HEALTH AND ACTIVE MODES IMPACTS

A technical paper prepared for the Investment Decision-Making Framework Review

11 MARCH 2020

Waka Kotahi NZ Transport Agency is developing a new Monetised Benefits and Costs Manual (MBCM) to replace the existing Economic Evaluation Manual (EEM). Parameter values for health and active modes, including the use of e-bikes, have been updated.

Key findings of the review are that there is strong evidence on the health benefits of physical activity. Electric-assisted cycling through pedal-assist type electric bicycles can provide moderate level intensity and related health benefits. There is a lack of evidence on the level of physical activity provided by electric scooters. A local case study carried out in Auckland found that electric bicycle commuters travel up to 15km each way for work compared with 5km on a conventional bicycle. Electric scooter users utilising shared platform devices typically travel around 1.1km per trip (median), which suggests this is not a key mode for commuting to work purposes. 40% of surveyed electric scooter users in Christchurch indicated that they would have walked otherwise. The majority of surveyed users also indicated their main trip purposes to be for recreation, social outings, and running errands.

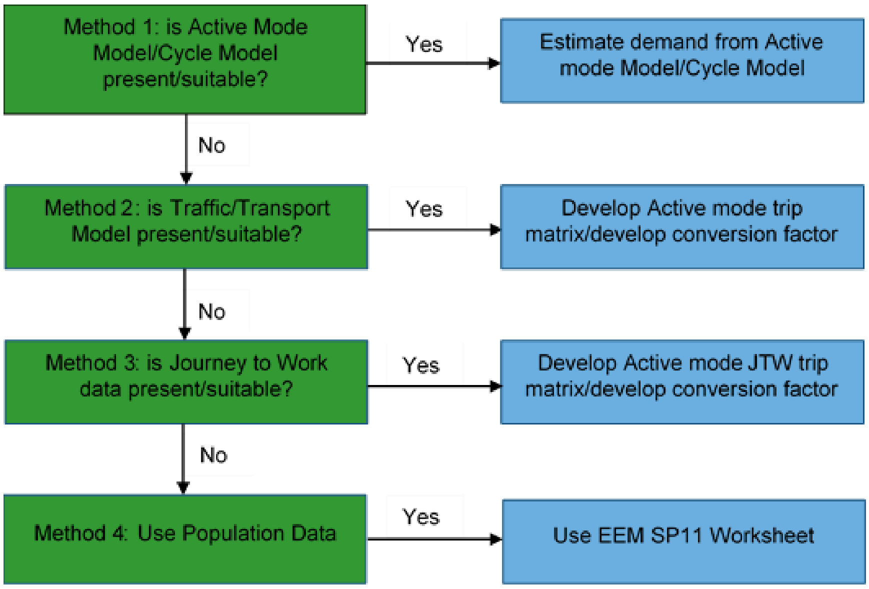
As a result of the review a revision to parameter value benefits is recommended as set out in table 1.

Table 1: Recommended health benefit values, on a per km basis

Active Mode Type	2020 proposed values		Existing
	Health Benefits for New User ($/km)	**Maximum Annual Benefit per New User (2018 $)**	**Health benefits for new User ($/km)**
Conventional cycling	$2.20	$2,500	$1.30
Walking	$4.40	$1,250	$2.60
Electric assisted cycling	$1.00	$2,000	n/a

Demand Estimation

A demand estimation procedure for the active modes, including the electric assisted modes, illustrated below, has been developed as part of this work.



Further work on developing demand estimation is being undertaken by a research project initiated by the Urban Mobility team. The results of this research can be incorporated into the Economic Evaluation Manual (EEM) when that is available. These results may be available in 2021.

This report was commission by Waka Kotahi NZ Transport Agency and prepared by Ayesha Weerappulige and Jerry Khoo.

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EXECUTIVE SUMMARY

Background

The health benefits framework was first brought into the New Zealand transport economic evaluation framework in 2002 under the then Transfund Project Evaluation Manual. Further work, carried out in 2007 and 2008, formed the basis of health benefit values adopted in the Economic Evaluation Manual (EEM).

Since the last iteration of the EEM, there has been an emergence and observed uptake of electric assisted modes such as electric bicycles and electric scooters within New Zealand. As such, there is a need to review the health benefit framework in the current EEM and assess if health benefits can be attributed to any of the emerging electric assisted modes.

Approach and scope

As part of the EEM update project, Waka Kotahi NZ Transport Agency commissioned a review of the health benefits framework. This also included a review of the demand estimation methods used for the active modes, such as walking and cycling, and for the electric assisted active modes, such as electric bicycles and electric scooters.

This review investigated recent research and studies that could supplement the current EEM health benefits framework. A literature review was conducted to assist with ascertaining the health benefits attributable when converting a sedentary person to an active person and developing the demand estimation framework. This review also considered and recommended further improvements that can be made for the valuation and appraisal of health benefits.

Findings

The key findings from our literature review are as follows:

Physical activity requirements

- There is strong evidence of health linkages to physical activity.
- A minimum of 150 minutes per week of moderate physical activity is recommended for 18–64-year olds. This is equivalent to 30 minutes per weekday and was used in the previous EEM Health Framework evaluation.
- In European cities, cycling as an activity has been shown to achieve the weekly physical activity recommendations set by the World Health Organisation.
- 51% of adults in New Zealand are physically active for at least 30 minutes per day for five or more days per week.
- Physical inactivity is estimated to account for approximately 3% of all health benefits lost in New Zealand.

Electric assisted modes

- Electric assisted cycling, through pedal assist type electric bicycles, can provide moderate physical level intensity
- There is a lack of evidence on the level of physical activity provided by electric scooters
- A local case study carried out in Auckland found that electric bicycle commuters travel up to 15km each way for work compared with 5km on a conventional bicycle
- There is a lack of information and research on distances covered by people that use privately owned electric scooters
- Electric scooter users utilising shared platform devices typically travel around 1.1km per trip (median), which suggests this is not a key mode for commuting to work purposes. 40% of surveyed electric scooter users in Christchurch indicated that they would have walked otherwise. The majority of surveyed users also indicated their main trip purposes to be for recreation, social outings, and running errands.

Growth trends

- Bicycle purchasing levels in New Zealand are comparable to Australia and several European countries.
- There is strong growth in electric bicycle sales in Europe, particularly in the Netherlands where it has exceeded 40% of total bicycle sales.
- Electric bicycles are experiencing strong growth in the electric bicycles import market in New Zealand and are estimated to be around 15% of the total bicycle import.
- Anecdotal evidence suggests that the size of the electric bicycle market in New Zealand will continue to grow.
- Local research indicates that pricing could still be a barrier for uptake of electric bicycles especially for lower socio-economic groups.

Recommendations

This review has suggested updated health benefits for the active modes and estimated for electric assisted cycling. The values recommended are shown in Table 1 below.

Table 1: Recommended health benefit values on a per km basis

Active mode type	Health benefits for new user ($/km)	Maximum annual benefit per new user (2018 $)
Conventional cycling	$2.20	$2,500
Walking	$4.40	$1,250
Electric assisted cycling	$1.00	$2,000

This review has not found any research or evidence on the level of physical activity provided by electric scooters and as such it is recommended that health benefits for electric scooters will not apply until further research can substantiate the level of physical activity for this mode of travel.

A demand estimation procedure for the active modes, including the electric assisted modes illustrated below, is also proposed.

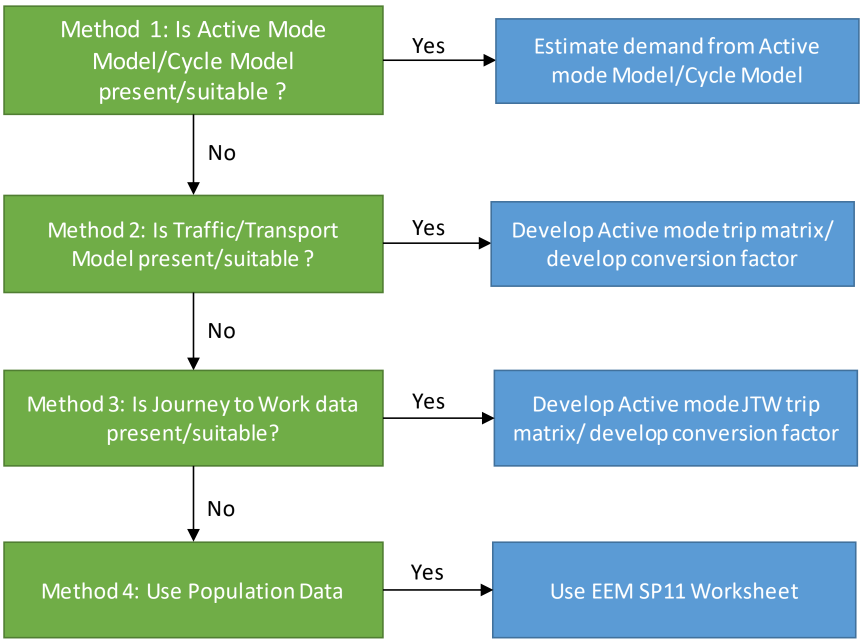

Figure 1: Demand Estimation Methods Procedure

Key items in the demand estimation methods for active modes require further work before inclusion into the EEM, such as:

- further development or guidance on the active mode share vs trip distance distribution curve. This curve is location specific and guidance could potentially surround the type of user and land use characteristics (eg major city, regional towns)
- develop a trip distribution curve for the electric assisted modes.

The further requirements above are mainly for Method 2. Once these are further refined, the above framework and guidance note can be updated by Waka Kotahi and included in the EEM.

Key recommendations of this review are provided in Table 2. The priority for delivery (from a time and resourcing perspective) is based on the relative ease of implementation (easy, medium or hard) as well as corresponding benefits (high, medium or low).

Table 2: Other Key Recommendations

Recommendations	Priority
Ensure that equity distributional impacts will be reported in the Business Case process. Specifically, this should be reported in the proposed Appraisal Summary Table that is being developed through Waka Kotahi and Ministry of Transport Investment Decision Making Framework (IDMF) review.	1st priority
That the demand estimation procedure from this review be used as a starting point to estimate the demand of active modes. That Waka Kotahi follow up with Tauranga City Council in early 2020 to determine if their work can inform the initial EEM guidance. Ideally this would occur prior to completion of the Waka Kotahi research projects that are due for completion in late 2020.	1st priority
Fund research on assessing the mental health benefits for consideration as part of the health benefit framework.	2nd priority
Fund research to further understand and assess the health benefits gained among specific ethnicity groups through the use of active mode and electric active mode transport.	2nd priority
Quantify the health impact of air pollution as a part of vehicle emission costs.	2nd priority
Establish the monitoring of active mode and electric assisted active mode activities in conjunction with the local authorities.	Strategic
Assess any potential vehicle ownership and operating cost savings for the low socio-economic groups through incentives and/or financial assistance (eg as part of vehicle purchase feebate scheme).	Strategic
Waka Kotahi to explore with NZ Customs the ability to introduce sub-codes for the import categories of bicycles and the electric assisted modes.	Strategic
Carry out or monitor any international research regarding physical activity levels and associated health benefits achieved by electric scooter users.	Low priority

1. CONTEXT

1.1 Introduction

Waka Kotahi is currently reviewing its wider Investment Decision Making Framework (IDMF). This includes methods used to prioritise and allocate the National Land Transport Fund (NLTF) and the Economic Evaluation Manual (EEM).

As part of the EEM update project, Waka Kotahi commissioned a review of the health benefits framework. This includes:

- demand estimation methods for the active modes, such as walking and cycling
- demand estimation methods for the electric assisted active modes, such as electric bicycles and electric scooters.

The aims of this review are:

1. to evaluate updates that can be incorporated into the next version of the EEM
2. to provide recommendations for future development work in this area.

1.2 Approach

An assessment of previous work was undertaken to understand the principles adopted in the current EEM health benefits framework. This included the following documents:

- Development of Procedures for the Evaluation of Cyclist Facilities (Beca, 1999)
- Health Benefits of Walking & Cycling (Beca, 2007)
- Valuing the Health Benefits of Active Modes (Genter et al., 2008).

An overview of the current EEM health benefits evaluation framework is presented in Section 2 of this report.

This Review investigated recent research and studies that could supplement the current EEM health benefits framework. A literature review was conducted to:

- ascertain the health benefits attributable to converting a sedentary person to an active person (Section 3.1)
- develop the demand estimation framework for active and electric assisted active modes (Section 3.2)

Informed by the above we have suggested several recommendations for the EEM update. These recommendations can further improve the valuation and appraisal of health benefits for the active modes, including the electric assisted active modes.

2. OVERVIEW OF ACTIVE MODES EVALUATION FRAMEWORK

2.1 The health benefits framework

This review reports on the current health benefits framework and focuses on the following key components:

1. Direct and indirect health costs
    - Direct Costs: Costs associated with the health care systems that the community and the patients bear directly (ie through tax transfers and user pay fees)
    - Indirect costs: Costs associated with the changes in quality of life (measured in morbidity and mortality), as well as lost productivity and earnings as a result of illness incurred
2. Evaluation approaches to account for the direct and indirect health costs
3. Extent of health benefits applicable to the electric assisted active modes (eg electric bicycles and electric scooters)
4. Demand estimation methods for the active modes and the electric assisted active modes
5. Practical application of health benefits.

2.2 Historical development of EEM health benefits framework

The health benefits framework was brought into the New Zealand economic evaluation framework in 2002 under the Transfund Project Evaluation Manual (PEM). This health framework was predominantly based on the Beca (1999) report for Transfund that looked at the development of procedures for the evaluation of cyclist facilities.

The methodology considered several approaches including:

- insurance premium reduction
- increased life expectancy
- death rate savings through increased cycling activity.

