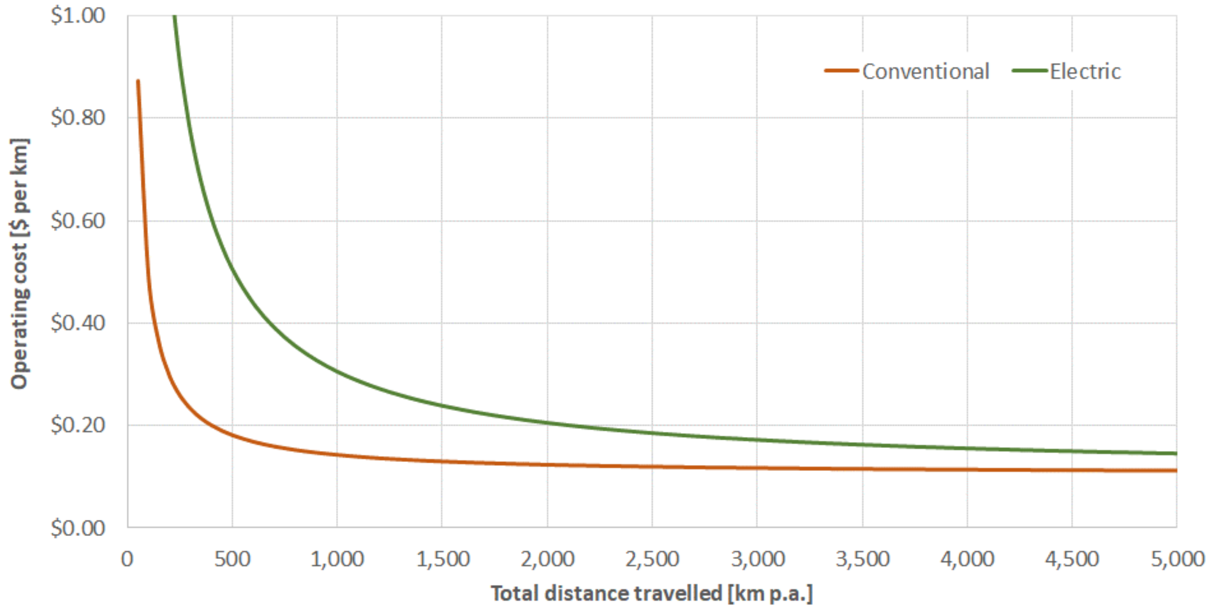
We assume electric bicycles incur additional maintenance costs of $1,000 during their lifetime to cover battery replacement and additional servicing. Electric bicycles also consumer electricity. Though usage depends on the level of power assistance used by the rider, our industry engagement suggests average electricity consumption of 12 Wh/km. Assuming an average cost of 30 c/kWh for electricity, this equates to an additional 0.36 c/km travelled, which brings the total operating costs of electric bicycles per kilometre to 13.74 c/km, compared to the 13.38 c/km calculated for conventional bicycles.

[11] While this may seem high, we note many conventional bicycles and e-bikes may be imported as (key) components that subsequently need to be assembled, if not also tested.

[12] Sourced from can.org.nz/article/bicycle-running-costs

Using these assumptions, Figure 1 plots average operating costs (that is, total purchase and maintenance costs) for bicycles and electric bicycles versus annual distance cycled p.a. Total operating costs per kilometre decline sharply with distance travelled p.a., reaching a lower limit around $0.11-$0.16 per kilometre, respectively, when travelling more than 3,500 km p.a.

Figure 1: Operating costs for bicycles and e-bikes versus annual distance travelled



In Appendix D, we use data from the HTS to estimate the average distance travelled per bicycle, which we find to be 219km p.a. [13] This in turn implies an average cost of $0.31 and $1.19 per km for conventional and electric bicycles, respectively. Evidence suggests, however, people who buy electric bicycles travel considerably further than those that use conventional bicycles. Indeed, recent research found people who switch to e-bikes from a conventional bicycle increase the distance they cycle by a factor of three (Fyhri and Sundfør, 2020). More recent versions of the HTS are now asking questions on the use of electric bicycles, although this data is not yet available. In the absence of this data, we must rely on other sources and assumptions. If we assume the factor of three differential applies to the average distance travelled per electric vis-à-vis conventional bicycles, and we assume the latter make-up $s_c = 97\%$ of the total bicycle fleet[14], then we can use the average distance travelled per bicycle (219km p.a.) to estimate the average distance travelled per conventional bicycle, D, as follows:

$$3D(1 - s_c) + Ds_c = 219 \Rightarrow D = 206\ km\ p.a.$$

Using the estimate for D, we can then estimate the average distance travelled per electric bicycle at 619 km p.a. (that is, 3x206). With these figures in hand, we can now estimate average operating costs of $0.29 per km and $0.43 per km for the average conventional bicycle and e-bike,

