Domestic Transport Costs and Charges Study

Working Paper D3
Health Impacts of Active Transport

Prepared for Te Manatū Waka Ministry of Transport (NZ)
University of Otago, in association with Ian Wallis Associates Ltd
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Disclaimer

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

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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.

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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

DALY	Disability Adjusted Life Year
DTCC	Domestic Transport Costs and Charges (Study)
EEM	Economic evaluation manual, NZ Transport Agency
MET	Metabolic Equivalent of Task
NZD	New Zealand Dollar
PAATM	Physical Activity and Active Transport Model
PT	Public transport
QALY	Quality Adjusted Life Year
TOF	Transport Outcomes Framework
VSL	Value of a Statistical Life
VSLY	Value of a Statistical Life Year

Executive summary

Overview

Transport influences public health through multiple pathways including through road traffic crashes, air pollution, noise and physical activity (Briggs et al., 2015). These pathways impact a wide range of health outcomes including injury, type 2 diabetes, respiratory diseases, cardiovascular diseases, selected cancers and mental health (Briggs et al., 2015, Woodcock et al., 2007). 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.

This Working Paper details the incremental (marginal) costs associated with physical activity-related health impacts of transport. We focus on public health impacts associated with physical activity, while noting that air pollution and injury-related costs are covered elsewhere in the DTCC study.

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

Methodology

We use an established multi-state life table model to estimate the health impacts and health system savings associated with different transport modes. As we are only focussing on physical activity and we cannot make assumptions about physical activity forgone by the use of physically inactive transport modes, we only consider modes that involve some physical activity and thus result in an increase in overall physical activity. The values we derive are therefore more accurately described as benefits (economic cost savings) resulting from an increase in physical activity.

We generated a probabilistic sampling framework 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 (VSL) approach to value a Quality-Adjusted Life Year (QALY). We used the Ministry of Transport VSL for 2018 ($4,340,000), consistent with the 2018 base year of the analysis.

Results

We estimate that walking results in 0.013 QALYs gained per 1,000km travelled, and cycling is associated with approximately half the 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. By monetising these health gains, we estimate the health -related benefits to individuals per kilometre of walking to be $2.73 and per kilometre of cycling to be $1.51 (with 4% discounting applied).

In addition, travelling by active modes of transport, or modes that are associated with active travel, results 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 above values representing the socio-economic health benefits of walking and cycling.

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, relative to no travel or to travel by car or other modes which do not involve significant physical activity.

Limitations, future updates and potential additional areas of work

Our results are likely to provide conservative estimates of the benefits from the use of active transport modes. Future work to include additional benefits from mental health and obesity impacts arising from transport would be valuable to enable a more holistic analysis. In addition, we note that current work to update the New Zealand VSL could also provide the opportunity to update our estimates. However, we caution that there are limitations in the use of an injury-based VSL to derive monetary values for the non-injury outcomes considered in this analysis.

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, and
- 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. Consistent with this focus, all economic and financial cost figures are given in June 2018 dollars.

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

Transport influences public health through multiple pathways including through road traffic crashes, air pollution, noise, and physical activity (Briggs et al., 2015). These pathways impact a wide range of health outcomes including injury, type 2 diabetes, respiratory diseases, cardiovascular diseases, selected cancers, and mental health (Briggs et al., 2015, Woodcock et al., 2007). 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.

This Working Paper deals with physical-activity-related health impacts of transport associated with the NZ transport system and its use. We detail the marginal costs associated with physical activity-related health impacts of transport. We focus on public health impacts associated with physical activity as air pollution and injury-related costs are covered elsewhere in the DTCC Project. As we are only focussing on physical activity and we cannot make assumptions about physical activity forgone by the use of physically inactive transport modes, we only consider modes that involve some physical activity and thus result in an overall increase in physical activity. The values we derive are therefore more accurately described as economic cost savings (or benefits) resulting from an increase in physical activity and may be interpreted as benefits relative to no travel or to making the same trip by a non-active mode (e.g. driving a car). Specifically, we present per person km physical activity-related health values for walking, cycling, public transport, e-biking, scootering and skateboarding, for use in project and policy appraisal tools, such as cost-benefit analysis.

This working paper begins with a summary of the role of transport in physical activity. Next, we review the valuation of health impacts before moving on to the methodology used to produce cost estimates of the physical activity-related health impacts of different transport modes. We present estimates of the monetary benefits arising from physical activity for each mode. We then provide commentary of the implications of our findings for transport planning and policy.

We emphasise that this paper is concerned only with the health-related social costs and benefits of ‘active’ transport modes, relative to no travel or relative to modes involving no or minimal physical activity (such as travelling as a car driver or passenger). No attempt is made to include other socio-economic costs or benefits arising in the choice between modes (e.g. car and PT operating costs, travel times and reliability of alternative modes etc).

In relation to the Transport Outcomes Framework, this Working Paper contributes to Economic Prosperity by more clearly accounting for the health costs and benefits of alternative modes of transport. It also contributes to the Healthy and Safe People outcome by highlighting the potential benefits to health that could be realised from shifting travel away from private motor vehicles and other non-active modes to more physically active modes. By monetising these benefits and providing a more complete picture of the health impacts of alternative modes of transport, this Working Paper also contributes to the overall guiding principle of mode neutrality.

Chapter 2 Methodology

2.1 Approach

2.1.1 Theoretical underpinnings

Linking transport, physical activity, and health

Increased physical activity has a wide range of positive health impacts including reduced incidence of cardiovascular disease, stroke, type 2 diabetes, and selected cancers (World Health Organization, 2010). The World Health Organization recommends that adults should accumulate at least 150 minutes of moderate-to-vigorous physical activity per week (World Health Organization, 2010). Around half of New Zealand adults fail to meet these recommendations (Ministry of Health, 2019). High prevalence of physical inactivity places a high burden on public health and health systems (Ding et al., 2016).

Active forms of transport, such as walking and cycling, are a widely-recognised way to increase physical activity (Brown et al., 2016). In New Zealand, people who walk and/or cycle are more likely to meet physical activity guidelines (Shaw et al., 2017). In settings where active transport is widespread, many people may accumulate recommended amounts of physical activity through active transport alone (Fishman et al., 2015).

Considering physical activity when assessing the public health costs of transport is vital. The majority of the health gain associated with increasing walking and cycling results from increases in physical activity (Mizdrak et al., 2019). In addition, increases in physical activity outweigh other health impacts of changes in transport mode in most settings (Tainio et al., 2016). The inclusion of active transport in economic evaluations of the impact of transport policies and projects has become more common and there are a number of international tools available to assess the health impacts of changes in transport use (Brown et al., 2016).