The range of benefit generated by these approaches was found to be between $0.05/km and $0.40/km. This generally depended on the method of estimation, longevity of activity, and other health improvements ascribed to cycling.

Due to level of uncertainty about the magnitude of the benefit, a conservative position of allowance was suggested for the PEM to allow $0.15/km or $3.00 per hour for the health benefit. The adopted value in the PEM was $0.16/km for new cyclists.

Since then, more epidemiological data was available from the Ministry of Health and Sport New Zealand (formerly Sport & Recreation New Zealand, SPARC). Waka Kotahi (formerly Land Transport New Zealand) commissioned Beca to update the attributable health benefits in 2007. Based on the information available, the health benefits and components used at that time are summarised in Table 2.1.

Table 2.1: Beca (2007) Health Benefit Components and Values

Health benefit component	Per inactive person $/year
Willingness-to-pay (WTP) of avoided years of life lost (YLL) and avoided years of life disabled (YLD), to give avoided disability adjusted life years (DALYs) per year for the total inactive population at that time (33%)	1,840
Health sector resource costs	450
Lost output resource costs	790
Total	3,080

To attribute this value to new active mode users the following methodology was applied:

- It was assumed (in the most optimistic case) that the inactive population would be attracted in proportion to their representation in the population (33%).
- Cycling is generally more strenuous than walking.
- Applying the remaining $1,000/year over the quantum of annual walk and cycle travel distance required for a change between inactive and active status.
- This resulted in the health benefit per km to be calculated at $0.80/km for walking and $0.40/km for cycling. The methodology is illustrated in Figure 2.1.

cycling)

Figure 2.1: Conversion of benefit to per km basis, illustrated based on Beca (2007)

It was noted in the 2007 report that there was considerable scope for more detailed analysis. Waka Kotahi (then Land Transport New Zealand) subsequently commissioned a more detailed research of this in 2008. Through more detailed analysis, the 2008 research report (Genter et al., 2008) estimated a mean value of $3,672 annual health benefit from converting an inactive person to an active person. This was a slight increase on the Beca (2007) estimate of $3,080. The major difference between the two reports was how this annual value was converted to a per km value for walking and cycling, which were:

1. Users deriving health benefits: The 2008 research report assumed that all users derive some health benefits, including users who are already active. A weighted factor of 0.52 was applied including the prevalence and proportion of inactiveness over three activity categories (sedentary, inactive and active). This was a 56% increase from the 2007 report which stated the value at 0.33.
2. Distance over which the benefits are received: The 2008 report applied between 624 km (active) and 1,250 km (sedentary), which implied an increase of over 100% from 2007 value.

Based on this work, Waka Kotahi adopted a health benefit rate of $1.30/km for new cyclists and $2.60/km for new pedestrians. It is unclear how Waka Kotahi arrived with these values, however this appears to be adopted based on the average of the Beca (2007) and mid-point value of the 2008 research report. The historical development summary of this is shown in Figure 2.2.

There is currently no guidance on the health benefits applicable to the electric assisted active modes.

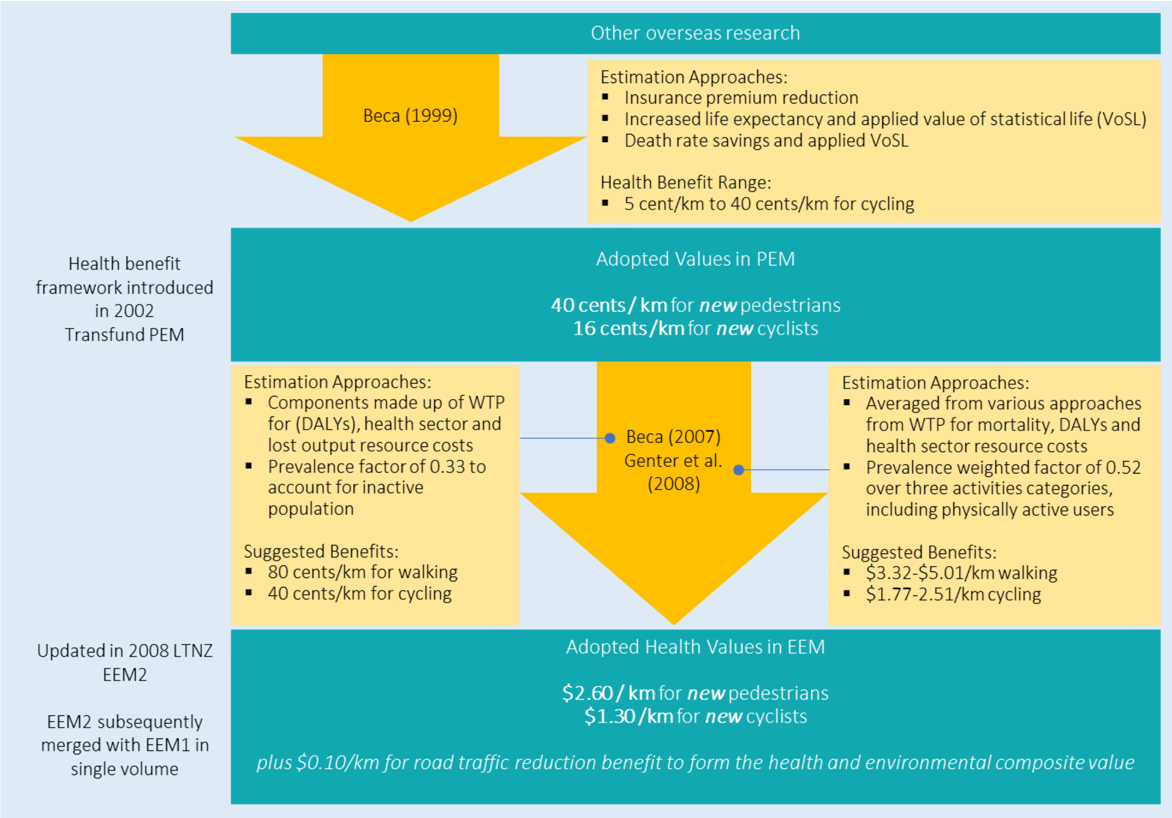

Figure 2.2: Summary of development of health benefit framework in New Zealand

2.3 Demand estimation

The main factors influencing demand for walking and cycling generally include (Waka Kotahi, 2018):

1. availability of facilities
2. type and quality of facility including cycle parking, signage, and safety of use
3. location, route length, and connectivity of walking and cycling paths or lanes population served by the facilities, and
4. education, promotion and marketing.

The Waka Kotahi EEM provides a cycle demand analysis procedure to calculate the demand for a new cycle facility. This procedure is primarily an estimation model based on the proximity of the cycling population within the project catchment area.

It provides a procedure to calculate the population within the cycle facility catchment area. It also considers the probability of new cyclists using the facility which is a function of distance from the facility and the existing commuting mode share of cycling. The cycling mode share is provided for each territorial local authority and is derived from New Zealand Census mode share data.

This procedure provides a simple and standardised approach in assessing the likely demand of a new cycle facility. However, there are some remaining challenges:

1. the procedure does not provide a solution when dealing with routes or facilities that serve the same population catchment
2. the procedure relies heavily on the population catchment area and is not suitable for project sites without a population catchment (eg industrial, commercial, and/or recreational areas)
3. the procedure does not provide enough granularity to assess the options further (eg what is the demand for a change in the level of facility provided), and

4. there is currently no guidance within the EEM to estimate the demand for walking or electric assisted active modes.

There are a number of other methods adopted in practice beyond the standard EEM procedures. For instance, a Strategic Active Mode Model (SAMM) was recently developed by the Auckland Forecasting Centre. This model uses derived land use and network data directly from its Macro Strategic Model (MSM). The data is then input into the refined zone system used in the Macro Public Transport Model (MPT).

Other demand estimation methods are briefly reviewed and presented in the literature review (Section 3.2). This includes a summary of other demand estimation procedures adopted in selected international countries, as well as specific procedures or modelling techniques adopted locally.

3. LITERATURE REVIEW

3.1 Health benefits framework

This section summarises the existing literature and research into the health benefits produced due to active mode transport. It will provide an understanding of the health benefits gained from converting a sedentary person to a physically active person. This section outlines:

- the health linkages to physical activity
- the physical activity requirements to achieve desirable health outcomes
- how health is measured and quantified
- the level of physical activity and overall health status of the New Zealand population
- linkage between active modes (including electric assisted active modes) and physical activity
- impact of air pollution
- different health benefit estimation approaches.

3.1.1 Health linkages to physical activity

Key Takeaways

- *There is strong evidence of health linkages to physical activity*
- *The risk factors of physical inactivity include cardiovascular diseases, cancer, depression, and type 2 diabetes*

Globally, health is defined as the state of physical, mental and social well-being (WHO, 2010). However, this term is typically understood as the absence of disease. In recent years, awareness surrounding mental health and general well-being is becoming prevalent.

There is strong evidence of health linkages to physical activity. Physical inactivity is the fourth leading risk attributing to global mortality (WHO, 2010). This risk factor leads to noncommunicable diseases (NCDs) such as cardiovascular diseases, cancer, and type 2 diabetes. These NCDs result in almost 70% of global deaths.

Currently, NCDs attribute to almost 50% of the overall global burden of disease (WHO, 2010). Studies have shown that people are becoming less active, resulting in health problems and economic costs which are affecting society. Physical inactivity contributes to 6% of the burden of disease from coronary heart disease (Raser et al., 2018). Physical inactivity also results in 75% of the burden of disease in type 2 diabetes and 9% in premature mortality. Chronic conditions such as cardiovascular disease (CVD), cancers, and obesity are health issues especially prevalent in New Zealand (Genter et al., 2008).

Strokes, a form of cardiovascular disease, contributes the largest amount to the economic cost of physical inactivity in New Zealand. Depression has the lowest contribution to the direct cost of physical inactivity. This is because:

- people suffering from depression may not be hospitalised
- there is currently no precise estimate for the cost of treating depression through the primary health care system in New Zealand.

However, depression can potentially have significant economic costs to individuals, family, health services, and society as a whole. Economic costs related to depression can be generated by:

- increased morbidity and mortality
- impaired social, family, educational and work functioning
- increased substance abuse (particularly alcohol) and accident rates
- increased outpatient and inpatient treatment.

3.1.2 Health quantification measures

The following metrics are used to quantify and measure health within a given population.

Quality-Adjusted Life Year (QALY): Evaluates the quality of life and estimates health gain within a population. It is a product of life expectancy and the measure of the quality of life of the remaining years. One QALY is equivalent to a year's worth of ideal health.

Disability-Adjusted Life Year (DALY): Evaluates the burden of disease and estimates health loss within a population. One DALY equates to one lost year of "healthy" life. Figure 3.1 provides an example of a DALY calculation.

Years of Life Lost (YLL): The years of life lost due to premature disability and is calculated by multiplying the number of deaths at each age.

Years Lost due to Disability (YLD): YLD is calculated by multiplying the number of disability cases with the average duration of the disability cases. This figure is then weighted by a disability factor which is also age-adjusted.

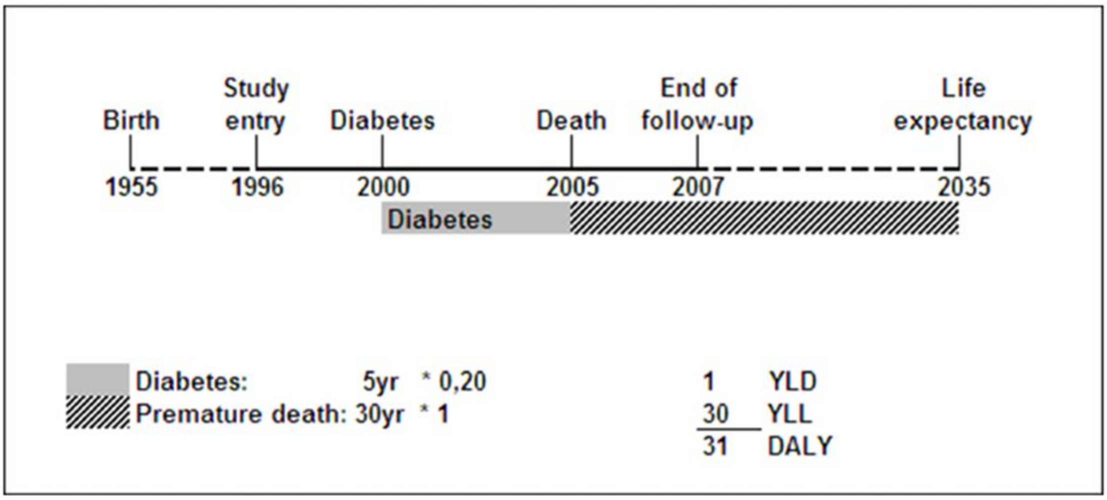

Figure 3.1: Example of DALY calculation. Disability weights of 0.20 used in calculation example (Sourced from Struijk et al, 2013)

3.1.3 Physical activity requirements

Key Takeaways

- *A minimum of 150 minutes of moderate physical activity is recommended for 18–64-year-olds. This is equivalent to 30 min per weekday and was used in the previous EEM Health Framework evaluation (refer to Figure 2.2)*
- *In European cities, cycling as an activity has been shown to achieve the weekly physical activity recommendations set by the World Health Organisation*

Physical activity is an effective method to treat health concerns relating to obesity, depression and hypertension. In recent years, the World Health Organisation (WHO) has focused on preventing noncommunicable diseases by promoting physical activity.

This is evidenced by the development of a global set of standards that define the required amount and intensity of physical activity to help prevent noncommunicable diseases. The standards identify the appropriate amount of activity based on the different age groups.