[13] This figure includes all travel undertaken by walking and cycling regardless of the trip purpose. We note people often use formal walking and cycling infrastructure for recreational purposes, that is, infrastructure serves all trip purposes. And, in the case of cycling, we suggest people consider all trip purposes—whether recreational or otherwise—when making decisions about bicycle purchase and maintenance. For this reason, we include recreational travel (both on- and off-road) in our estimates of usage.

[14] The import data from Statistics New Zealand suggests e-bikes represent 12% of total bicycles imported in the period 2017-19. Our assumption that e-bikes make up 3% of all bicycles is likely to be revised upwards over time.

respectively. To finish, we use our earlier assumption on the composition of the bicycle fleet to arrive at a fleet-weighted average operating cost of $0.30 per km cycled. Applying the same calculation to maintenance costs, that is, excluding purchase costs, implies composite marginal operating costs of $0.13 per km. The cost model associated with this report presents further details on our estimates of cycle operating costs.

3.4 User time costs

Our assessment of travel time costs for walking and cycling is set out in appendix G. This is based principally on HTS estimates for the annual amount of travel (person km, person hr) spent in walking/cycling, to which we have applied 'standard' values of time from MBCM.

Based on our estimate of the average value of time of $11.92/hour for both walking and cycling ,the total annual costs are approximately $1800 million, comprising $1560 million for walking, $230 million for cycling.

3.5 User health benefits

Health benefits are a significant factor in many people's choice of walking and cycling relative to other (more sedentary) modes. Appendix F applies the methodology developed in the DTCC working paper D3: Health Impacts of Active Transport to estimate the annual health benefits (to walkers/cyclists and to the health system) from walking/cycling relative to travel by other (more sedentary) modes. It finds a total annual benefit of some $2350 million, split about $1900 million from walking, $460 million from cycling.

3.6 Summary of Economic Costs

Table 6 presents our estimates of the economic resource costs to government, which draws on our earlier estimates of unit costs (c.f. Table 4) and infrastructure supply (c.f. Table 5). We estimate the total direct costs to government from providing walking and cycling infrastructure are $1,496 m p.a.

Table 6: Economic resource costs to Government [million $ p.a.]

Location	Footpaths	Cycle paths	Total
Urban	$1,289.59	$151.41	$1,441.00
Rural	$43.00	$11.99	$54.99
Total	$1,332.59	$163.41	**$1,495.99**

Table 7 uses data on usage of walking and cycling from the HTS to standardise economic costs per trip and kilometre travelled for urban vis-à-vis rural and walking vis-à-vis cycling.

Table 7: Standardised economic costs to Government

Location	Data	Walk	Cycle
Urban	Costs [$ m. p.a.]	$1,289.59	$151.41
	Trips [m. p.a.]	709.03	78.59
	Distance [m. km p.a.]	617.83	271.71
	$ per trip	$1.82	$1.93
	$ per km	$2.09	$0.56
Rural	Costs [$ m. p.a.]	$43.00	$11.99
	Trips [m. p.a.]	35.28	3.27
	Distance [m. km p.a.]	37.64	17.53
	$ per trip	$1.22	$3.67
	$ per km	$1.14	$0.68

Table 8 combines the standardised economic resource costs to government presented in Table 7 with our estimated average operating costs of cycling.

Table 8: Average direct economic costs (excluding travel time) per kilometre travelled

Location	Costs	Walk	Cycle
Urban	Government	$2.09	$0.56
	Private	-	$0.30
	Total	$2.09	$0.86
Rural	Government	$1.14	$0.68
	Private	-	$0.30
	Total	$1.14	$0.99

In terms of **marginal costs**, walking has zero marginal cost, as it is both non-congestible and comes with minimal operating costs. While cycling is also non-congestible, it incurs non-zero operating costs. As per Chapter 3.3, we estimate average (and marginal) cycle maintenance costs of $0.13 per km.