Public health costs

The costs associated with the public health impacts of transport include the social costs of illness and reduced longevity, health system costs, and costs resulting from the knock-on impacts of poor health on other domains (e.g. workforce productivity) (Litman, 2020). Assessing the magnitude of public health costs is difficult – not least due to the challenges of quantifying and monetising these public health impacts.

Social costs of illness and reduced lifespan

This cost measures the value society places on avoiding illness and gaining improved life quality and longevity. Changes in the number of deaths (mortality) and years lived with illness (morbidity) both contribute to the overall health impact. Over time, measures that combine mortality and morbidity into a single metric have been developed. Combined metrics include Quality Adjusted Life Years (QALYs) and Disability Adjusted Life Years (DALYs). Both these measures combine years of life lost (to account for mortality) and years lived with disability (to account for morbidity) but differ in the approaches used to value years lived in imperfect health. QALYs, DALYs, and other related measures of health impact are commonly used in cost-effectiveness and cost-utility analyses but are not compatible with cost-benefit analyses, which require monetary values (McDaid et al., 2015, Powell et al., 2010, Ryen and Svensson, 2015).

A common way to estimate monetary values of life or healthy years is to us a Value of Statistical Life (VSL) (Ryen and Svensson, 2015). This is the value that a society places on avoiding the loss of one life. VSL is usually determined by revealed or stated preference methods (or occasionally Human Capital methods, although these do not capture as broad a value of life as stated or revealed preference methods) and is typically focussed on valuing reductions in risk of specific cause of death (e.g. road traffic crashes or fire etc.). The method used can have a large influence on the value determined this (Kniesner and Viscusi, 2019, Preval, 2014). Research has shown VSL varies greatly between countries and depends on the cause of death or risk surveyed, the survey design, the population surveyed, the ability of respondents to assess large versus small risks to life, GDP/capita and many other contextual and cultural factors (Hirth et al., 2000, Ryen and Svensson, 2015, Lindhjem et al., 2011, van Wee and Rietveld, 2013). Therefore, to determine a value of health benefits or lives saved/lost it is important to use a VSL developed in the local context, in this case a New Zealand-specific VSL.

The main VSL used in New Zealand was developed for the road transport sector through a willingness-to-pay survey conducted in 1989 to estimate the amount society was willing to pay to avoid deaths from traffic crashes (Miller and Guria, 1991). Since this is the predominant VSL used for New Zealand policymaking and there is no VSL estimate for the risk of diseases of physical inactivity, it is the value used in this report to represent the social value of lives saved from increased physical activity. However, there are two very important caveats. Firstly, this value was determined with road injury risk in mind. Studies have shown that the value people place on avoiding a risk is highly dependent on what that risk is and how much perceived control one has over avoiding it. For example, the willingness to pay to avoid the risk of dying from fire or drowning is substantially lower than that for traffic injury, while the VSL estimate for cancer risk is substantially higher than that for traffic injury (Guria, 2010, Kniesner and Viscusi, 2019, Preval, 2014, Wren and Barrell, 2010, Olofsson et al., 2019). This is important in this context because, while this valuation is within the transport field, the values we are estimating are for the avoidance of a range of chronic illnesses, which would likely have different values than the avoidance of traffic injury. It is unknown whether these values would be higher or lower than the current transport VSL and extensive willingness-to-pay surveying would be required to determine this.

Secondly, the current transport VSL was estimated from a survey conducted in 1989. Research has shown that people's value of avoiding risk changes with time as knowledge develops and economies change (Ryen and Svensson, 2015). An update of the transport VSL in 1997/98 suggested that the transport VSL should be substantially higher than the 1989-indexed value then being used, although this recommendation was not incorporated into policy, with the earlier VSL continuing to be used (Guria et al., 2003). As the current VSL is over 30 years old it is unclear how accurately it represents New Zealand society's current values. The relevance and validity of the current VSL for Māori is also uncertain. The original report on the New Zealand VSL by Miller and Guria found that differences in VSL by ethnicity were not statistically significant at the 90% confidence level, but the sample sizes for ethnicities other than Pākehā were small (e.g. n(Māori) = 40, n(Pākehā) = 494) (Miller and Guria, 1991). Further work is needed to establish how the concept of VSL fits within a Māori world-view and whether the values used appropriately reflects Māori values (Mills et al., 2012, Willing et al., 2020). Work is currently underway (funded under Waka Kotahi NZTA's sector research programme) to establish a new transport VSL, although this value is not available at the time of writing this report. For the benefit of future transport-related health valuations it is important to address physical inactivity- and air quality-related health risks as well as injury risks; and also to carefully consider the applicability of the methodology and resulting values to Māori.

From VSL it is possible to estimate the value of a statistical life year (VSLY) using average life expectancy, average age and an appropriate discount rate. This value is approximately equivalent to the social value of a QALY. However, there are key conceptual differences between a VSLY and QALY approach. The purpose of a QALY is to standardise health states across different conditions and over time. Using the QALY concept, one year of perfect health is equivalent to two years at 50% health, which both represent one QALY. Some VSL research has shown that VSL does not (and some argue should not for ethical reasons) vary substantially with age, [1] despite older people having fewer years of life remaining. This means that VSLY cannot be constant in order to maintain a constant VSL across ages (Asim and Petrou, 2005, Guria, 2010). Again, it is important to point out that there have been few studies that have investigated VSL or VSLY from a Māori perspective and it is possible that even a constant VSL regardless of age may be problematic for Māori given the importance placed on Kuia and Kaumātua as leaders and repositories of cultural knowledge (Durie, 1999, Willing et al., 2020).

Another approach to determine the value of a QALY is to carry out stated preference surveying (similar to that used to determine VSL), but to ask questions on willingness to pay for improved life quality and increased years of life. Willingness-to-pay QALY surveys from other countries have shown that the value of a QALY does vary by age, with older people placing more value on an extra year of life than younger people. Other studies have found a U-shaped curve where QALYs for children and older adults are valued higher than those of young-to-middle-aged adults (Asim and Petrou, 2005). Surveys have also shown that the value of a QALY differs depending on whether it is in relation to a year of improved quality or an additional year of life (the latter being valued higher) (Herrera-Araujo et al., 2020). This variation is a significant issue for assigning a single monetary value to a QALY. From a health perspective QALYs are supposed to be equivalent to each other, so whether they come from extending an older or younger person's life or whether they come from improved quality or extended life, all QALYs are equivalent. However, when it comes to assigning a monetary value to a QALY it is very difficult to get agreement on what that value should be. Different groups in a population also attribute different values to life, raising further equity issues with producing one value for all QALYs (Asim and Petrou, 2005, Ryen and Svensson, 2015). Unfortunately, no willingness-to-pay surveying has been carried out in New Zealand to determine the societal value of a QALY here. It is also worth noting that QALYs themselves come from Western philosophical constructs and do not capture health values important to Māori. This key limitation emphasises the importance of considering how current economic measures of health might be perpetuating or exacerbating health inequity in New Zealand (Willing et al., 2020).