The recommendations specifically apply to cardiorespiratory health, metabolic health, musculoskeletal health, cancer, functional health (including prevention of falls), and depression (WHO, 2010). These global physical activity recommendations set by the WHO are also applied in New Zealand by the Ministry of Health.

Physical activity is characterised as undertaking at least 30 minutes of brisk walking or moderate-intensity physical activity (or equivalent vigorous activity), for at least 10 minutes at a time, five days a week (Ministry of Health, 2016). This is equivalent to 150 minutes of moderate-intensity physical activity per week.

Physical activity intensity levels can vary between sedentary, light, moderate, and vigorous:

- Light-intensity activity: Incorporates fitness which does not result in an apparent increase in heart-rate and breathing. Slow walking is an example of light-intensity activity.
- Moderate-intensity activity: Results in an apparent increase in heart-rate and breathing. Brisk walking is an example of this intensity level. Moderate-intensity physical activity has higher relevance to the public health goals of policy implementation compared to vigorous-intensity activity (WHO, 2010).
- Vigorous-intensity activity: Results in a very noticeable increase in heart-rate and breathing levels. Running is an example of vigorous-intensity activity.
- Vigorous-intensity activity: Results in a very noticeable increase in heart-rate and breathing levels. Running is an example of vigorous-intensity activity.

Figure 3.2 shows the recommended physical activity levels and amounts for three age groups (WHO, 2010).

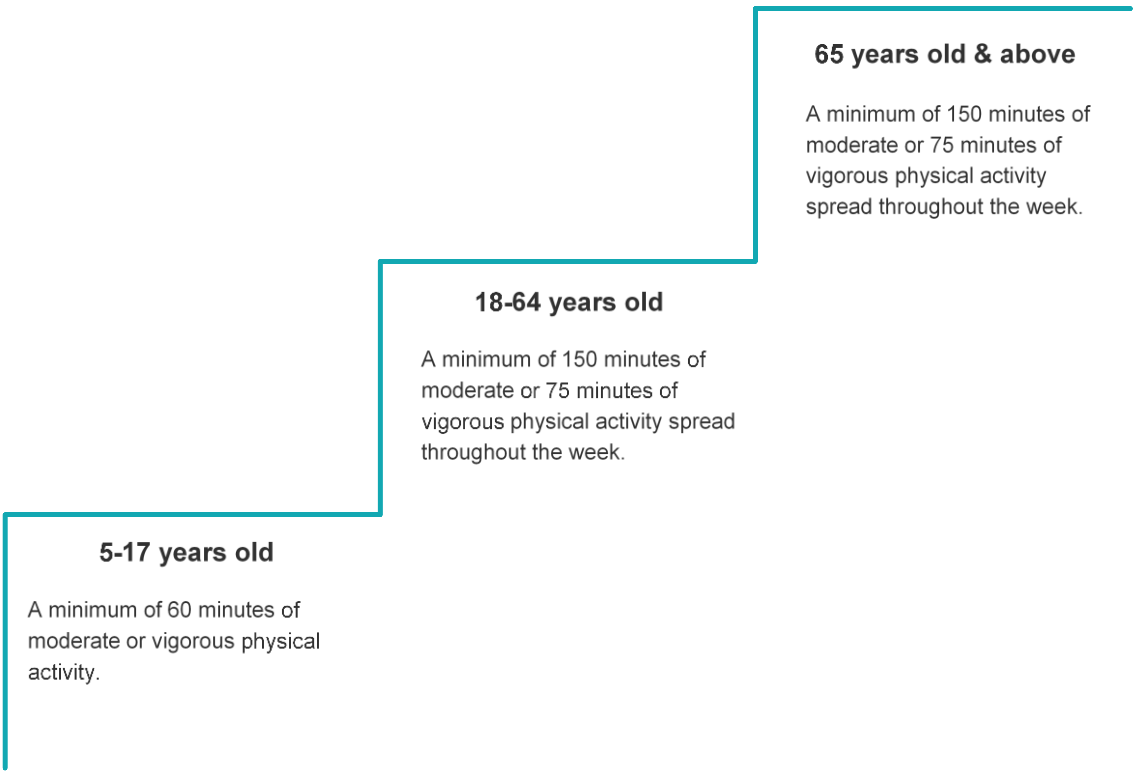

Figure 3.2: Global and New Zealand recommendations on physical activity for health benefits (WHO, 2010)

5–17 years old

- Maintaining high amounts and intensities of physical activity in childhood and continuing into adult life will result in a favourable risk profile. There are lower rates of morbidity and a lower risk of mortality to noncommunicable diseases later in life.
- Aerobic type activities are favourable to achieving greater health benefits.

- Vigorous-intensity activities allow for the strengthening of muscles and bones. This level of activity is recommended to be carried out at least three times a week.

18–64 years old

- Additional health benefits will be received if adults complete 300 minutes of moderate-intensity aerobic physical activity or 150 minutes of vigorous-intensity aerobic physical activity.
- Muscle strengthening activities two or more days per week will further provide health benefits. Biomedical benefits can be gained from undertaking regular physical activity throughout the week (5 or more times per week).
- Integrating physical activity, such as walking or cycling, into daily commuting or travel purposes will assist people in achieving the recommended weekly physical activity amount.
- Further evidence is required to identify if more than 300 minutes of physical activity per week will provide increased health benefits.

65 years old and above

- The older adult age population group is generally considered to be the most inactive.
- An individual in this age group who exerts low physical fitness will require a lower amount and intensity of physical activity to achieve the same health benefits when compared to other age groups. This is due to older population groups generally having lower exercise capacities.
- Exercise for older adults with poor mobility is considered safe. Regular exercise can reduce the risk of falls by approximately 30% (WHO, 2010). The most suited physical activity trains balance and incorporates moderate-intensity muscle strengthening movements.
- Similarly, to the adult age group between 18–64 years, older adults should increase moderate-intensity physical activity to 300 minutes per week or increase vigorous-intensity aerobic physical activity to 150 minutes per week to gain additional health benefits.
- However, evidence suggests decreasing marginal benefits will result from physical activity amounts above 300 minutes of moderate-intensity physical activity per week. Exceeding the WHO recommendation can result in a higher risk of injury.

A study was carried out to assess cyclist behaviour in seven European cities. It showed that a high proportion of cyclists were able to achieve the weekly recommendation of moderate physical activity solely due to their daily commute and travel purposes (Raser et al., 2018).

3.1.4 New Zealand's health status

Key Takeaways

- *Low levels of physical activity are estimated to account for approximately 3% of all health benefits lost*
- *51% of adults in New Zealand are physically active for at least 30 minutes 5 or more days per week*
- *Approximately 50% of all age groups between 18 to 64-year olds meet the guidelines for physical activity. This is 42% for the 15 to 17-year-old age group, 46% for the 65–74-year-old age group and 33% for the 75-year-old and above age group*
- *Pacific (44%) and Asian (39%) ethnicity groups have lower proportions of a physically active population compared to European (50%) and Maori (50%) ethnic groups*
- *New Zealanders lose over 1 million years of healthy life each year (DALYs) due to low levels of physical activity*
- *246 premature New Zealand deaths (deaths occurring before 65 years old) occurred in 2009 due to physical inactivity alone*

The Annual Update of Key Results 2013/14 (Ministry of Health, 2016) states that 51% of adults in New Zealand are physically active for at least 30 minutes on five or more days per week. 14% of adults are physically active for less than 30 minutes per week. According to the University of Auckland's Youth' 12 national survey, only 10% of secondary school students carry out the recommended 60 minutes of daily physical activity.

New Zealanders lose over 1 million years of healthy life each year. An average of 1,092,000 DALYs were lost each year between 1990 and 2013 (Ministry of Health, 2016). In 2013, the DALYs were divided between males (51.5%) and females (48.5%). Considering differences in population size and age structure, it was found that males experience 15% more health loss than females (age-standardised DALY rates in 2013 of 225 per 1000 and 195 per 1000, respectively).

Low levels of physical activity are estimated to account for approximately 3% of all health lost (Health Loss in New Zealand, The Ministry of Health, 2016). This review found that:

- half of this cost can be attributed to health promotion and health expenditure costs
- the other half of the cost is due to indirect expenses such as pain, suffering, and loss of productivity
- a previous study (Market Economics, 2013) estimated that physical inactivity cost New Zealand $1.3 billion in 2010, which is equivalent to 0.7% of GDP. This cost has increased by a staggering amount since 1992, when the estimated cost of physical inactivity was $179 million (equivalent to $270m in 2010 when accounting for inflation).

The Lancet medical journal ranked New Zealand 27th out of 122 countries on a list of the most inactive countries. 246 premature New Zealand deaths (deaths occurring before 65 years old) occurred in 2009 due to physical inactivity alone (Market Economics, 2013).

Physical activity trends and correlation in New Zealand

Age trends

The Ministry of Health's New Zealand Health Survey examined social statistics and physical activity. The survey suggested there were similar physical activity levels across all age populations. The exception was the 75 years and above age group where just 33% were meeting physical activity guidelines (Ministry of Health, 2016). Figure 3.3 shows the comparison of various age groups in achieving physical activity guidelines.

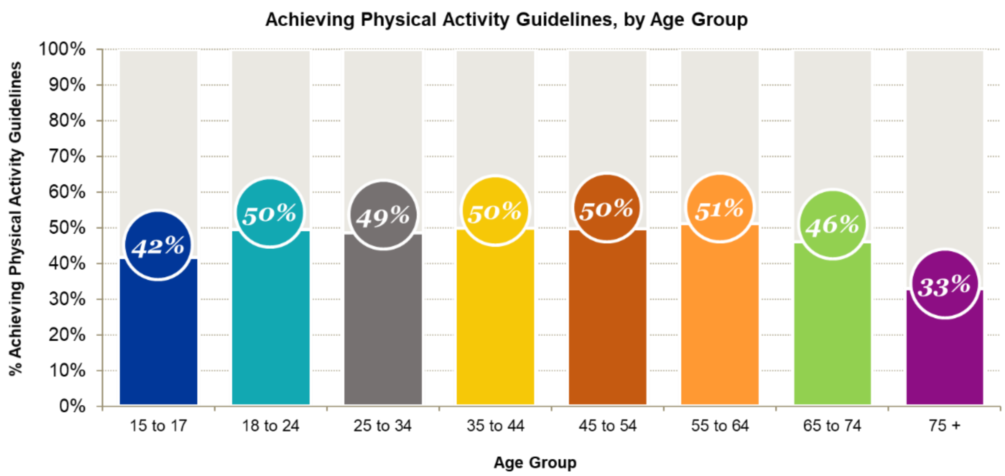

Figure 3.3: Age population group and physical activity (Stats NZ, 2017)

Gender trends

Males tend to have a higher probability of achieving the physical activity guidelines in comparison to females. 55.2% of the male population in New Zealand achieves at least 150 minutes of physical activity across a week. 48.5% of females are achieve this physical activity guideline (Ministry of Social Development, 2016).

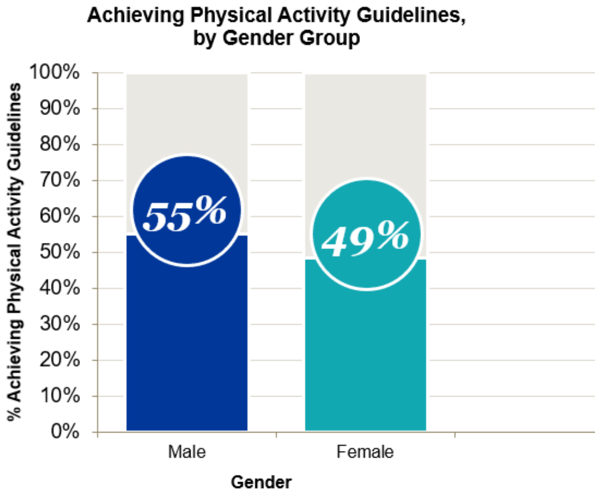

Figure 3.4: Gender and physical activity (Ministry of Social Development, 2016)

Ethnicity trends

The Ministry of Health assessed the association between ethnicity groups and the expected amount of physical activity undertaken by each ethnicity group. 49.5% and 49.6% of the European and Maori populations were achieving the physical activity guidelines (Ministry of Health, 2016). Asian and Pacific ethnicity groups were less likely to be physically active. 38.7% of Asian population and 43.8% of Pacific population achieved the physical activity guidelines in 2016 (Ministry of Health, 2016).

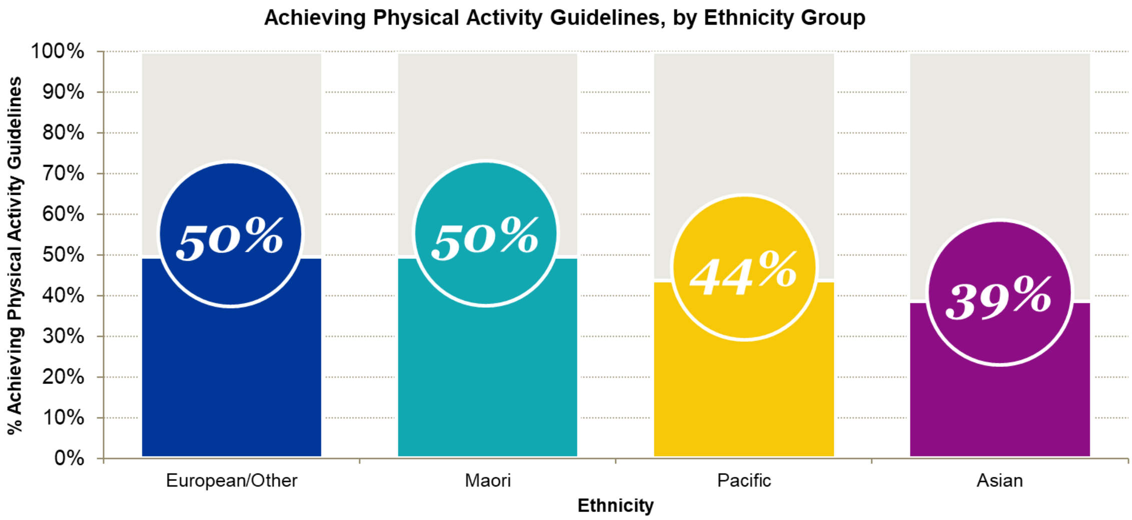

Figure 3.5: Ethnicity and physical activity (Stats NZ, 2017)

Regional trends

The 2013/2014 New Zealand Health Survey conducted by the Ministry of Health showed that people residing in Canterbury and Otago/Southland had the highest percentages of people achieving physical activity guidelines with 77% and 72.6% of the population areas respectively (Ministry of Social Development, 2016). The Auckland and Taranaki regions were found to have the lowers proportions of physical activity at 43.2% and 43.3% of the population regions respectively.