Sensitivity testing – land values

To finish, we observe a discrepancy between the approach we use to value land in Chapter 3.2.2 and that used in another part of the DTCC study, namely WP C2 “Valuation of Road Infrastructure”. We explore this discrepancy in more detail in Appendix E: the .2 Oshot of this discussion is our estimated value of land used for walking and cycling (c.f. Chapter 3.2.2) is significantly higher than that implied by the estimated value of land for the road corridor (c.f. WP C2). To understand the effects of this discrepancy, we considered an alternative scenario where land used for walking and cycling is valued at an 85% discount to the value of land calculated in Chapter 3.2.2. Applying this discount serves to bring the price of land we use here broadly into alignment with that used in WP C2. Average direct economic costs resulting from this scenario are presented in Table 9.

Table 9: Standardised economic costs to Government – low land value scenario

Location	Data	Walk	Cycle
Urban	Costs [$ m. p.a.]	$310.10	$67.84
	Trips [m. p.a.]	709.03	78.59
	Distance [m. km p.a.]	617.83	271.71
	$ per trip	$0.44	$0.86
	$ per km	$0.50	$0.25
Rural	Costs [$ m. p.a.]	$38.76	$11.71
	Trips [m. p.a.]	35.28	3.27
	Distance [m. km p.a.]	37.64	17.53
	$ per trip	$1.10	$3.58
	$ per km	$1.03	$0.67

Compared to Table 7, we find much lower per kilometre cost rates in Table 9, especially for urban walking (-76%) and cycling (-55%). We also note—when using the lower land values—the relative costs of walking and cycling in urban areas are lower than those for rural areas. These estimates indicate that the price of land used to value walking and cycling infrastructure is somewhat critical to the results. Given the uncertainty attached to the price of land used for transport purposes, we suggest it should be a focus of future research. Appendix E briefly discusses some interesting questions that arise when seeking to value land used for transport. On balance, we consider that a strict application of the "over-the-fence" methodology, as we use in Chapter 3.2.2, seems likely to over-estimate the value of land used for transport purposes.

Chapter 4 Limitations and future updates

We note several primary limitations of our analysis that can inform future updates. In terms of costs, the lack of detailed information on the physical extent of walking and cycling infrastructure in New Zealand seems to be a major barrier to more detailed analysis. We suggest further work could seek to develop and make available more comprehensive and consistent spatial data on walking and cycling infrastructure, possibly by combining open-source OSM data with the road asset information held by Councils. When considering land costs, moreover, there seems to exist a lack of clarity on the value of land occupied by the road corridor, of which walking and cycling infrastructure comprises one part. We recommend further work look to use consistent methodologies for valuing the land used for transport purposes. Our preliminary analysis highlights the potential risk that the land occupied by the local road network is being significantly undervalued by local councils, which—if true—may have broader economic and financial ramifications, for example for local government financing. The question of how to value land used for transport purposes is, in our view, not necessarily straightforward and requires answers to difficult questions, such as the endogeneity that exists the value of land and the transport network. Finally, we caution again that the HTS data we use will not capture recent growth in cycling, such as that resulting from the surge in electric bicycles, which may cause us to over-estimate the standardised costs of cycling. Obviously, addressing this limitation requires more recent HTS data becoming available. In general, we suggest future updates focus on addressing these basic data limitations.

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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 : Usage data

A3.1 Mode share

We source usage data on walking and cycling from the MoT's HTS between 2015 and 2018. The share of trips and kilometres travelled by several different modes are summarised in Table 10, for all trip types. We find walking accounts for 11.8% of total trips and 1.3% of total kilometres and cycling for 1.3% of trips and 0.6% of kilometres. These results indicate that walking (particularly) and cycling are primarily associated with shorter than average trips.