Despite these limitations, it is necessary to capture the health impact of transport decisions in a way that helps decision-makers make trade-offs between competing policies or projects. Since cost-benefit analyses are an important part of this process in transport decision-making, we need to assign a monetary value to a QALY (McDaid et al., 2015). Without QALY valuation surveying specific to New Zealand and in the context of the DTCC Study, the best option is to use VSL to approximate the social value of a QALY in order to help ensure consistency across different

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1 It is worth noting that studies from other countries show that VSL does vary with age, with the value reaching a maximum between 40 and 65 years, again highlighting the variability of VSL estimates and the importance of context-specific values (van Wee and Rietveld 2013).

domains assessed. This is the approach adopted in this working paper, with methods detailed later.

Health system costs

The health system accounted for over $18 billion of government spending in the 2018/19 financial year (over twice that of transport spending at $8.4 billion) (New Zealand Treasury, 2019). Different health conditions are associated with differing health system costs, with non-communicable diseases accounting for the majority of health expenditure (Blakely et al., 2019). Reducing the incidence of health events associated with transport has the potential to reduce health system costs. For example, previous research has estimated that switching a quarter of short trips (<5km) to walking and cycling would be expected to result in health system cost savings of $750 million over the life course of the New Zealand population (based on a 3% real discount rate) (Mizdrak et al., 2019). Including costs to the health system associated with transport should assist with aligning policies with the Treasury's Living Standards Framework.

We frame health system costs as the costs to government associated with providing health care and preventative services. High quality national level data provides the ability to estimate these costs in detail, accounting for co-morbidities. We note that individuals experience out-of-pocket expenses associated with healthcare (e.g. costs associated with GP visits), but we were unable to include these in our analysis of the public health costs associated with different modes of transport.

Productivity cost impacts

The physical activity-related health impacts of transport also result in other costs across society. Specifically, increased physical activity and improved health are associated with less time off work and a reduction in lost output from physical inactivity. Weerappulige and Khoo (2020) estimate the annual value of physical activity with regards to lost output to be $943 per person (2018 NZD). However, the authors note that there are considerable uncertainties in the level of lost output. In addition, there are ethical issues associated with available measures of lost productivity as they do not account for the contributions of those not in the paid labour force (Weerappulige and Khoo, 2020).

The 2018 update of the social costs of road crashes report (Ministry of Transport, April 2019) states that VSL includes the loss of output due to permanent disability for non-fatal injuries and calculates temporary loss of output for serious and minor injuries using the average length of hospital stay for each injury severity and average daily earnings. Appendix A2 of the June 2006 update of the social costs of road crashes expands on this by including loss of output in VSL and states that:

"As the Value of Safety survey conducted during 1989/90, from which the current VOSL is established, did not explicitly separate out the potential loss of income from cost of pain and suffering, individuals might have included an allowance for income losses due to loss of life or permanent disability when they responded to the survey. Therefore, we assumed the loss of output due to permanent impairments is covered under the loss of life and life quality component."

In theory it is possible to use measures from other countries as a proxy to indicate the ratio of the cost of loss of output to the cost of pain and suffering. The UK WebTAG data book (Department for Transport (2019) table A4.1.1) states that the value of lost output for a road fatality was GBP537,307 and human costs were valued at GBP1,024,773 (both 2010 values). If we argue that lost output from fatality and permanent disability are included in the New Zealand VSL estimate, the UK equivalent value would be GBP1,562,080 with lost output making up 34.4%. Applying this to the New Zealand VSL we could assume that lost output is valued at $1,492,825 (34.4% of $4,340,000).

There are significant issues with this approach. The primary issue is that, as mentioned earlier, these sorts of estimates vary substantially between countries, so it is likely that the New Zealand estimate could be significantly different to this. We also cannot conclude that the ratio of lost output to human costs in the UK would apply to New Zealand as it is not clear whether the survey questions and methodology used for the UK valuation are comparable to the New Zealand valuation. Furthermore, it is not known whether the loss of productivity values associated with road injury are applicable to diseases of physical inactivity, so using a ratio estimated in a different country for a different cause of death and disability using different survey methods would substantially reduce the accuracy of these estimates for the sake of a false sense of precision.

Assuming VSL, and therefore VSLY, provides a measure of permanent loss of output due to death or permanent disability still does not account for temporary loss of output for less severe injuries. Adding in a measure of temporary loss of output is difficult when using the QALY (or DALY) metric as we cannot differentiate between temporary or permanent disability resulting from a lack of physical activity (or avoided by an increase in physical activity). Therefore, to avoid double-counting it seems appropriate for the purposes of DTCC to assume productivity costs are covered by VSL and VSLY, but cannot be separated from other social costs covered by VSL. Therefore, we should not add additional lost output costs using the Weerappulige and Khoo (2020) method.

2.1.2 Methodological overview

We use an established multi-state life table model to estimate the health impacts and health system savings associated with different transport modes. As we are only focussing on physical activity and we cannot make assumptions about physical activity forgone by the use of physically inactive transport modes, we only consider modes that involve some physical activity and thus result in an increase in physical activity. The values we derive could therefore be more accurately described as economic benefits resulting from an increase in physical activity.

We generated a probabilistic sampling framework to run through thousands of different transport scenarios and estimate the health and health system cost impacts of each scenario. The results from scenario modelling were used to derive average physical activity-related health 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 other modes resulted in changes in physical activity. For all modes covered, benefits were separated into direct savings to the health system, and social benefits associated with individual level changes in health status. The latter was based on using a VSL approach to value a QALY.

2.1.3 Physical Activity and Active Transport Model (PAATM)

The PAATM is an established proportional multi-state life table model designed to estimate the health impacts of changes in physical activity and transport patterns. Full model details have been published previously (Mizdrak et al., 2018). In this Working Paper, we present key features of PAATM and adaptations made to the model for this project.

PAATM simulates population cohorts under different scenarios and outputs of the model include health gains (in QALYs) and changes in health system costs. Modelled cohorts representing the entire New Zealand population are defined by 5-year age group, gender, and ethnicity (Māori and non-Māori). Cohorts are simulated from the base year of the model (2011), in annual time steps, for the remainder of their life course (or until age 110). PAATM includes three exposures (physical activity, fine particulate matter, and distance travelled) and nine health conditions related to transport (see Figure 2-1). Given that the public health impacts arising from air pollution and road injuries are covered by other sub-consultants in the DTCC Study, these pathways were switched off for our analyses. This means that the modelled impacts exclusively represent the health impacts from changes in physical activity.