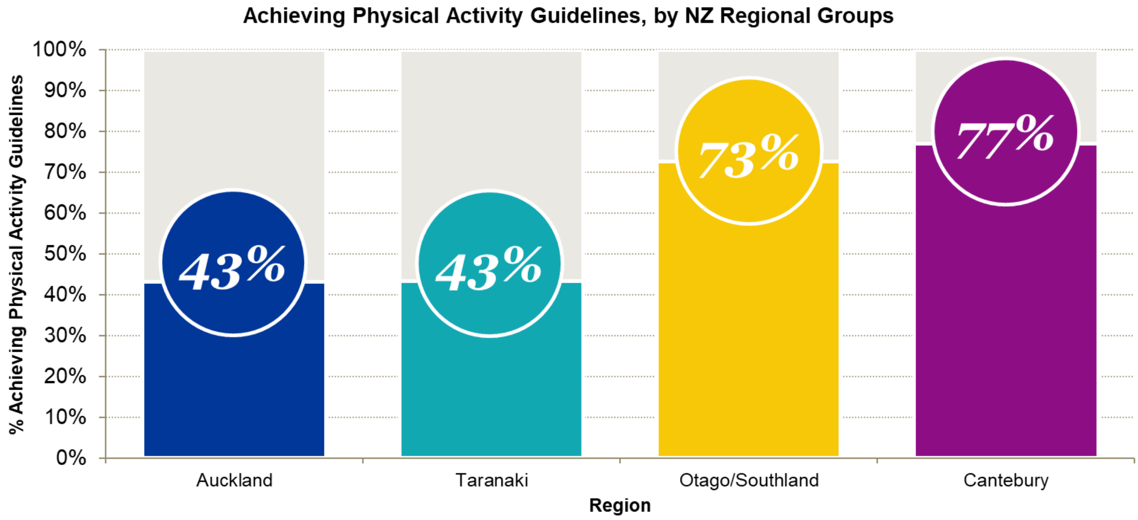

Figure 3.6: NZ regions and physical activity (Ministry of Social Development, 2016)

Socio-economic trends

The health survey also showed that there was a slight difference between the physical activity guidelines achieved by people at varying deprivation levels.

Quintiles are used to categorise the level of socioeconomic deprivation in New Zealand. Quintile 1 characterizes the population residing in the least deprived 20 percent of socio-economic area. Quintile 5 represents the population living in the most deprived 20 percent of socio-economic area.

The health survey indicated that quintile 5 had the lowest percentage of people meeting physical activity guidelines (Ministry of Social Development, 2016). Refer to Figure 3.7 for a comparison of the five quintile level areas and the percentage of the population achieve physical activity guidelines.

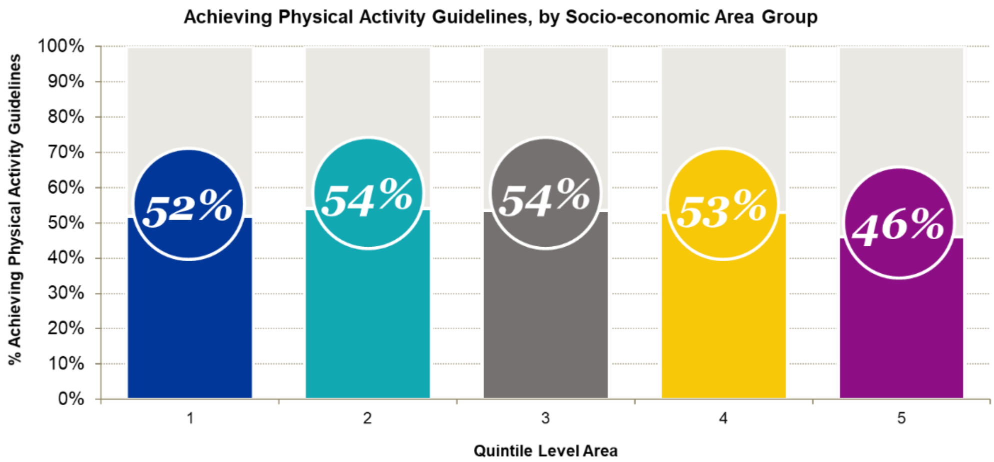

Figure 3.7: Socio-economic area and physical activity (Ministry of Social Development, 2016)

3.1.5 Linkage between transport mode and physical activity

Key Takeaways

- *Electric assisted cycling, through pedal assist type electric bicycles, can provide moderate physical level intensity*
- *There is no evidence on the level of physical activity provided by electric scooters*
- *80% of mixed mode cycling commuters and 90% of cycling only commuters meet the physical activity guidelines*

Active modes of transportation can be an effective tool to help incorporate physical activity into an individual's lifestyle.

- Hoehner et al. (2012) explains that commuting distance and time spent in a vehicle is linked to adverse effects in cardiorespiratory fitness, adiposity, and other metabolic risk factors.
- A study by the University of Glasgow (Celis-Morales et al., 2017) explored the association between different types of active commuting and cardiovascular disease, cancer, and all-cause mortality. It was found that commuting completely or partially by cycle was considered the most effective in terms of achieving physical activity guidelines.
- An article published by the University of Auckland stated that a shift in 5% of vehicle kilometres to cycling would result in increased physical activity and subsequently, health benefits where approximately 116 deaths are avoided annually (Lindsay et al.,2011).

As shown in Figure 3.8, 80% of mixed mode cycling commuters and 90% of cycling only commuters meet the physical activity guidelines.

- Cycling is considered to incorporate the highest physical activity level as cardiorespiratory fitness is involved. Cycling is also associated with the lowest risk of incident cardiovascular disease (CVD), mortality and cancer (Celis-Morales et al., 2017).
- Walking commuters are considered to achieve higher physical activity than non-active commuters but there is no cardio-respiratory fitness involved. Walking commuting is associated with a lower risk of CVD however there was no evidence to show a lower risk in cancer and mortality.
- Greater health benefits are gained from cycling due to the higher intensity exercise when compared to walking.

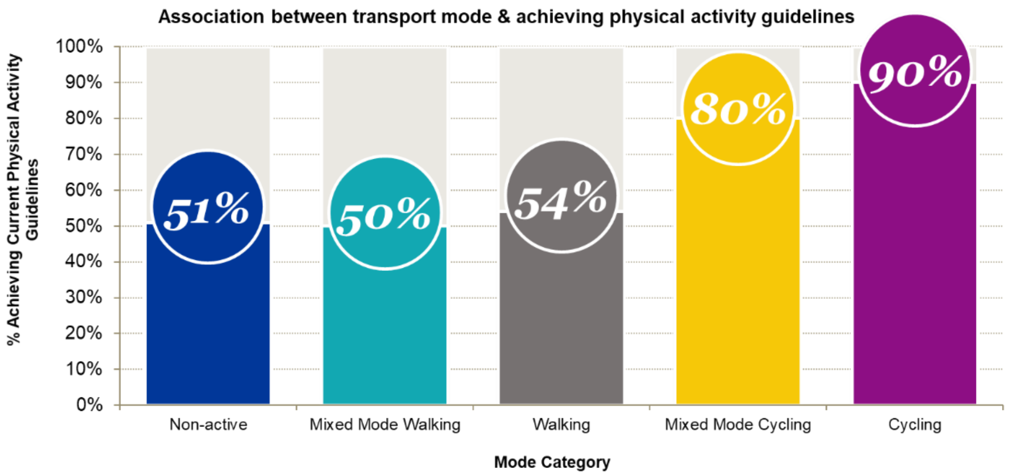

Figure 3.8: Transport mode and physical activity (Celis-Morales et al., 2017)

The level of physical activity is often measured in terms of metabolic equivalent of task (MET). The MET is an objective measure of the ratio of the rate at which a person expends energy. This is relative to the mass of person, measured while performing specific physical activity, and compared to a reference. The reference is set at the energy expended when sitting quietly which is roughly equivalent to 3.5 ml of oxygen per kg per minute.

Figure 3.9 shows the MET ranges for each intensity level of physical activity from sedentary to vigorous.

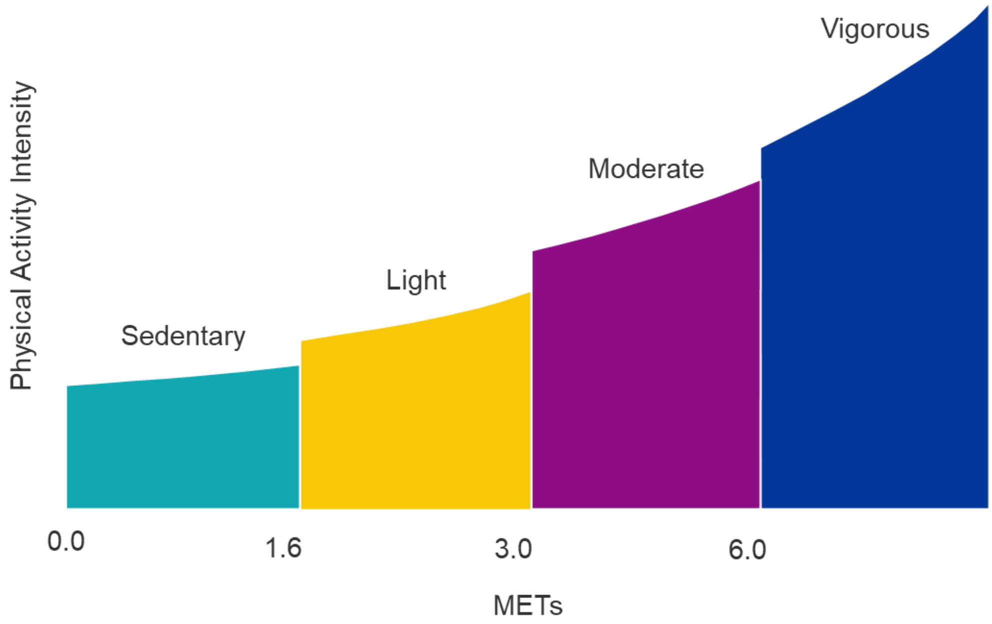

Figure 3.9: Physical activity intensity level and associated MET range (Malnes, 2016).

A systematic review of the health benefits provided by electric bicycles was undertaken in 2018 (Bourne et al., 2018). This systematic review examined the physical activity, cardiorespiratory, metabolic, and psychological outcomes associated with electric-cycling (for pedal assistance type only). These outcomes were compared against conventional forms of cycling and walking, where possible.

This systematic review looked at seven electronic databases, clinical trial registers, grey literature, and reference lists to identify previous studies carried out. 17 studies (11 acute experiments and six longitudinal interventions) were identified involving a total of 300 participants. This systematic review found that:

- electric cycling has lower physiological markers of intensity than conventional cycling
- the mean and median of estimated METs attributed to conventional cycling or electric cycling without assistance was found to be 6.1 and 8.5 respectively
- the mean and median of estimated METs attributed to assisted electric cycling was found to be 4.9 and 8.3 respectively
- the strength of this finding depends on the physiological assessment measure and route topography.

There is moderate evidence showing electric cycling provides individuals moderate intensity physical activity. This result is also deemed to represent the average users well. Studies have also shown that more physically able and active users do not use the full capacity of the electric assistance available on electric bicycles. The average heart rate on an electric pedal assist mountain bike was found to be 94% of the average heart rate of the conventional mountain biking use (Hall et al., 2019).

This review has not found any research or evidence on the level of physical activity provided by electric scooters. It is likely that there is limited physical exertion while using an electric scooter. Therefore, health benefits will not apply until further research can substantiate the level of physical activity for this mode of travel.

3.1.6 Relationship between air pollution and active transportation

Key Takeaways

- *Mode shift from motorised vehicles to active modes can reduce carbon emissions in the transport system*
- *Active mode users exposed to air pollution in urban centres may have adverse health consequences. This impact should be considered as the economic spillover externality for motorised vehicles and as such this cost should be incorporated within the cost of emission*
- *There is opportunity to further quantify the emission health impact on active mode users*

Many factors should be considered when understanding the relationship between air pollution health and active transportation. Having increased active mode commuters and less vehicles on the road will reduce the amount of CO_2 emissions. However, active mode commuters may experience adverse health effects from air pollution when travelling in close proximity to motorised vehicles.

Active mode user air pollution exposure is considered high in the urban environments. This may result in adverse health consequences such as cardiovascular and respiratory diseases.