Table 10: Mode share by trips and distance travelled (Source: HTS)

Mode	Trips [%]	KMs [%]
Cycle	1.29%	0.59%
Walk	11.84%	1.30%
Public transport	2.52%	3.20%
Motor vehicle	83.76%	91.58%
Other	0.59%	3.34%

The data in Table 10 is expanded in Table 11, where we disaggregate current walking and cycling trips and kilometres between urban and rural areas. This disaggregation is based on the definitions of urban and rural mesh-blocks published by Statistics New Zealand. We then assign walking and cycling trips recorded in the HTS to urban and rural areas based on the mesh-block where trips originate. On this basis, we find the average walking and cycling trip is approximately 0.88km and 3.53km, respectively, with longer average trip distances found in rural vis-à-vis urban areas.

Table 11: Walking and cycling travel demands

Context	Mode	Trips [m p.a.]	Distance [mkm p.a.]	Avg trip [km / trip]
Rural	Cycle	3.269	17.5	5.364
	Walk	35.276	37.6	1.067
	Total	38.545	55.2	1.431
Urban	Cycle	78.588	271.7	3.457
	Walk	709.034	617.8	0.871
	Total	787.622	889.5	1.129
Overall	Cycle	81.857	289.2	3.534
	Walk	744.310	655.5	0.881
	Total	826	944.7	1.143

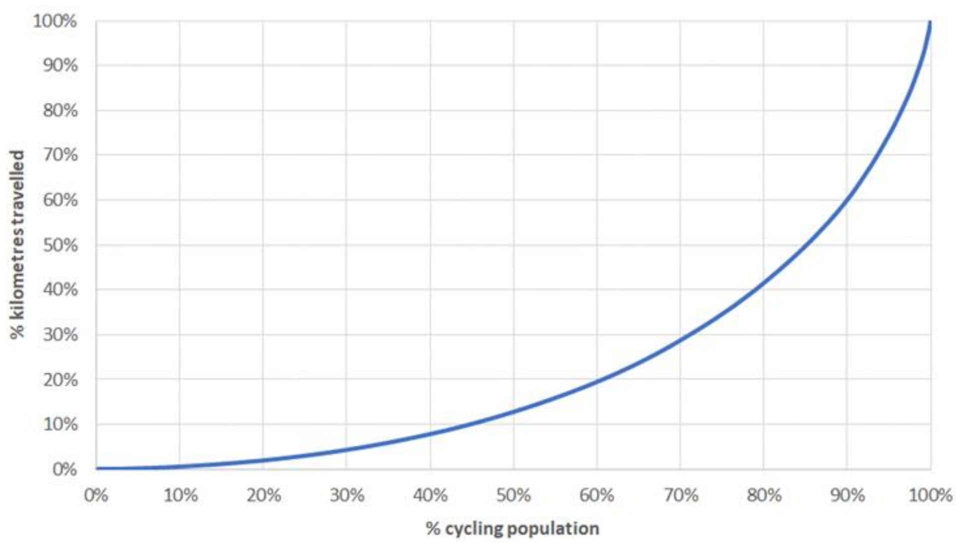
Overall, urban areas in New Zealand account for approximately 94% of the total distance travelled by active modes, which is greater than their share of the population. These results suggest the demand for walking and cycling is higher (relative to the populations involved) in urban parts of New Zealand, which likely reflects the effects of land use density on distances between destinations. While walking and cycling make-up a modest amount of overall travel, their proportionate contribution to meeting overall travel demands is greater in urban areas.

A3.2 Bicycle stocks and demand distribution

Using the HTS, we estimate there are approximately 1.3 million working bicycles in New Zealand, which equates to an average of approximately 0.26 per capita or 0.75 per household. If we assume the average bicycle has a lifetime of 10-years, then maintaining current stocks would require the addition of 130,000 bicycles p.a. Moreover, to hold the number of bicycles per capita constant in an environment of 1.9% population growth p.a. requires an additional 30,000 bicycles per annum. Together, the effects of bicycle turnover and population growth suggests approximately 160,000 bicycles need to be manufactured or imported into New Zealand every year to maintain current bicycle stocks per capita. Data from Statistics New Zealand, however, indicates approximately 285,000 bicycles p.a. were imported into New Zealand during the three years from 2017 to 2019, of which 13.5% were electric “e-bikes” (NB: We do not have data on the number of bicycles manufactured in New Zealand). On this basis, current growth in New Zealand’s bicycle stocks appears to be running higher than the level required to both maintain current stocks and meet population growth. That is, levels of bicycle ownership in New Zealand appear to be increasing, aligned with the growth in usage. We can combine information on the total number of bicycles with total distance cycled to estimate average distance cycled per bicycle: 289,242,319 km / 1,322,015 bicycles ~= 219km per bicycle p.a..