PAATM captures the impact of changes in moderate and vigorous physical activity, consistent with relative risks used to generate population impact fractions. Physical activity in PAATM is expressed as a change in MET (metabolic equivalent of task) minutes per week of moderate and vigorous activity (Mizdrak et al., 2018). A MET is the ratio of work metabolic rate to a standard resting metabolic rate where one MET is equivalent to sitting quietly (Ainsworth et al., 2000). Moderate activities are those with MET values between three and six, and vigorous activities have a MET value greater than 6. Throughout this analysis, we assumed a walking speed of 4.4km/hr (Ministry of Transport, 2015) and a MET value of 3 (a moderate activity). For cycling, we assumed a speed of 10.5km/hr and a MET value of 3.5 (consistent with recorded speeds in the Household Travel Survey data).

PAATM is built in Microsoft Excel and is run using custom-built macros in Visual Basic for Applications (VBA).

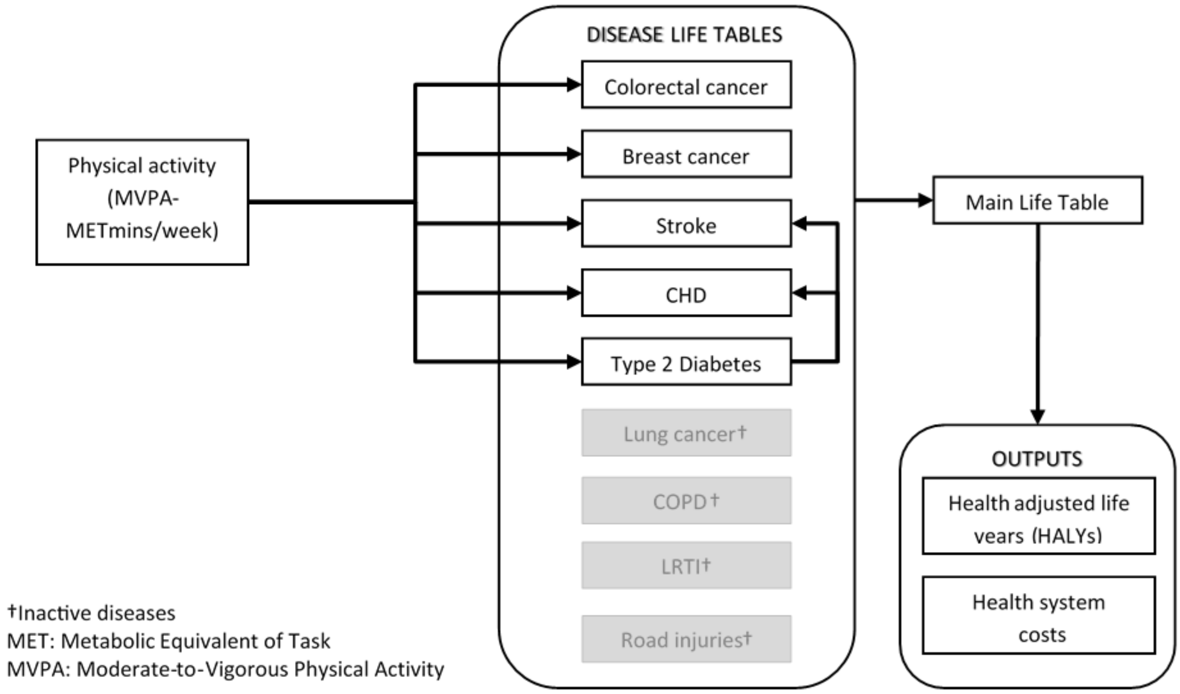

Figure 2-1: Conceptual diagram of the Physical Activity and Active Transport Model (PAATM) (adapted from Mizdrak et al. (2018))

2.2 Data sources and literature

PAATM is parameterised with high quality national-level epidemiological and population data from relevant administrative sources. Parameters include estimates of distance travelled by mode from the Household Travel Survey (2003-2014), physical activity levels from the 2011 New Zealand Health Survey (Ministry of Health, 2012), and health and health system costing data from the Ministry of Health. Although more recent data are available for several of the included parameters, we used 2011 as the base year as a full update of all model parameters was beyond the scope of this project. Results were scaled to 2018 using the OECD Consumer Price Index for New Zealand.

Health system costs captured in the model include publicly-funded health events recorded in the Ministry of Health National Collections datasets, which account for 82% of all health expenditure in New Zealand (Blakely et al., 2019). The datasets included cover hospitalisations, outpatient care, cancer registrations, retail pharmaceuticals, laboratory claims, and general medical services claims (Blakely et al., 2019). Detail on how costs are assigned to specific disease states has been documented elsewhere (Kvizhinadze et al., 2016, Blakely et al., 2019). For the non-communicable diseases that contribute to our estimates, the majority are treated in public hospitals and captured within our health system cost estimates (Blakely et al., 2019). Therefore, estimates of health system costs associated with distances travelled by different transport modes would be unlikely to change substantially if private healthcare was included.

2.3 Analyses

2.3.1 Scenarios

To calculate public health costs on a per kilometre basis across different modes, we used PAATM to estimate the health impacts and health system costs associated with a range of changes in the distances travelled by active modes (i.e. different transport scenarios). First, we reviewed the international literature examining the associations between transport-related physical activity and total physical activity to determine the extent to which increased physical activity from active transport was compensated by decreased active travel in other domains (e.g. leisure). Evidence from the UK, USA and the Netherlands concluded that active travel does not substitute for other exercise and adds to total physical activity (Panik et al., 2019, Sahlqvist et al, 2012). Additionally, a further UK study found active commuting was associated with a more favourable pattern of movement behaviour in discretionary time (Foley et al., 2019). In this study, active commuters accumulated 30-60 minutes less screen time per week than those using inactive modes (Foley et al., 2019). Given the findings of our review, an increase in the distance travelled by an active mode was assumed to result in a corresponding increase in the amount of physical activity for this analysis. We assumed no change in non-transport-related physical activity in response to changes in transport-related physical activity, consistent with the international literature (Foley et al., 2019, Sahlqvist et al., 2012, Panik et al., 2019).

We set up a probabilistic sampling framework that randomly selected transport scenarios from within a plausible range for each of the 5,000 model iterations. These randomly selected transport scenarios flowed onto a change in the physical activity, which flowed on into health and health system cost impacts. A probabilistic sampling framework was chosen as it provided a way to capture the range in the expected value of health impacts that could result from different projects resulting in different changes in transport patterns over differing locations and time horizons.