A study conducted in the Netherlands stated that cyclists tend to inhale 2.3 times the amount of air inhaled by drivers (Genter et al., 2008). Similar inhalation levels of carbon monoxide were recorded by the two different modes; however, cyclists were shown to inhale significantly larger doses of nitrogen dioxide during the same commuting distance. Factors such as frequency and duration of vehicles stopping at intersections, proximity of active mode route and motorised traffic, temperature, wind speed and street environments all affect the air pollution exposure.

Conversely, walking and cycling modes have a key role in reducing carbon emissions in transport systems. Emissions produced from cycling is approximately 10 times less than the emission produced from motorised vehicles (Neves et al., 2019).

Lindsay et al. (2011) stated that a 5% shift in vehicle kilometres to cycling would also reduce vehicle travel and this would save approximately 22 million litres of fuel and reduce transport-related greenhouse emissions by 0.4%. Six fewer deaths will also result due to reduced air pollution from vehicle emissions. After considering the adverse and positive effects of active transportation and air pollution exposure, it has been stated that the benefits gained from walking and cycling physical activity outweigh the detrimental air pollution and traffic incident risk effects (Raser et al., 2018).

There remains the ethical dilemma that an increase in active modes will likely result in an increase in the absolute number of air pollution related morbidity and mortality. It has been suggested that the economic costs of air pollution should be attributed to motor vehicles rather than active modes, ie considered as a spillover externality for motorised vehicles. As such, it is recommended that this be captured within the costs of carbon emission. Any positive or negative change can then be compared between projects or programme options.

Given the level of this impact is dependent on various factors described above, the incorporation of this health impact within the health benefit framework is likely to require further research and analysis.

3.1.7 Health benefits estimation approaches

Health benefits estimation is generally based on one or more of the following approaches:

- measure of mortality savings through evaluating reduction of mortality loss as a result of physical inactivity (or amount of avoided years of life lost, YLL)
- measure of morbidity savings through evaluating reduction of morbidity loss as a result of physical inactivity (or amount of avoided years lost due to disability, YLD)
- measure of savings in DALY, or loss of “healthy” life (DALY is essentially summation of YLL and YLD).

An example of health benefits estimation can be seen in the WHO’s Health Economic Assessment Tool (HEAT). HEAT estimates the value of reduced mortality as a result of regular walking or cycling.

There is a linear relationship between dose and response, ie an increase in physical activity is associated with a health benefit. The tool also applies a risk reduction factor for walking and cycling. A summary finding concludes that, on average, a population of regular cyclists are 10% less likely to die from all causes combined than a population of non-cyclists (WHO, 2017).

As outlined earlier in Section 2.2, the previous studies in 2007 and 2008 have also adopted similar approaches to the WHO's HEAT model. The exception is that the morbidity component is not included in the HEAT model.

The health costs for the HEAT model are considered to be the indirect costs. These costs are mostly economic costs in terms of lost productivity and earnings but also embody social psychological pain, suffering, and grief.

Expenditures by healthcare providers are considered to be the direct costs. These costs can include the cost of hospital stays, pharmaceutical medicine, and outpatient services. A previous study was conducted in 2013 to estimate the costs of physical activity in New Zealand (Market Economics, 2013). That study broadly applied the above indirect costs and accounted for the direct and other costs attributed to physical inactivity.

3.2 Demand estimation approaches

Key Takeaways

- *A number of methods are available for demand estimation purposes. The choice is largely dependent on data availability, scale of project or effort required, budget, resourcing availability, and the desired precision and accuracy*

A high-level literature review has been carried out to identify the general process of demand estimation for walking, cycling, electric cycling, and electric scootering. A number of published papers and guidelines in New Zealand, Australia, the US, and European countries were reviewed. The general choice of the demand estimation approach largely depends on the following factors which include but are not limited to:

- data availability or obtainability
- scale of the project
- budget and time available
- desired precision and accuracy.

3.2.1 Walking

The Australian Transport Assessment and Planning (ATAP) indicates that there are limitations to modelling pedestrian activity given the variations in length and purpose of trips. The variation in trip purpose can limit modelling accuracy, ie trip purposes, such as commuting and leisure travel, will respond differently to an intervention.

Our experience indicates that for walking commuting trip purposes, demand estimation methods can broadly follow the same methods used for cycling. This is described further in Section 3.2.2.

As per Federal Highway Association (FHA) Guidebook on Methods to Estimate Non-Motorized Travel, the pedestrian demand estimation methods are:

a. Sketch planning method

b. Pedestrian demand model

a. Sketch planning method

The pedestrian demand is predicted as a function of the adjacent land use in the form of a regression equation.

A case study was undertaken in mid-Manhattan, New York to predict the pedestrian volume within a high-density urban area (Pushkarev et al., 1971). Pedestrian counts were obtained from aerial photographs. These were used to determine the regression coefficients for variants (adjacent land use comprising of office, retail, and restaurants).

Another study using multiple regression analysis was done by Desyllas et al. (2003) to develop a pedestrian model applicable to large cities like London. This approach employs multiple regression analysis of independent variables against the dependent variable of observed pedestrian flow. The pedestrian counts were obtained through manual observation. Other inputs to the model were:

- land use data such as office, retail, commercial, education, vacant, public buildings, or residential
- street grid configuration modelled by Visual Graph Analysis (VGA)
- accessibility to Public Transport (included in the VGA).

The stepwise regression model is shown below:

$$
\begin{aligned}
Log(flow) = {} & A\ x \log(average\ visibility\ within\ street\ network) \\
& + B\ x\ (accessibility\ to\ London\ underground\ station) + C\ x\ pavement\ width \\
& + D\ x (\%\ of\ \ frontage\ that\ is\ retail) + Constant
\end{aligned}
$$

The R^2 value for the forecasted flows vs observed flows obtained was 0.82. This is an improved version of previous studies done by Pushkarev (1971) and Hillier (1993) who stated the value as 0.61 and 0.55 respectively.

b. Pedestrian demand model

The pedestrian demand model is a 4-step modelling process that employs regional traffic models integrated with transport planning software.

An example of this model can be seen in the work of Clifton et. al (2015) in Oregon, US. The author developed a pedestrian demand estimation tool using the 4-step demand modelling process. This included modelling pedestrian analysis zones (PAZs) and applying a destination choice model to assign the walk trips produced in each PAZ to a destination.

3.2.2 Cycling

The demand estimation methods for cycling activity can be generally classified into the following approaches:

a. Comparison studies
b. Aggregate behaviour studies
c. Sketch planning method
d. Discrete choice models
e. Traditional demand models
f. GIS-based approaches
g. Combination of the above approaches

a. Comparison studies

This method predicts cycle demand by comparing the cycle facility with a similar facility based on comparable population and land use characteristics. There are two types of before and after comparison studies:

- compare the usage levels before and after a facility improvement
- compare travel levels across facilities with similar characteristics.

An example of the comparative study method is given in the United Kingdom Department for Transport (DfT) online Transport Analysis Guidance (WebTAG) for active travel mode appraisal.

- The demand impact is estimated by reference to before and after demand surveys for a completed active travel initiative in a similar area.
- The comparative analogous initiative in a similar area is used to derive 'with project' (project case) demand estimates.
- Underlying demand growth rates in the catchment area of the proposed active travel initiative are used to estimate 'without project' (base case) demand.

A feasibility study of a rail trail in Central Massachusetts (Lewis and James, 1997) estimated the cycle demand using comparison analysis. The users of this trail would be primarily commuters and school children during weekdays in regular commuter hours. Retirees and stay-at-home parents would use the trail for recreational purposes during the middle part of the day. An estimate of the demand for the proposed rail trail, known as Central Mass, was determined by comparing counts to a similar cycle facility known as Minuteman.

The following types of comparison studies were used to estimate the demand of the Central Mass rail trail:

- Population comparison: The proportion of the population served by Minuteman and Central Mass was used to obtain an estimate of the demand for the proposed facility.
- Before/After count comparison: A survey before and after the cycle facility was taken. The before facility count of the Minuteman corridor is 6 times higher than Central Mass.

- Work trips comparison: On the Minuteman trail, 13% of people walk to work and 1.8% cycle to work. On Central Mass 3.4% walk and 0.3% cycle to work. Hence, the number of cyclists is 6 times greater and the number of pedestrians is 3.8 times greater on the Minuteman trail.

This method requires extensive count data (before and after facility construction count data, count on parallel facilities etc.) to identify significant statistical expression. However, demand estimation for a proposed cycle facility can be completed with relatively few skills or knowledge.

b. Aggregate behaviour studies

This method estimates the demand using regression analysis. The regression equation can be applied to estimate demand in other areas. To formulate the regression equation, it is essential to identify factors which can influence the level of cycling in the project area and the magnitude of those factors.

An example of aggregate behaviour studies is an activity or agent-based model. An activity or agent-based model considers the characteristics and behaviours of individuals. This is in contrast to traditional, strategic transport models which use a trip-based approach that considers the characteristics of individual trips. This is described further in part e. Traditional demand models.

c. Sketch planning method

This method is used widely within the literature due to its simplistic methodology. It applies general rules to trip length, mode share, and other aspects of active travel behaviour. It is considered to be a relatively inaccurate method to estimate the number of pedestrians or cyclists using a facility.

An example was of this was Barnes and Krizek (2005), who used a sketch planning method to estimate the daily cyclist volume across several U.S. cities. They formulated three regression equations based on three areas with similar characteristics and number of commuter cyclists.

$$A = x\% + y * C$$
$$x \text{ and } y \text{ are regression constants}$$
$$A = \text{ \% of adult population who cycle each day}$$
$$C = \text{ bicycle commute share}$$

Regression analysis was applied to three different regions within the US. For example, for metropolitan regions the statistical area constants are x = 0.3, y = 1.5 with R^2 =0.7.

d. Discrete choice models

In this model, demand is calculated as a function of several variables including travel time, gender, and availability of cycle facilities. The models can be calibrated by stated preference survey data. In a stated preference survey, a hypothetical situation is presented to travellers. They are then asked to make a choice based on the given attribute of the alternative.

Ryley (2006) carried out research using discrete choice models and stated preference surveys to estimate demand in Edinburgh, Scotland. The city is a compact, high-density city suited to cycling. The survey was posted to 3,000 residents in a prepaid envelope within four selected zones.

Based on the responses received, the frequency of travel for each mode was determined. A logit formula was developed using an exponential utility function for the two choices – current mode of travel and bike. It is a linear equation of measured data multiplied by various weights.

$$U1_{cm} = \beta 1 \; x \; time_{cm} + \beta 2 \; x \; pay_{cm} + \beta 3 \; x \; facil_{cm} + \beta 4 \; x \; route_{cm}$$

$$U2_{bike} = MSC_{bike} + \beta 1 \; x \; time_{bike} + \beta 2 \; x \; pay_{bike} + \beta 3 \; x \; facil_{bike} + \beta 4 \; x \; route_{bike}$$

Where, U = utility

β = coefficient

facil = facilities

MSC = mode specific constants which reveals the level of bias of the model

cm = current mode

The key benefit associated with this method is that human behaviour is considered. The stated preference survey reflects the behaviour of people using different modes of travel and the attributes of those same modes. However, this method consumes a considerable amount of time due to effort required to run a stated preference survey.

e. Traditional demand models

Traditional four-step demand modelling combines trip generation, distribution, mode choice, and assignment. The main difference between modelling active modes and other modes such as vehicles are differences in the zone system and network. Trip lengths of the active mode are generally much shorter so the model should have smaller zone sizes and greater detail of routes.

An example of this model being used to estimate cyclist demand was undertaken by Jacyna et. al (2017). They developed a bicycle transport model for Warsaw, Poland using Transport Planning Software, VISUM.

The network consists of all cycle roads (cycle roads parallel to standard road is considered as one road), cycle paths, and pedestrian-cycle shared paths. The public cycle stations were included in the network. The model was optimised to capture enough network detail which provided an accurate demand estimate without over complicating the model. Based on trip generation coefficients and trip purpose, the number of cycle trips generated and attracted in the communication areas were determined.

The key benefit of this method is accuracy. This allows medium to long term planning of the transport network and analysis of the existing and future network performance in terms of travel time, delay, and speed. The main downside of this approach is that the transport models require an extensive amount of data to be considered accurate.

f. GIS-based approaches

This method graphically displays cycle trips within an area. It can highlight preferred cyclist routes through urban environments.

Wigan et al. (1998) examined the cycle demand of two off-road trails in Melbourne, Australia using survey and GIS modelling techniques. The number of people accessing the trail from different distances to the trails was plotted on a map. The distance from the trail was estimated as the distance from an individual's post code centroid. This analysis highlighted the choice of mode as a function of distance from the trail.

This method requires several types of input data and requires GIS expertise to estimate the cycling demand.

g. Combination of methods

Griffin (2009) outlined a methodology for estimating the bicycle and pedestrian demand using a combination of the sketch and planning method, GIS, and data obtained from a traffic demand model. The author used the forecasted motorised traffic volume as a proxy for bicycle and pedestrian trip demand, which was then adjusted using local land use densities. The traffic volume was loaded into the GIS network with dummy road segments used in the motorised traffic model removed from the map.

In another study, the total bicycle and pedestrian mode share for the Austin-Round Rock Metropolitan Area, US were calculated using the formulas developed by Krizek and Barnes. Bicycle mode share could be further refined by area type such as CBD, urban, suburban, and rural. The mode share was then multiplied by the current and forecasted automotive traffic volume, obtained from traffic demand models, and plotted to the GIS road network. Cyclist demand in other areas was then approximated based on the number of bicycles and pedestrians using the surrounding road network.

Further analysis of the different methods used to estimate cyclist demand are cited in a study undertaken by Land Transport New Zealand in 2007. The study was comprehensive and included a literature review and data analysis. The purpose of the study was to develop a methodology and subsequent estimation tool for on-road and off-road facilities at five sites each. On-road facilities include cycle lanes and share carriageway space with vehicles. Off-road facilities run parallel to the carriageway, separate to vehicle movements, such as shared paths.