We can also use the HTS to understand the distribution of the demand for cycling. For HTS respondents that report at least one cycle trip during the survey period. Figure 2 illustrates the percentage of kilometres travelled (vertical axis) versus the percentage of the population who cycle (horizontal axis). To construct Figure 2, we order the population from the shortest to longest distance cycled per person across all cycling trips. The curve in Figure 2 thus captures relative inequality in the distances cycled among the cycling population.

Figure 2: Distribution of the demand for cycling -- % cycling population versus % kilometres travelled



In a hypothetical situation where all those who cycled reported the same total distance travelled, Figure 2 would show a perfectly straight line emanating from the origin at a 45-degree angle (NB: This presentation is commonly used to illustrate income inequality). Figure 2 reveals that a small proportion of those people who cycle account for a large proportion of the total distance people report cycling. Specifically, 20% of people who cycle the most account for approximately 60% of total kilometres cycled. We expect many people in this 20% cycle regularly for both *transport* and *recreational* purposes, whereas many of the remaining 80% cycle only irregularly—for example on weekends and/or while on holiday. This highlights an important point: Most of our analysis uses overall averages, which are a convenient simplification of what appears to be relatively heterogeneous travel demand profiles.

Appendix 4 : Land Values

*[**Note:** This appendix should be treated as a draft only, pending feedback from our peer reviewers. The outcomes of this feedback may potentially result in: (i) changes in the land values and overall results in this paper; and (ii) changes in the land values and results in WP C2 'Valuation of Road Infrastructure'. They may also highlight the need for future work to be undertaken on a wider review of the basis for valuation of land used for the state highway and local road networks.]*

A4.1 Discrepancies in land values

In the course of our work, we identified a discrepancy between our analysis of land values for walking and cycling (WC) vis-à-vis another DTCC working paper, namely WP C2 "Valuation of Road Infrastructure". In the latter, the value of land used for the road network is estimated to be $33.4 billion, which comprises $13.7 billion and $19.7 billion for the state highway and local road networks, respectively.

We can, however, also use the method from Chapter 3.2.2 of this WP to estimate the value of land used for the road network. In Table 12, we summarise the results of such an analysis, where we estimate the value of land under a range of different assumptions for the average width of the road corridor.

Table 12: Comparing our estimate value of land for walking and cycling vis-à-vis the road network

Location	Land price [$ per sqm]	WC network [m. $]	Road network [km]	Road network (various average corridor widths) [m. $]				
				15	20	25	30	35
Urban	$673.06	$31,294	20,400	$205,956	$274,608	$343,261	$411,913	$480,565
Rural	$10.44	$133	99,600	$15,597	$20,796	$25,996	$31,195	$36,394
Total		$31,427	120,000	$221,554	$295,405	$369,256	$443,107	$516,959

Using the method adopted in Chapter 3.2.2 of this WP, we estimate the value of land used for walking and cycling to be approximately $31.4 billion. Using the same method to estimate the value of land used for the road network produces a range from $221.6 to $517.0 billion. The latter estimates are obviously much higher than the $33.4 billion used in WP C2 "Valuation of Road Infrastructure". In our view, the most likely explanation for this discrepancy is the relatively low value the latter attaches to land used for the local road network. The latter is approximately eight times longer than the state highway network and, moreover, is concentrated in urban areas, which we find have much higher land values. Given this context, we consider it unusual the estimated value of land used for the local road network is only slightly higher ($19.7 billion) than that of the state highway network ($13.7 billion). This discrepancy also highlights important questions about valuing land for transport purposes, which we discuss below.

A4.2 Valuing land used for transport

In this WP, we value land using what can be called an "over-the-fence" methodology. Under this approach, the value of land occupied by the road corridor is assumed to be the same as the market value of adjoining private land. This approach seems intuitive and reasonable, especially when considering small changes in land at the margin. In our view, however, the over-the-fence methodology raises some important economic questions when used to estimate the value of land used for the entire network.