The probabilistic sampling framework selected changes in distance travelled by active modes (walking and cycling) of +/-50% for each population group captured in the model. The limits of the changes in walking and cycling were set up to align with recent recommendations for NZ national targets for walking and cycling (Mandic et al., 2019). Changes in transport were uncorrelated across different population groups – i.e. a random draw of a scenario could represent a large increase in walking in young people accompanied by a decrease in walking for older adults or vice versa. As injury and air-pollution related impacts were not included in the model, results are the same regardless of whether a trip is a new walking/cycling trip, or one switched from driving.

In each scenario, changes in transport patterns were assumed to hold for 50 years; this seemed reasonable given the longevity of transport infrastructure (e.g. cycle lanes) but could be amended if other assumptions were preferable. The impact of duration is examined in sensitivity analyses. For each scenario, we estimated the population level changes in physical activity that would result from changes in the distance travelled by mode. For example, one iteration could represent a 10% increase in walking distance across the entire population.

Results for each scenario captured the total health and health system cost impact over the life course of the modelled population (i.e. the 2011 New Zealand population). For each scenario, we were able to estimate the per kilometre health and health system cost impact of changes in distance travelled by the different transport modes, by dividing the overall health impact by the overall change in distance travelled.

Each model iteration also randomly sampled other model parameters from their respective probability distributions (e.g. MET values by mode, disease rates). Probability distributions for all model input parameters are detailed in the PAATM Technical Report (Mizdrak et al., 2018). Both the walking and cycling scenarios were run 5,000 times to produce uncertainty intervals around the impact of transport changes on health and health system costs.

2.3.2 Valuation of health impacts

For consistency with other components of the DTCC Study, we convert modelled health impacts (estimated in QALYs) into monetary values using the VSL. The health evaluation literature provides a standard method for estimating the social value of a QALY by converting VSL to VSLY (O'Dea and Wren, 2012, Preval, 2014).

In doing this, it is important to apply an appropriate discount rate to determine the present-discounted value of a VSLY. If this is not done, once a discount rate is applied later in the CBA process the cumulative value of health benefits over the remaining average years of life will not add up to the VSL. Standard practice in the health evaluation literature is to annualise VSL by assuming that the sum of discounted future life years must equal the present VSL to ensure future life years are not undervalued (O'Dea and Wren, 2012, Weatherly et al., 2009). The standard discount rate in the health sector in New Zealand is 3.5% (real terms). The current New Zealand transport discount rate is set at 4% with scenario testing at 6% and 3% (Waka Kotahi, 2019).

The formula for converting VSL to VSLY is:

$$VSLY = VSL/\sum_{n=1}^{n=x}\frac{1}{(1+d)^n}$$

where x = the average life years remaining (determined by subtracting the average age from the average life expectancy of the population), and d = the discount rate.

Table 2-1 presents the VSL and other data used to calculate the June 2018-dollar value of a QALY and Table 2-2 presents the range of QALY values for each discount rate. Our results provide estimates of the health gains associated with different modes of transport for each of the provided QALY values.

Table 2-1: Values used to estimate the value of a QALY

Variable		Value (June 2018$)
VSL (June 2018 $)*		4,340,000
Population#	Male	2,319,558
	Female	2,380,197
Life expectancy‡	Male	80
	Female	83.5
Average life expectancy		81.8
Average age#		37.4
Average life years remaining		44.4

* Source: Ministry of Transport (April 2019); # Source: 2018 Census, Statistics New Zealand (2020); ‡ Source: 2016-18 Life Tables, Statistics New Zealand (2019).

Table 2-2: QALY values under differing discount rate assumptions

	Health sector discount rate	Transport sector discount rates*			Treasury discount rate
	3.5%	4%	3%	6%	5%
QALY value (June 2018$)	$194,769	$211,204	$178,938	$282,126	$245,714

* Note. Genter et al. (2008) and Weerappulige and Khoo (2020) do not apply a discount rate when calculating VSLY, contrary to standard practice. As such, Weerappulige and Khoo (2020) report a 2018 QALY value of $103,828

2.3.3 Estimates for non-modelled modes

Modes directly contributing to physical activity

Estimates for modes not explicitly modelled were derived from results for modelled modes (i.e. walking and cycling) based on the physical activity contribution for each mode. For each mode, we considered whether the mode contributed directly or indirectly to increased physical activity. Modes that were considered to have direct contributions to physical activity included e-bikes, scooters and skateboards (as assessed in this section). Modes that were considered to have indirect contributions to physical activity were public transport in urban areas – as the journeys that use these modes typically require people to be active for the access /egress legs of their trip (as assessed in the section immediately following).

The physical activity benefits of e-bikes have been derived from the modelled results for cycling using a scaling factor to account for the different amount of effort required to travel an equivalent distance by e-bike versus unpowered bicycle. Less effort is required to travel at the same speed on an e-bike than on a regular bike. People average approximately 5 METS when riding an e-bike at 15-20km/h (Peterman et al., 2016, Sperlich et al., 2012), which is around 85% of the effort required to travel the same distance at the same speed on a regular bicycle. We note that the 3.5 MET value used for cycling in this study corresponds to travelling at a much slower speed (10.5km/hour). Travelling at 15-20km/h on a regular bicycle would equate to higher METs than travelling at that speed on an e-bike. Accordingly, estimates of the health gains and health system cost savings for e-biking per km travelled are 85% of those of regular cycling. It is worth noting that although people riding e-bikes use less energy per km than those riding unpowered bicycles, a recent study has found that people riding e-bikes tend to cycle further and achieve similar amounts of physical activity to unpowered cyclists overall (Castro et al., 2019). Other studies have found that e-bike users get more physical activity than walkers but less than cyclists in total, although e-bike users report higher enjoyment scores than cyclists. This potentially makes e-biking a more likely substitute for car trips than unpowered cycling and still provides a significant contribution to meeting physical activity requirements (Langford et al., 2017, Bourne et al., 2018).

Few studies have quantified the energy expenditure of scooter and skateboard use. One study suggests that moderate skateboarding at 10km/h requires an effort of approximately 5-6 METS (Board and Browning, 2014), whereas an earlier study that conducted field tests involving 30 minutes of continuous skating on a flat surface suggests skateboarding at 8-14km/h requires an effort of approximately 8 METS (Hetzler et al., 2011). Given that skateboarding for transport would not typically involve uninterrupted skateboarding for 30 minutes, we have chosen to use 5.5 METS to estimate the physical activity benefits of skateboarding for transport. These benefits have been estimated from the modelled walking results using the scaling factors presented in Table 2.3 below.

Only one study has been published on the metabolic requirements of scooter riding. This study estimated that scootering at 6-12km/h requires approximately 4-8 METS (Willmott and Maxwell, 2019). To estimate the physical activity benefits of the use of (unpowered) scooters for transport we have assumed a travel speed of 9km/h and an equivalent effort of 6 METS. From this a scaling factor was determined to adjust the modelled results for walking. The physical activity benefits of e-scooters have not been estimated as no studies have been published on the metabolic requirements of riding an e-scooter: it is unclear how much this mode would contribute to physical activity (Fitt and Curl, 2020).