3.2.3 Electric cycle

Our high-level literature review did not yield any demand estimation methods derived specifically for electric cycles. However, the electric cycle demand can be estimated similarly based on the cycling demand estimation approaches described earlier. Further understanding on user characteristics, trip distances, and behaviour preferences is required to produce a detailed assessment of electric cycle demand. Some of the known characteristics are further detailed in Section 3.3.

3.2.4 Electric scooter

Our high-level literature did not yield any findings on demand estimation methods derived or adopted specifically for electric scooters. In some instances, electric scooter demand may be estimated using the approaches as described for cycling. However, further understanding of user characteristics and trip distances is required to enable an accurate assessment of electric scooter demand. Some of the known characteristics are further detailed in Section 3.3.

3.3 Growth trends

A review was undertaken to assess the growth of cycle and electric assisted active modes. Growth was assessed from accessibility and level of activity perspectives. These trends should be understood in reference to these perspectives to better recognise obstacles in the uptake of cycle and electric assisted active modes.

3.3.1 Sales trend for bicycle and electric assisted modes

Key Takeaways

- *Bicycle purchasing levels in New Zealand are comparable to Australia and several European countries*
- *There is strong growth in electric bicycle sales in Europe, particularly in the Netherlands where it has exceeded 40% of total bicycle sales*
- *Electric bicycle sales are also experiencing strong growth in New Zealand and are estimated to be around 15% of the total bicycle import market*
- *Anecdotal evidence suggests that electric bicycle sales in New Zealand will continue to grow*
- *Local research indicates that pricing could still be a barrier for the uptake of electric bicycles in New Zealand*
- *Global sales of electric scooters have been projected to achieve 56 million units globally which is comprised of 12 million privately owned units with the remaining units being utilised on shared platforms*
- *There is a lack of information to estimate the total sales or import of electric scooters in New Zealand*

The import of bicycles into New Zealand has been consistently trending at approximately at 5%-6% per capita over the last few years. This figure is relatively consistent with Australia and other OECD countries in Europe as shown in Figure 3.10.

It should be noted that these numbers also include the various type of bicycles such as normal touring/city, BMX, hybrid, children's cycles, electric cycles, racing, mountain, and folding bicycles. The above analysis suggests that New Zealand purchases bicycles at a rate that is comparable to many of the countries analysed. This suggests that any challenge in the uptake of cycling in general is not related to purchasing power parity.

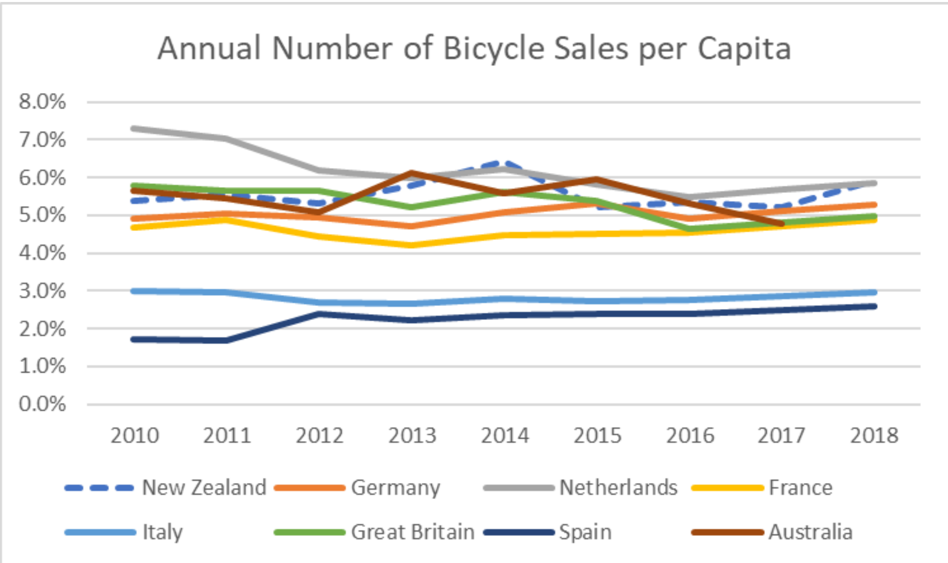

Figure 3.10: Annual Number of Bicycle Sales per Capita (CONEBI, 2017; Bicycle Industries Australia, 2017; Stats NZ, 2019; Beca Analysis). Data Inclusive of Electric Bicycles. New Zealand data comprised of import data as opposed to sales data

There is a growing trend in the sales of electric bicycles in several countries. In 2018, the Netherlands recorded that 40% of all bicycle sales were electric bicycles as shown in Figure 3.11. The projected trend means that electric bicycle sales will exceed 50% of all bicycles sales within the next few years.

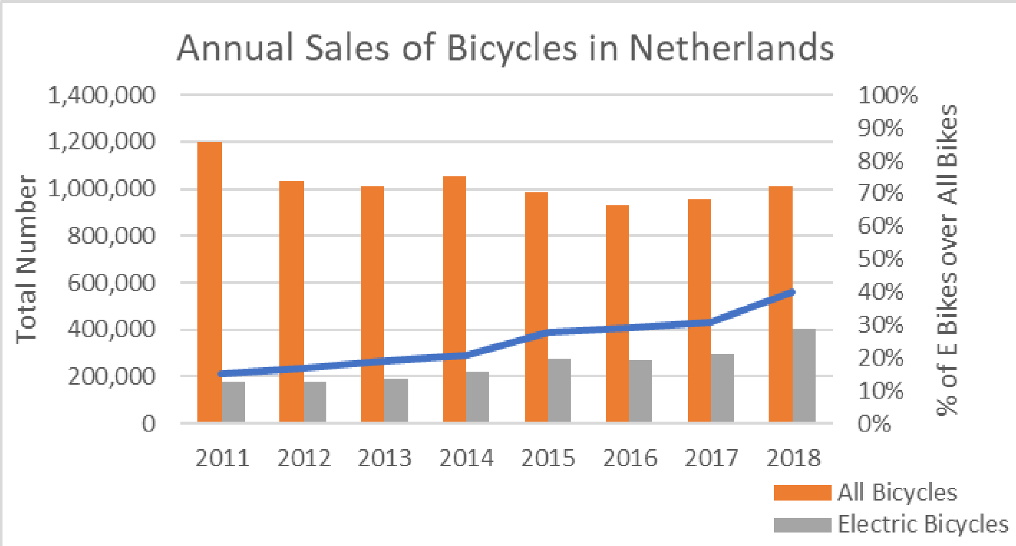

Figure 3.11: Annual Sales of Bicycles in Netherlands (Sourced from CONEBI, 2017; Beca Analysis)

The purchase of electric bicycles is not as strong in several other European countries such as France, Italy, the UK, and Spain as shown in Figure 3.12. This is particularly noticeable when the total sales of all bicycles have been relatively stable as shown earlier in Figure 3.10.

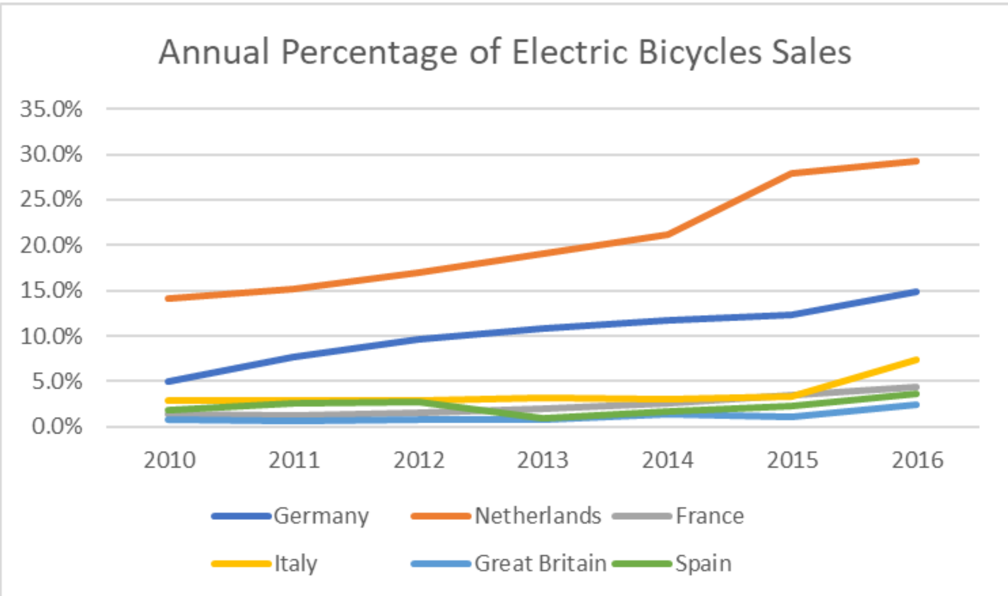

Figure 3.12: Annual Number of Bicycle Sales per Capita (CONEBI, 2017; Beca Analysis)

Within New Zealand, the estimated number of electric bicycles have been increasing significantly over the last few years. Based on Stats NZ data and our analysis, the number of electric bicycles imported into the country has exceeded 20,000 units per year (

Figure **3.13**). For comparison, there was a total fleet of 10,000 electric vehicles registered in New Zealand by late 2018 (Woods & Shaw, 2018).

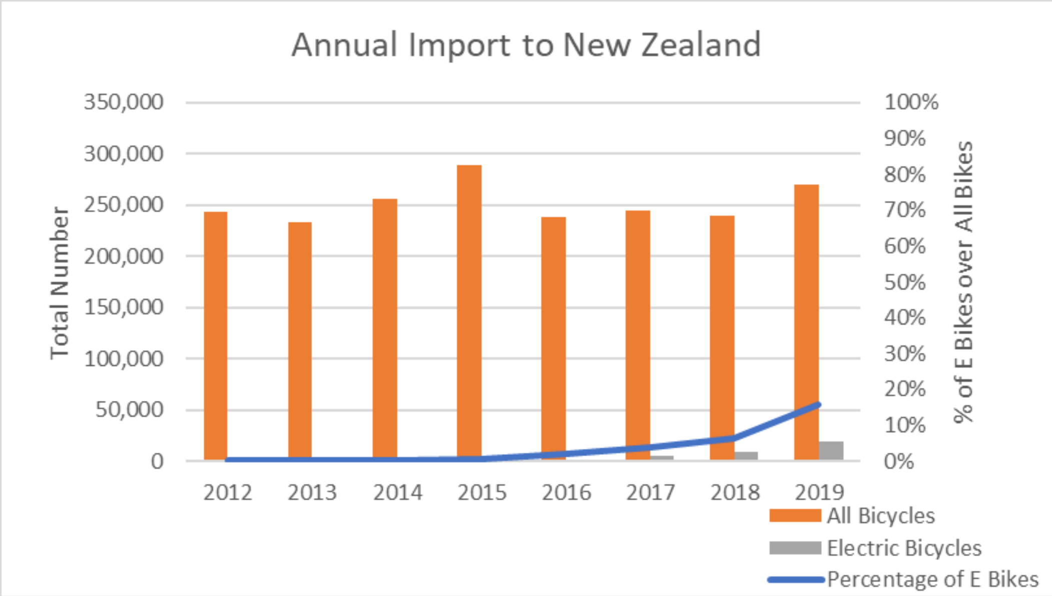

Figure 3.13: Annual Number of Bicycles Imported (Stats NZ, 2019; Beca Analysis)

The upward trend in the sale of electric bicycles in New Zealand is expected to continue. Based on our comparison of a Google web search of electric bicycles and bicycles (all bicycles) it can be deduced that New Zealand is broadly following the same 'interest' trend as observed in Netherlands with a slight time lag as seen in Figure 3.14. This finding, combined with the analysis of electric bicycle import data into New Zealand, suggests that the purchasing parity of electric bicycles is not a factor in the uptake of electric cycle activity when compared against other European countries.

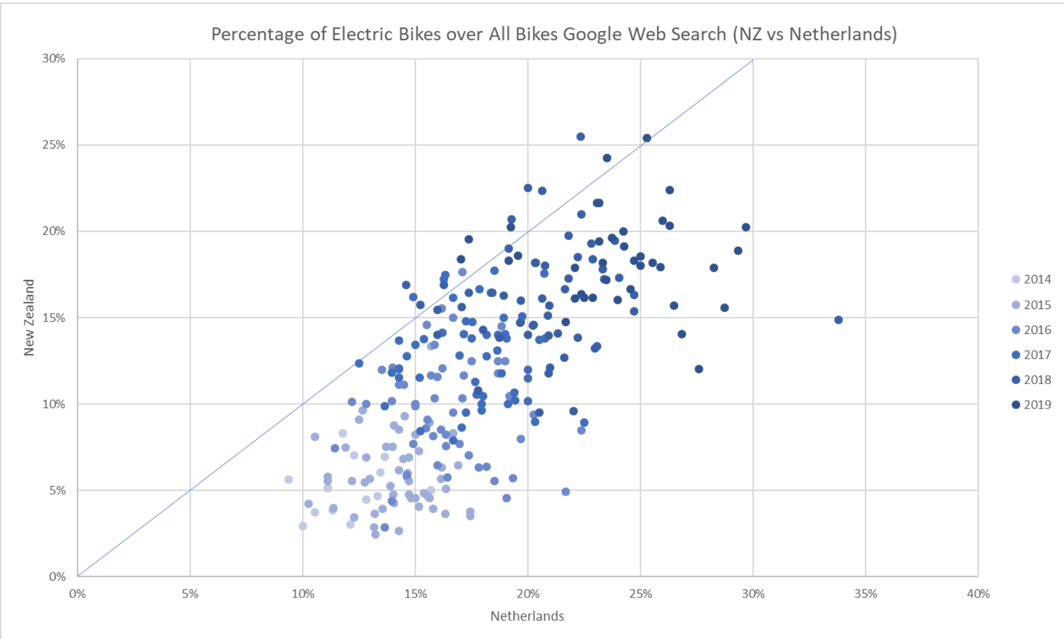

Figure 3.14: Percentage of Electric Bicycles over All Bicycles Google Weekly Web Search Comparison between New Zealand and Netherlands over 2014-2019 (Underlying data sourced from Google Trend, Beca Analysis)

It is acknowledged that current pricing levels of electric bicycles may not be affordable to across the reach of entire population, particularly with the lower socio-economic groups. A recent study by the University of Auckland (Wild & Woodward, 2018) found that participants experienced anxiety around the purchase of an electric cycle including the buyer's themselves. Bicycle retailers surveyed during the study also suggested that potential customers balked at the cost and were often worried about justifying the cost of purchase. Most buyers were currently in professional employment, or had retired from professional employment, and had medium to high incomes. The study also suggested that low income populations have the least ability to afford an electric bicycle, yet the same groups would also benefit the most through having access to one.