Perhaps the most interesting economic question is that the value of adjoining private land will, to some extent, reflect the presence of the transport infrastructure we seek to value. In technical economic parlance, the market value of private land is endogenously determined with the presence of transport infrastructure. If we consider an unlikely but illuminating counterfactual situation in which the land currently used for transport infrastructure was put to alternative uses, such as development or agriculture, then we would expect the market value of adjoining private land to fall—due to the loss of accessibility. In this situation, subsequently applying the over-the-fence methodology would lead to a lower estimate for the value of the land that was previously used to provide transport infrastructure.

A somewhat related economic question is whether the land that makes up the road corridor would fetch market value. We note much of this land is likely to be subject to additional legal constraints, such as easements for other infrastructure, which may constrain its potential alternative use. By ignoring these two questions, we suggest the over-the-fence methodology is likely to overstate the value of land used for transport purposes. Further research and deliberation on such issues would seem to be needed.

Appendix 5 : Estimation of benefits of walking and cycling

A5.1 Overview

This appendix sets out a methodology and its application to estimate the health- related economic benefits of walking and cycling modes relative to the other (sedentary) transport modes considered in the DTCC study. The DTCC comparative evaluation across modes will then apply these unit health benefit estimates (per kilometre travelled) to the current walking and cycling statistics to derive the annual economic benefits of walking and cycling, expressed as a negative cost relative to the other study modes.

The methodology outlined in this appendix follows that developed in the DTCC working paper D3: Health Impacts of Active Transport (but we do not attempt to describe that methodology in detail here). It addresses the health benefits (to both individuals and the health system) of increases in physical activity associated with greater use of ‘active‘ travel modes (principally walking and cycling) in preference to more sedentary modes (principally cars). It focuses on public health impacts associated with physical activity, while noting that other social and environmental costs (transport accidents, air pollution, GHG, noise) are covered elsewhere in the DTCC papers.

Transport affects public health through multiple pathways including through road traffic crashes, air pollution, noise and physical activity. These pathways impact a wide range of health outcomes - including injury, type 2 diabetes, respiratory diseases, cardiovascular diseases, selected cancers and mental health. The wide range of health impacts of transport results in costs to individuals, government and wider society. Estimates of the costs associated with the public health impacts are important to consider in assessments of the costs associated with the transport system and its use.

The ‘base case’ for our assessment has been taken as travel by means that involve no or minimal physical activity (often taken as travel by car). Our assessment thus compares the health-related economic cost savings (benefits) of using other (more active) transport modes with the ‘base case’ economic costs.

A5.2 Methodology

An established multi-state life table model was applied to estimate the health impacts and health system savings associated with different transport modes. As the focus was on physical activity, it was not appropriate to make assumptions about physical activity forgone by the use of physically inactive transport modes: rather, the assessment only considered modes that would involve some physical activity (exemplified by walking and cycling) and thus result in an increase in overall physical activity. The values derived are therefore more accurately described as benefits (economic cost savings) resulting from an increase in physical activity, rather than economic costs associated with reduced physical activity.

A probabilistic sampling framework was developed to run through thousands of different transport scenarios and estimate the individual health benefits (cost savings) and public health system cost impacts of each scenario. The results from scenario modelling were used to derive average physical activity-related health cost savings (or benefits) associated with different modes of transport on a per person kilometre basis. Estimates for modes not explicitly considered in the model (e.g., e-bikes, scooters, public transport) were obtained by scaling results from modelled modes, where there was evidence that these other modes resulted in changes in physical activity. For all modes covered, cost savings (benefits) were separated into direct costs savings to the health system, and individual socio-economic benefits associated with individual-level changes in health status. The latter was based on using a Value of a Statistical Life (VoSL) approach to value a Quality-Adjusted Life Year (QALY). The Ministry of Transport VoSL for 2018/19 ($4.34 million) was applied, consistent with the 2018/19 base year of the DTCC study.

A5.3 Results

It was estimated that walking results in 0.013 QALYs gained per 1,000km walked (relative to car travel), and cycling is associated with approximately half this health gain of walking per km travelled. Differences in the health gains across different modes represent differences in the effort required to travel by different modes (and therefore the amount of physical activity that is involved per kilometre travelled). Results reflect the total health gain expected over the life course of the population. Through monetising these health gains, the health-related benefits to individuals per kilometre of walking were estimated at $2.73 and per kilometre of cycling at $1.51 (with a 4% discount rate applied in each case).