Table 2-3: Scaling factors used to estimate physical activity-related health impacts (per km travelled) relative to factor for walking: modes directly contributing to physical activity

Active mode	Health benefit values per km travelled by active mode	Scaling factor (impacts per km of mode used, relative to walking)
Walk	$2.90	1.00
Cycle	$1.60	0.55
e-bike	$1.36	0.47
Scooter[2]	$2.84	0.98
Skateboard	$2.35	0.81

Modes indirectly contributing to physical activity: public transport

Public transport (mainly bus and train) trips are typically associated with increased physical activity (relative to not making the trip or making the trip by car), as they are typically preceded and/or followed by walking (or sometimes cycling) at either end of the overall journey. In situations where the walking (or cycling) distance associated with such a journey may be estimated, the health

2 This value relates to unpowered scooters (no information available for e-scooters).

benefits associated with the walk (or cycle) trip legs may be estimated directly, as in Table 2-3 (with zero physical activity-related costs applied to the actual public transport legs).

However, for situations where such estimates are not readily available, we have estimated scaling factors based on the average walking distances associated with each km of bus and train travel in New Zealand. The total distances of walking trips in the same journey as a bus or rail trip were calculated using 12 years of the NZ Household Travel Survey (2003-2014) and then divided by the total distance travelled by bus and rail: the results for such situations are given in Table 2-4.

The factors in this table (relative to walking trips) are to be applied to the total PT trip distance (ie not just the walking legs). For example, for an 8 km bus trip, the health benefits associated with walk access/egress to/from the bus service are estimated (on average) at $2.90 * 8 * 0.04 = $0.93. Similarly, for a 16 km rail trip, the health benefits associated with walk access/egress are estimated at $2.90 * 16* 0.05 = $2.32.

Comparable estimates for cycling, scootering and skateboarding trips were not attempted, given that only a small number of public transport trips involved access and/or egress trip legs by these modes.

Table 2-4: Default scaling factors relating to conversion of car trips to PT trips, where no specific information on the distance of PT access and egress legs is available

Trip main mode	Scaling factor relative to walking (applied to full trip distance)
PT - Bus	0.04
PT –Train	0.05

Minimal physical activity is attributed to long-distance public transport modes (e.g. long-distance rail) and driving, so these have not been included in this assessment. However, a move to greater use of shared long-distance transport may positively impact physical activity at destinations if private vehicles are not used at the destination. Quantifying any health benefits associated with use of long-distance public transport would require further research.

2.3.4 Additional analyses

We ran additional analyses to capture the extent to which results changed under different scenario specifications. We considered differences in the magnitude of scenario impact and baseline physical activity levels. Our additional analysis for magnitude provides benefit estimates across the scenario range (i.e. +/-50% change in distance travelled by mode), assuming the same percentage change in each age group. This provides an idea of the extent to which large increases in walking and cycling are likely to result in diminishing marginal returns.

In the second additional analysis, we assumed that the least active people in each modelled cohort account for the scenario changes in transport. Specifically, we apply the change in distance to the proportion of each modelled cohort reporting under 100mins per week of moderate intensity activity (or equivalent). This is approximately equivalent to changes in walking and cycling applying to the least active 30% of the population. This provides an idea of the difference in benefits associated with transport changes in those with lower levels of physical activity.

The results from additional analyses may be more appropriate to utilise in specific circumstances than the main results. For example, it may be appropriate to use the values reflecting benefits to those that are less active for environments where physical activity levels are low.

Chapter 3 Results, commentary and conclusions

3.1 Results and commentary

3.1.1 Social cost of illness and reduced lifespan

We estimate that walking results in 0.013 QALYs gained per 1,000km travelled, with cycling associated with 55% of the health gain per km of walking (Table 3-1). 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 accumulated over a kilometre travelled). Our results reflect the total health gain expected over the life course of the population (but excluding any impacts on public-sector health costs). Discounting was not applied to the estimated health gains to enable us to monetise a QALY with different discount rates (i.e. to prevent double discounting) (Table 3-2).

Table 3-1: Estimated physical activity-related health impacts (in QALYs) of different modes of travel

Mode	QALYs gained per million km travelled
Walking	12.94
Cycling	7.13
E-biking	6.06
Scooter	6.99
Skateboard	5.78

Table 3-2: Estimated net monetary benefits for physical activity-related health gains associated with different modes of travel

	Net monetary benefit (2018/19 NZD, per km)				
	Health sector discount rate	Transport sector discount rates			Treasury discount rate
	3.5%	4%	3%	6%	5%
QALY value	$194,769	$211,204	$178,938	$282,126	$247,714
Walking	2.52	2.73	2.32	3.65	3.21
Biking	1.39	1.51	1.28	2.01	1.77
E-biking	1.18	1.28	1.08	1.71	1.50
Scooter	1.36	1.48	1.25	1.97	1.73
Skateboard	1.13	1.22	1.03	1.63	1.43

3.1.2 Health system costs

Travelling with active modes of transport, or modes that are associated with active travel, results in cost-savings to the health system in addition to individual benefits from improved health, as summarised in Table 3-3. Increased physical activity that results from active transport results in reduced incidence of non-communicable diseases (e.g. cardiovascular disease, selected cancers). Decreased incidence of non-communicable diseases results in savings to the healthcare system, even after accounting for increases in costs associated with increased longevity. As with estimates of the health gain, health system cost estimates reflect the total over the life course of the 2011 New Zealand population and do not represent annual cost savings.

Table 3-3: Health system cost savings associated with different modes of travel (undiscounted, additional to monetised health benefits in Table 3-2).

Mode	2018/19 NZD per kilometre
Walking	0.155
Cycling	0.088
E-biking	0.074
Scooter	0.086
Skateboard	0.071

Taking these health system cost savings together with the socio-economic cost savings to the individuals concerned in the previous section, our conclusion (based on a 4% discount rate) is that there would be a reduction in economic costs (or a net economic benefit) to society of $2.885 per km walked or $1.598 per km cycled, relative to no travel or to travel by car or other modes which do not involve significant physical activity.

3.1.3 Additional analyses

We find decreasing marginal returns from greater increases in distances travelled by walking and cycling (see Figure 3-1). This finding is expected given the underlying dose-response relationships between physical activity and disease incidence. As distances travelled by walking and cycling increase, a greater proportion of the population are taking part in higher levels of physical activity, with decreasing marginal benefits. For example, 83% of the potential health gains per million kilometres are achieved at 50% of the modelled physical activity increase (assuming this is distributed across the entire population). As per the main results, cycling has smaller benefits per kilometre than walking because less physical activity is required in order to travel a kilometre.