There is lack of information available on the purchase or import of electric scooters in New Zealand. In the past year, shared micro-mobility platforms have gained temporary access to provide shared electric scooters to some urban centres. Internationally, shared micro-mobility is shown to be growing significantly. In terms of cumulative rides and uptake, shared micro-mobility services have overtaken ride-hailing services exponentially as shown in Figure 3.15.

The Barclays Research (2019) also estimates that micro-mobility (including electric bicycles) original equipment manufacturers could see a projected annual sales volume of 56 million units globally. This is approximated to be comprised of 12 million privately owned units and 44 million units operating on a shared micro-mobility platform.

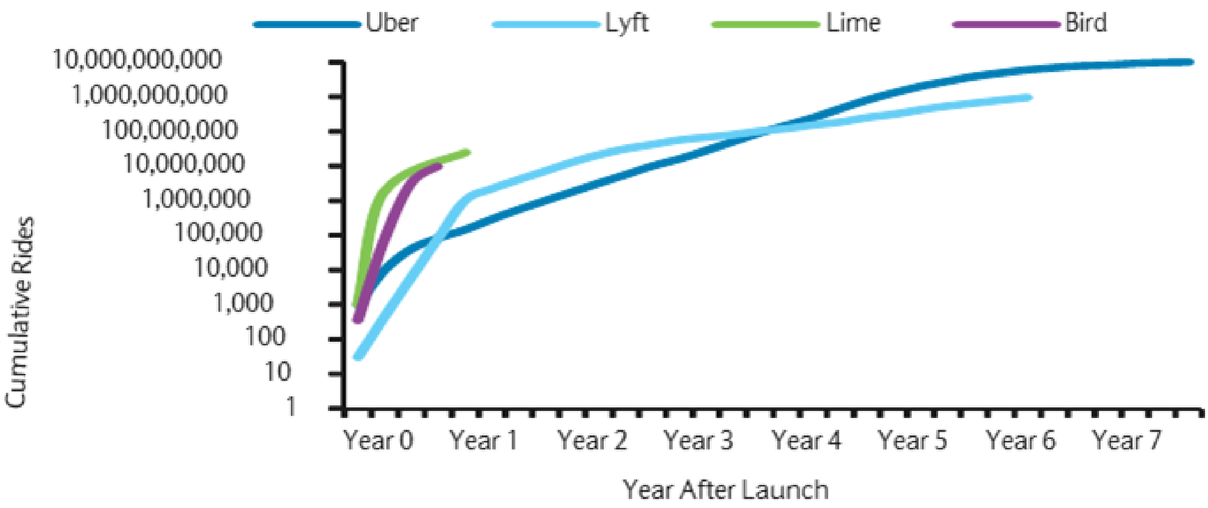

Figure 3.15: Cumulative Number of Rides for Shared Mobility Services (Barclays Research, 2019)

3.3.2 User trends and characteristics

Key Takeaways

- *A local case study in Auckland found that electric bicycle commuters travel up to 15km each way commuting to work compared to 5km on a conventional bicycle*
- *Higher monitoring and more comprehensive surveys are required to understand electric bicycle usage characteristics across New Zealand*
- *There is a lack of information and research on distances covered by electric scooters owned by users*
- *Electric scooter users on shared platform typically travel around 1.1km per trip. This suggest that this mode is not preferred for commuting to work purposes*
- *40% of surveyed electric scooter users in Christchurch indicated that they would have walked if the scooter system was not there. The majority of surveyed users said trips were primarily for recreation and social purposes*

Transport mode choice is directly influenced by trip characteristics including trip purpose and complexity. With the emerging transport mode of electric assisted active modes, commuters are able and more willing to cover longer distances than before.

There are two models currently in operation for the use of electric assist active modes:

- privately-owned use
- shared-platform use.

A case study of privately-owned electric bicycles was carried out by the University of Auckland (Wild & Woodward, 2018). The study showed that electric bicycle commuters can travel up to 15km each way to work. In comparison, conventional bike users generally travel up to 5km. The maximum distance covered for walking commuters was found to be around 3km.

There is lack of data and research on the distances covered by people that have privately-owned electric scooters.

Trip distribution for different shared micro-mobility modes in the San Francisco/Bay Area is shown in Figure 3.16. General observations are:

- Electric scooters were shown to have the shortest average range of approximately 800m. Shared conventional bicycles had an average range of 1.3km and shared electric bicycles generally around 1.5km but with a larger spread over 5km.
- The distribution of trips by time of day during the week is shown in Figure 3.17. This shows that shared electric scooters and dockless bicycles do not have a distinct period of use during the morning and afternoon peak periods. Shared electric bicycles and docked bicycles have a more defined period of use during the morning and afternoon peak periods.
- These findings suggest that shared electric scooters are not generally used for commuting purposes. This is due to the trip time distribution and the average distances covered during a commute.

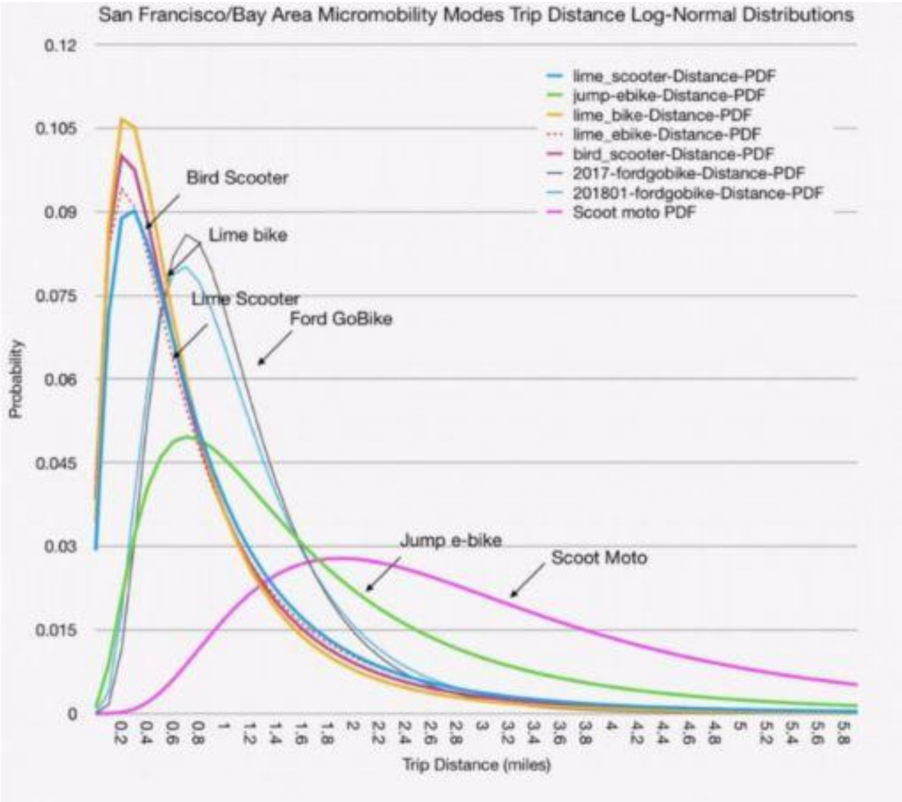

Figure 3.16: San Francisco/Bay Area Shared Platform micro-mobility Trip Distance Distributions, by Modes (Bruce, 2019)

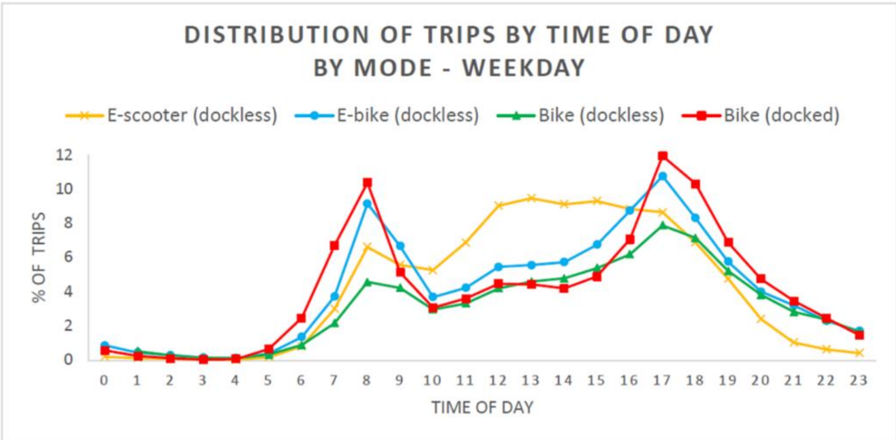

Figure 3.17: San Francisco/Bay Area Shared Platform Micro-mobility Time Distribution, by Modes (Bruce, 2019)

In the local context, a Christchurch City Council micro-mobility survey and separate Lime e-scooter data for the period between February 2019 and October 2019 were assessed to provide an understanding on the user trends and characteristics. The key findings from this analysis are:

- Lime scooters tend to be located in the central city and nearby surrounding suburbs.
- The survey found that electric scooter trips replaced 40% of walking trips as shown in Figure 3.18.
- 25% of survey respondents would have driven a personal car, rode a motorcycle or used ride sharing service/taxi as shown in Figure 3.18. This suggests that a quarter of electric scooter journeys have replaced motor vehicle trips.

- 4% of survey respondents would have travelled by public transport without electric scooters. 18% of trips are within 50m, from where the Lime trip was initiated or completed, of the public transport stop catchment area.
- The survey also showed that the most frequent types of trips taken are related to recreational and social activity purposes as shown in Figure 3.19.

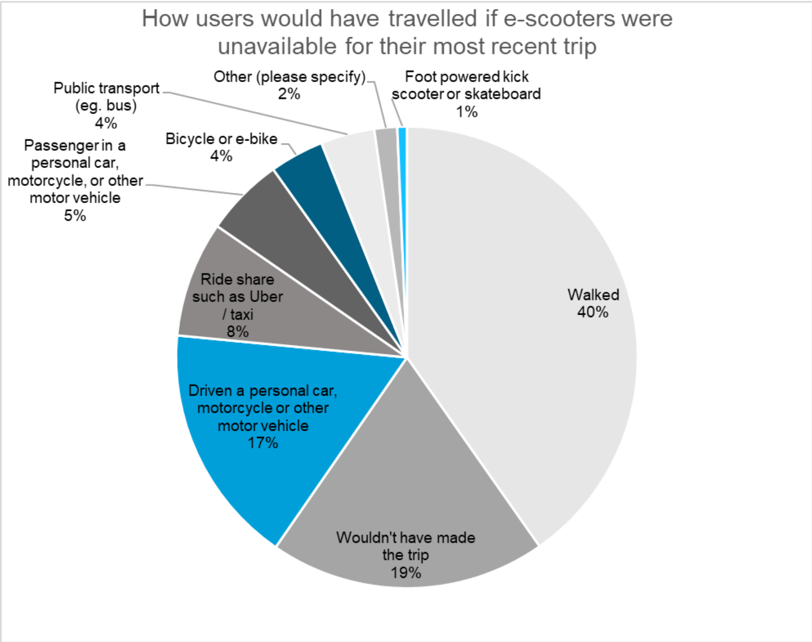

Figure 3.18: Potential transport modes replaced by e-scooters (Christchurch City Council, 2019)

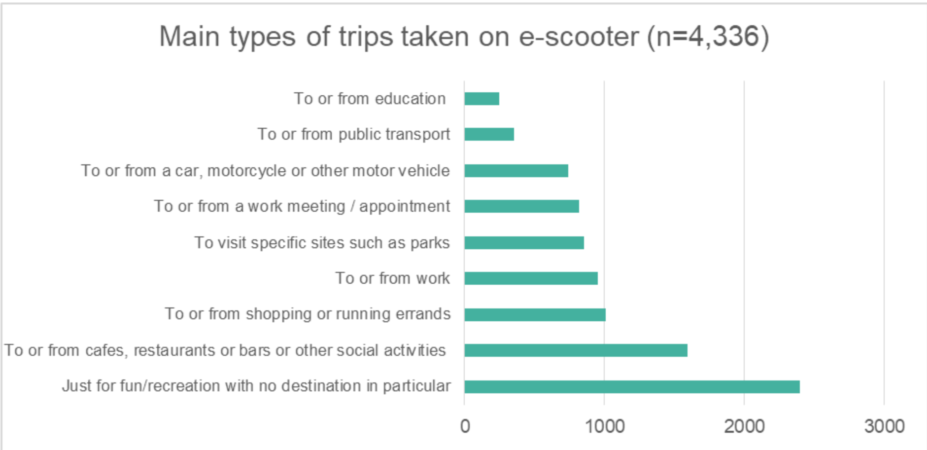

Figure 3.19: Purpose of e-scooter trips (Christchurch City Council, 2019)

Figure 3.20 shows the trip distance covered by e-scooters on the Lime shared platform. The mean trip distance was found to be 1.6km, while the median trip distance is 1.1km.