In addition to these benefits to the individuals concerned, travelling by active modes of transport, or modes that are associated with active travel, would result in cost-savings to the health system. Increased physical activity that results from active transport results in reduced incidence of non-communicable diseases (e.g., cardiovascular disease, selected cancers). This in turn results in savings to the healthcare system, even after accounting for increases in costs associated with increased longevity. Active travel involving walking or cycling results in net health system cost savings of $0.155 per kilometre walked and savings of $0.088 per kilometre cycled: these figures are additional to the above values representing the socio-economic health benefits of walking and cycling to participants.

Taken together, these figures represent a reduction in economic costs (or a net economic benefit) to society of **$2.885 per km walked or $1.598 per km cycled**[15], relative to no travel or to travel by car or other modes which do not involve significant physical activity.

Based on HTS estimates of the amount of walking and cycling undertaken in NZ on an annual basis, our assessment of the total economic benefits associated with all current walking and cycling (relative to use of sedentary modes) is:

- Walking: 655.5 million person km * $2.885/km = $1,891.1 mill p.a.
- Cycling: 289.2 million person km * $1.598/km = $462.1 mill p.a.
- Total economic benefit = **$2,353.2 mill p.a.**

These benefit figures have been included in the DTCC economic assessment of the overall economic impacts (per year) of NZ's current walking and cycling travel as components of the domestic transport system.

A5.4 Illustrative application

As an illustrated application of the above benefit rates, the potential health-related benefits were assessed if 1.0% of current NZ person kilometres of car travel were to switch to active modes, with

15 This rate for cycling is based on unpowered cycles. The extent of physical effort required per kilometre is rather lower for e-bikes, but this is largely (or completely) compensated for by the typical increase in annual cycle kilometres per person for people switching from unpowered cycles to e-bikes.

75% of these switching to walking and 25% to cycling (giving a weighted average benefit of $2.563 per person km).

Given the total NZ car/light vehicle travel of 35.7 billion vehicle km pa at an average car occupancy of 1.56 persons (giving a total of 55.7-billion-person km pa), a 1.0% modal switch from car travel would represent 557 million person kilometres pa. At the weighted average benefit rate ($2.563/person km), the annual economic health benefits would be valued at $1,427 million p.a.: this is a substantial amount relative to most of the other cost and benefit estimates derived elsewhere in this study. Of course, in overall transport economic terms, these health benefits will typically be partially (or totally) offset by increased travel times, which are not addressed here - although such increases seem likely to be minimised (in urban areas in particular) through the use of e-bikes.

Appendix 6 : Estimation of travel time costs

Table 13 sets out our estimates of the total time and associated annual time costs spent in walking/cycling in NZ. The key sources used are:

* Trips, Kms: NZ HTS statistics (2018-21)
- Ave speed: Typical values for both modes
- Value of time: MBCM evaluation values (updated to 2018/19), estimated 5% working time, 95% non-working (including commuting) time.

The resultant total time cost of $1793 M pa ($1,563 M walking, $230 M cycling) has been applied as the best estimate of travel time costs for the two modes in the DTCC evaluation of economic costs for each mode.

Table 13:: Calculation of Walking/Cycling Travel Time Costs, 2018/19

Measure	Walking	Cycling	Total	Notes, Sources
1.Trips -mill pa	744.31	81.86	826.17	HTS
2.Kms- mill pa	655.47	289.24	944.71	HTS
3.Ave speed-km/hr	5.0	15.0		Typical ave speeds (multiple sources)
4.Hours – mill pa	131.09	19.28	150.37	(2)/(3)
5.Ave VoT -$/hr	11.92	11.92	11.92	Refer Notes
6.Tot costs -$mill pa	1562.8	229.8	**1792.6**	(4)*(5)
7. Ave cost/km -$	$2.38	$0.79	**$1.90**	(6)/(2)

Notes:

(5). VoT based on MBCM (Table 15) car driver values for evaluation etc purposes (updated to $2018/19, (factor 1.52) of $36.25/hr for working time, $10.64 average for non-working (including commuting) time (as used in WP). IWA estimates that walking/cycling time is 5% working time, 95% non-working time, giving weighted average of $11.92/hour.

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