Our results show that the per km health gains for walking and cycling are considerably larger for those that are the least active (<100 minutes of moderate intensity activity per week or equivalent) (Table 3-5 -may be compared with Table 3-1, Table 3-2 and Table 3-3, which relate to people with average activity). Correspondingly, the health system cost savings (per million kms) are larger for the less active than for those who are more active.

3.2 Conclusions

We calculate the benefits associated with physical activity-related health impacts of different modes of transport. Our results represent the lifetime impacts per kilometre travelled by the mode in question.

The health impacts of a given kilometre increase in walking and cycling are greatest for those who are least active. We note that there would be greater health benefits (per km travelled by active modes) of encouraging active modes of transport in geographic areas or populations that currently have lower levels of physical activity.

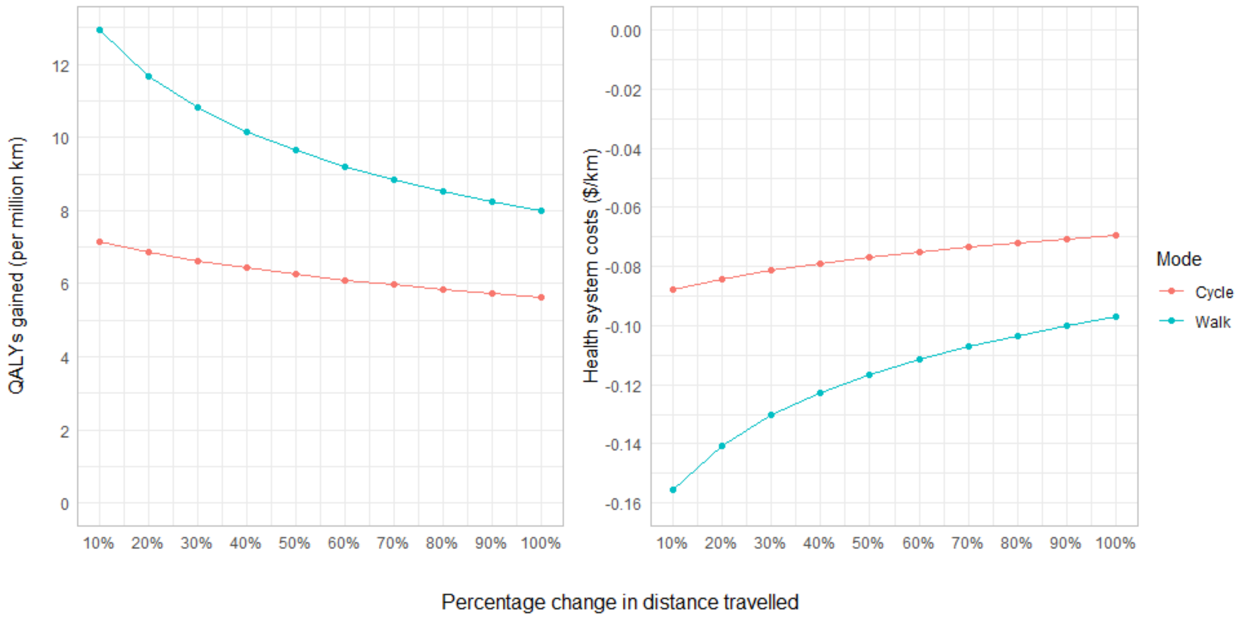

Figure 3-1: Sensitivity of results to magnitude of change in distance travelled

Table 3-4: Physical activity-related health impact results assuming travel is made by those who are least active

	QALYs per million km	Net monetary benefit (2018/19 NZD, per km)*	Health system benefit (2018/19 NZD, per km)
Walking	24.80	4.83	0.30
Cycling	16.80	3.27	0.21

Note:*Using a QALY value of $211,204

We use an established multi-state life-table framework that has been extensively used to evaluate the health impacts of different interventions and behaviours in New Zealand, including evaluations of changing transport patterns (Mizdrak et al., 2019). PAATM accounts for the large potential gains from increasing physical activity due to the low current levels of physical activity in New Zealand. It also accounts for decreasing marginal returns on increasing physical activity that reflect the dose-response relationship between physical activity and various non-communicable disease outcomes (Kyu et al., 2016, Wahid et al., 2016)

Our methodology also means that we capture the individual level health impacts in addition to health system impacts of poor health resulting from physical inactivity. We present the relative size of these two components of the public health costs associated with different modes of transport.

We find that the direct health impacts outweigh the health system costs in terms of the magnitude impact – on a per km basis, health system cost impacts are 5% of the overall health impact.

Our results likely respresent a conservative estimate of the impact of different modes of transport on public health. There is increasing evidence that physical activity impacts on a much larger number of conditions than those modelled here, including on a number of mental health conditions (2018 Physical Activity Guidelines Advisory Committee Scientific Report, 2018). Our work implicitly assumes that transport-related physical activity has the same health impact as physical activity gained in other domains (e.g. leisure). Whilst we believe this assumption is robust for the physical health impacts (e.g. cardiovascular disease), there may be important differences in the mental health impacts of different types of physical activity (see Teychenne et al. (2020)) that would warrant careful consideration prior to incorporating mental health impacts into our methodology.

3.2.1 Comparisons with similar work

The values presented in this report differ from those presented in previous NZ assessments on this topic, (Genter et al. (2008) and Weerappulige and Khoo (2020)) (Table 8) for two main reasons. Firstly, the value assigned to a QALY/DALY is substantially different because Genter et al and Weerappulige and Khoo did not apply a discount rate to determine the present discounted value of a year of life from VSL. This means that using the values derived in those reports will substantially underestimate the social value of extended or improved life in the future (see methodology section for further details).

Secondly, the methodologies to determine the changes in health from the uptake of walking or cycling are substantially different between this study and Genter et al. (2008) and Weerappulige and Khoo (2020). Genter et al. (2008) and Weerappulige and Khoo (2020) use a comparative risk assessment approach that assumes that any changes in physical activity have always applied and the health benefits are realised instantly. However, if people increase their physical activity today, then many of the health impacts may not be realised until many years later (e.g. impact on cancers). The use of the comparative risk assessment approach in Genter et al. (2008) and Weerappulige and Khoo (2020) therefore results in an overestimate of the health gains of physical activity. The approach used here accounts for the time lag between changes in activity and changes in risk of disease. This results in a more nuanced and realistic estimation of the total health benefits associated with changes in physical activity and, therefore, a more accurate estimate of the per km value of active modes.

Finally, our approach differs from that of Genter et al. (2008) and Weerappulige and Khoo (2020) by accounting for the expected life remaining. Both Genter et al. (2008) and Weerappulige and Khoo (2020) value the premature mortality associated with physical inactivity at the full VSL, rather than as a proportion based on expected life remaining. Again, we consider our estimates are more realistic.

Table 3-5: Comparison of per km health benefit values

	Genter et al (2007 $)			Weerappulige & Khoo (2018 $)	This report (2018/19 $)
	Low	Medium	High		
Walking	$3.53	$4.27	$5.01	$4.40	$2.90
Cycling	$1.77	$2.14	$2.51	$2.20	$1.60
E-biking	-	-	-	$1.00	$1.36

3.2.2 Use of estimates in project appraisal

Our estimates of the physical activity-related health benefits can be used directly to give an idea of the physical activity impacts of different transport initiatives. In particular, our estimates are likely to be beneficial in the appraisal of projects and policies that encourage novel active transport behaviour, or mode shift to active transport. For example, if a new 10km cycleway linking two destinations is expected to have 200,000 users per year, the expected physical activity impact would be calculated by multiplying together the length (10km), number of users (200,000), and value of a km cycled ($1.51 health benefit (4% discount rate – from Table 3-2), $0.088 health system cost savings (total, undiscounted – from Table 3-3). This would give an estimated benefit of $3.02 million in health gains and save the health system around $176,000, over the lifetime of the cycleway users. This calculation assumes that the cycleway users would not otherwise make the same trip by bike or other active mode (e.g. if they would otherwise not travel or would make the same trip by car).

The 'true' health impacts associated with increased physical activity will differ depending on a number of population characteristics (including but not limited to health status, current physical activity levels, age). Ideally, a detailed health impact assessment based on the population targeted by a transport project would be conducted that would account for these differences. However, our estimates are designed to provide a reasonable proxy that ensure that physical activity impacts can be readily incorporated into economic appraisals where there is limited time or resource to conduct more detailed health impact assessments.

Chapter 4 Limitations and future updates

4.1 Guidance for updating

This Working Paper uses an established multi-state life table model to estimate marginal (incremental) costs for the physical activity-related health impacts of different modes of transport. Population characteristics (such as disease rates) used in the model are unlikely to change substantially enough to radically alter the estimates presented in this Working Paper. Annual update of costs to account for inflation (e.g. using the New Zealand Consumer Price Index) is likely to be adequate.

In its present form, PAATM is not publicly available due to the need for specialist training to run and appropriately process model results. However, work is currently underway to provide an open-access and more user-friendly model interface in years to come.

To update the values in this Working Paper with a new or alternative VSL the formula in section 2.3.2 should firstly be used to determine the appropriate VSLY. This new VSLY can then be used with the QALY per million km values from Table 3-2 to determine a new per km dollar value (according to the mode involved) of the social costs of transport-related physical activity.

4.2 Limitations and exclusions

We were unable to consider some of the wider impacts of public health impacts beyond the health system (e.g. workforce productivity, out-of-pocket health expenditure). Recent research has found that illness accounts for approximately $2.6 billion (2018 USD – approximately $3.8 billion in 2018 NZD) income loss per year amoung 25-64 year olds in New Zealand (approximately 4.5% of total income in this population group) (Blakely et al., in preparation). By reducing illness through increased physical activity, we would also expect an impact on workforce participation and productivity. Disease-specific estimates of income loss for the same diseases modelled would be required to quantify income losses relating to different transport modes using our methodology. These disease-specific estimates were not available at the time of writing, but it is possible that such estimates could be incorporated in future work.

Our estimates of health system cost impacts capture publicly-funded health events, but do not capture private healthcare costs. The majority of healthcare in New Zealand is publicly funded, albeit with variation across different diseases and health conditions. Our results may be a slight under-estimate of true health system costs, but the impact is likely to be minimal given that the health conditions captured in the model are ones with minimal private sector involvement.

We note that by including a physical activity component for public transport modes, there is the potential to double-count benefits arising from promoting active transit modes. However, as new public transport routes may be considered separately from wider public transport investments, our estimate of the public health impact associated with these modes provides decision-makers with the ability to estimate the costs associated with physical activity benefits of public transport based on expected patronage of services at a generic level, regardless of the availability of specific estimates for access/egress by active transport. To prevent double-counting, users should use our scaled public transport estimates (e.g.as in Table 2.4), only where separate information on walking for access/egress to/from public transport is not available.

4.3 Potential areas for further work

A number of areas have been identified in which further work could expand the scope of our current understanding and estimates of the health and related impacts of transport-related physical activity.

Firstly, further work to ascertain impacts of transport-related physical activity on obesity and mental health would be valuable to understand the additional health benefits that may accrue to active transport users (beyond those covered here). At present, the link between transport-related physical activity and both obesity and mental health outcomes is unclear. For example, increasing walking and cycling may result in weight loss if individuals do not consume additional food to compensate for the energy expended while walking and cycling. However, the extent of compensation of energy expended through physical activity with energy intake from increased food is currently unknown.

Secondly, evaluation of the appropriateness of the application of the VSL to non-injury health impacts and/or alternative valuation of health gains is needed. As noted in section 2.1.1, work is currently underway to update the transport VSL. For the VSL update to be useful for this sort of health impact valuation it is important that the survey is designed to assess the values society places on avoiding the types of chronic illnesses discussed in this Working Paper as well as those for injury. The VSL update also provides an opportunity to assess the value placed on a QALY directly by incorporating questions that assess the willingness-to-pay for a gain in life expectancy or life quality. Further, the VSL update offers the chance to assess the contribution of lost productivity to the overall VSL, allowing us to get a clearer estimate of the productivity costs of temporary and permanent disability or illness.

Thirdly, the work outlined in this paper indicates a strong case for the inclusion of health-related benefits (and costs) in the 'standard' transport evaluation procedures used in NZ (as in the Waka Kotahi MBCM). The work outlined in this paper, together with selected earlier NZ-based research studies, would appear to provide the basis for updating and enhancement of the current MBCM health-related evaluation procedures.

Finally, behavioural research on the impact of specific policies and infrastructure investments on active transport patterns is needed. We provide a straight-forward example of the use of our estimates for appraisal purposes but acknowledge that policymakers may lack information on how specific investments are likely to change active transport behaviours. For example, policies to change speed limits along particular stretches of road are likely to have knock-on impacts on walking and cycling. Whilst our estimates could be used to examine the physical activity-related impacts of such changes, there may be insufficient data on likely behaviour changes to enable detailed appraisal in such instances. In general, while this paper offers enhanced evaluation methods for assessing the impacts of active transport initiatives on an 'ex ante' basis, there is a strong case for more and better 'ex post' evaluations of such initiatives - which in turn should lead over time to improvements in 'ex ante' assessment procedures .

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 D3

Health Impacts of Active Transport

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