Lime data for Christchurch indicates that the electric scooter trip distance in the morning peak is longer than trips during other periods of the day as shown in Figure 3.21. The median trip distance in the morning peak was 1.6km compared to 1.1km for other times as shown in Figure 3.22. This suggests that trips in the morning peak are due to a higher proportion of users commuting to work.

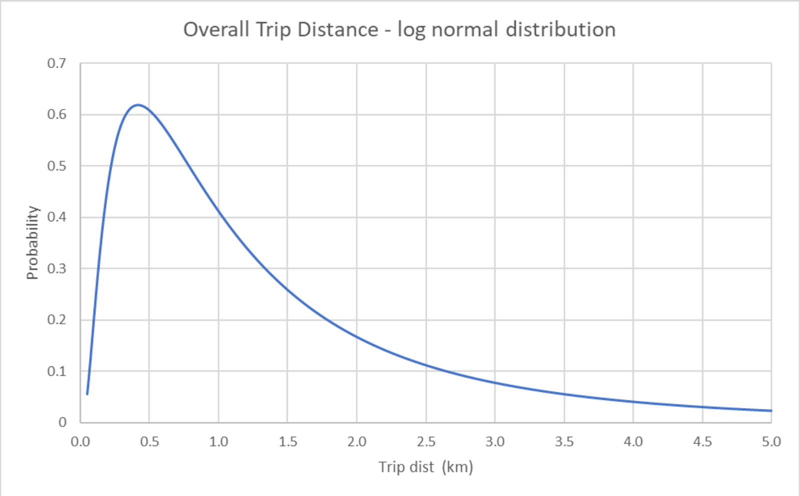

Figure 3.20: Overall trip distance travelled by e-scooters

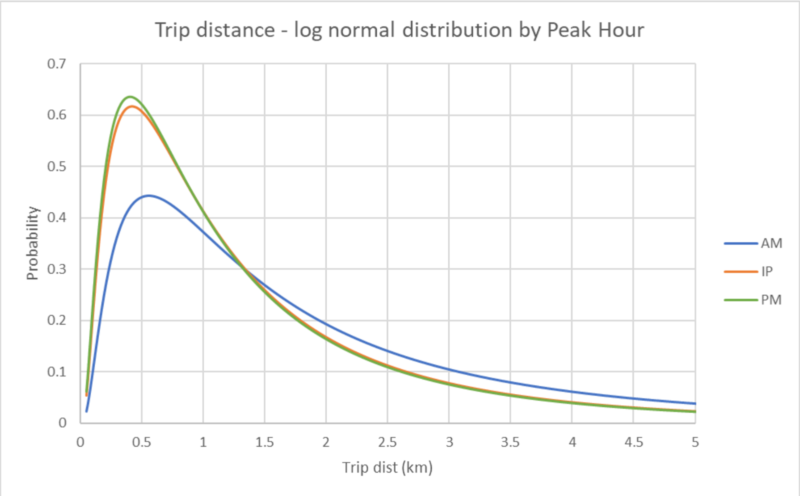

Figure 3.21: E-scooter trip distances categorised by time periods

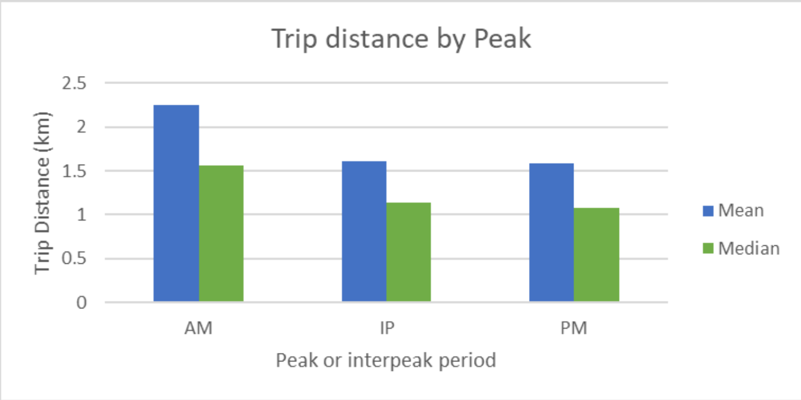

Figure 3.22: Trip distance based on time periods

Lime data for Christchurch suggests that electric scooter use on weekends is comparable to the weekday use as seen in Figure 3.23. Further analysis of trip data found that Saturday had the highest average trip distance. The weekend average trip distance was higher than the weekday average trip distance as shown in Figure 3.24.

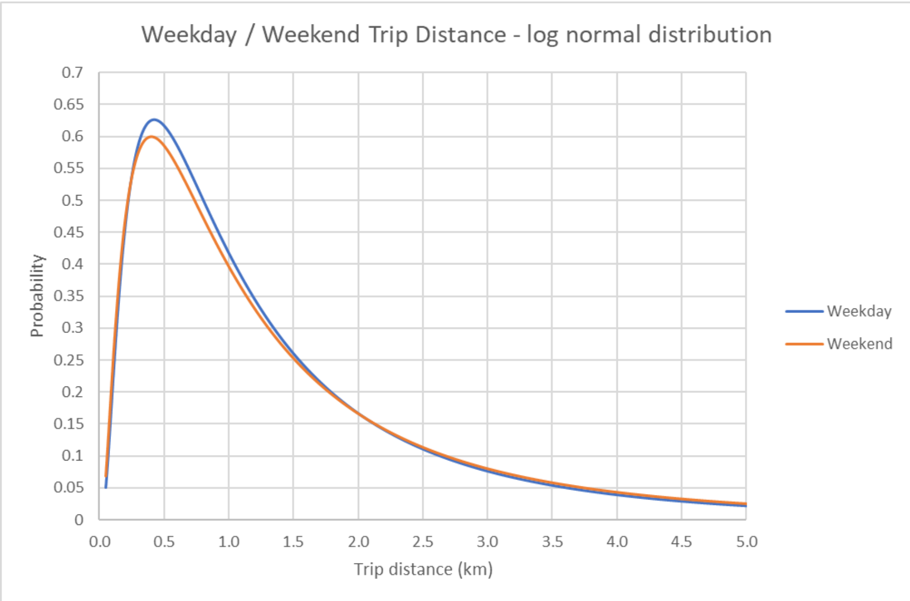

Figure 3.23: Weekday and weekend e-scooter trip distance comparison

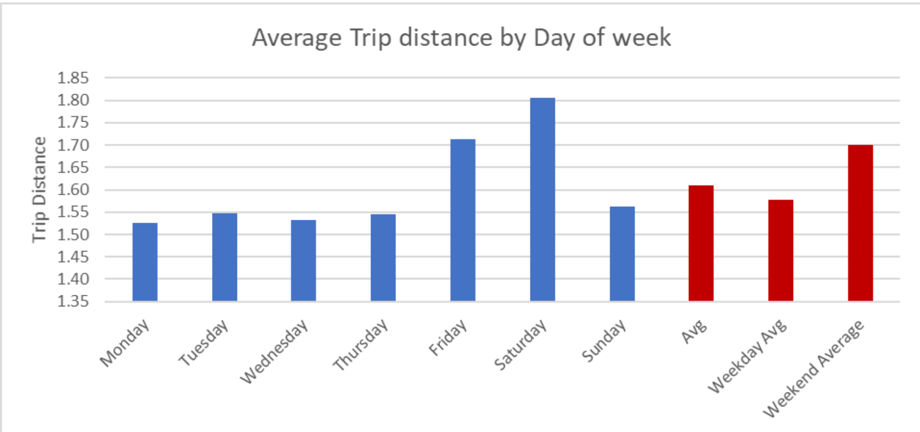

Figure 3.24: Average trip distance across the week

3.3.3 Cost drivers, potential barriers and technological trends

A high-level review was carried out to understand:

1. Cost drivers for the electric assisted modes
2. Technological trends in relation to pricing and the range covered by these devices
3. Other potential barriers and implications to the electric assisted modes.

Our observations include:

1. Cost drivers for the electric assisted modes
    - There has been no comprehensive research that has found key cost drivers for the electric assisted modes. Our high-level review suggests that the biggest cost factor can be attributed to the battery. The batteries used in the electric assisted modes are predominantly lithium-ion batteries with lithium nickel manganese cobalt oxide (NMC) cathodes. NMC provides batteries with a lower energy density, a longer battery life, and a lower likelihood of fire or explosion. The price of cobalt appears relatively stable at present, but the manufacturers were exposed to significant price rise over 120% in 2017 due to global supply shortage (BMI Research, 2018).
    - The emerging research areas for batteries are generally around life extension, increasing energy density, improved safety, cost reduction, and charging speed. Continued research into graphene-lithium batteries has the potential to revolutionise electric batteries through significant gains in energy density and charging speed.
    - While there are only a handful of battery manufacturers, there is lack of standardisation in the charging interface. This limits opportunities for local authorities to develop universal charging stations or areas for electric bicycle users.
2. Technological trends in relation to pricing and the range covered by these devices
    - Entry costs for shared electric mobility modes appears to be on the high side. For instance, Flamingo (2019) charges $1 to unlock and $0.38 per minute of use, which suggests a value comparable to the value of time for work travel purpose, but significantly higher than for commuting and other non-work travel purposes. This implies that at current price point, the shared electric mobility modes are unlikely to significantly grow their mode shares, with users primarily for short journeys.
    - The electric assisted modes industry is fragmented with a wide variety of manufacturers ranging from large multinational corporations to small privately-owned companies. For instance, the top six producers of electric bicycles account for under 33% of the global market (Charterian, 2019). The nature of the fragmented market indicates that that there is generally a low entry barrier for manufacturers to enter the market. It also indicates that there are many opportunities for manufacturers to differentiate their electric assisted mode products. With potentially longer range and higher capacity batteries, it is also highly likely that there will be innovation around the electric mobility modes, for instance in promoting electric cargo bicycles.
    - The potential of shifting to these non-traditional modes and the trends above are currently being researched in another Waka Kotahi research project (ART 18/12).
3. Other potential barriers and implications to the electric assisted modes
    - A barrier with the uptake and ownership of electric assisted modes is the perceived lack of security when parked in public places. In New Zealand between 2015 and 2018 there were over 12,000 reported stolen bicycles (NZ Herald, 2019). This can discourage users parking more expensive electric bicycles and electric scooters in public places without a safe and secure storage area.
    - Availability of safe infrastructure remains a large barrier for higher and more universal uptake of electric assisted modes.

4. HEALTH BENEFIT ESTIMATION

4.1 Estimate of health benefits

4.1.1 Value of increasing healthy life quality and expectancy

Estimating life quality and life expectancy benefits has followed the previous methodology while updating the statistical data with the latest information available. The figures used to calculate the total DALY are presented in Table 4.1.

- The previous DALYs value used in the health benefits estimation was from 1996. The value of this figure has increased significantly since then. The latest information from the Global Health Data Exchange shows an estimated total of 1,093,000 DALYs in New Zealand in 2017.
- The Population Attributable Fraction (PAF) for physical inactivity was also updated using data from the Health Loss in New Zealand 1990–2013 report (Ministry of Health, 2016). This value has been reduced from 7% to 3%.
- The monetary value of each DALY was updated using the most recent Value of Statistical Life (VoSL).

Mortality costs attributable to physical inactivity were estimated from statistical data of deaths and causes extracted from Statistics New Zealand (Stats NZ, 2016). The proportion of the inactive population was estimated from a publication of the Ministry of Health (Ministry of Health, 2016). Morbidity costs were estimated using the Years Lost due to Disability (YLD) statistics.

Table 4.2 highlights the mortality value from physical inactivity due to different causes of death and the associated factors. Table 4.3 provides the values used to calculate the morbidity value attributable to physical inactivity.

The two different methods used to calculate the total estimated economic benefit of increasing healthy life quality and expectancy are reported below:

- DALY approach suggests a health benefit of $1,771.
- he mortality and morbidity approach suggest a value of $7,075.
- This gives an average value of $4,424.

Table 4.1: Total Estimated Economic Benefits – Total DALY Approach

Items	Value
Total DALYs per year in New Zealand[1]	1,093,254
Population Attributable Fraction for physical inactivity[2]	3%
DALYs attributable to physical inactivity, per year	32,798
Total physically inactive adult population	1,922,375
DALY value (NZD)[3]	$103,828
Total value of DALY attributable to physical inactivity, per capita per year (2018 $)	**$1,771**

1. Institute for Health Metrics and Evaluation (IHME), *GBD Results Tool*
2. Ministry of Health, *Health Loss in New Zealand 1990–2013* (2016)
3. Updated based on latest population and life expectancy statistics

Table 4.2: Mortality Attributable to Physical Inactivity

Causes	Deaths (2016)[1]	ERR[2]	Pe[3]	Pe (ERR)	PAF	Attributable deaths
Breast cancer	674	0.21	49.8%	0.10	0.09	63.8
Colorectal cancer	1,268	0.66		0.33	0.25	313.7
Hypertension	1,667	0.3		0.15	0.13	216.7
CHD/IHD	4,663	0.45		0.22	0.18	853.7
Stroke	2,322	0.6		0.30	0.23	534.2
Osteoporosis	44	0.59		0.29	0.23	10.0
Diabetes TII	843	0.5		0.25	0.20	168.1
Depression	54	0.28		0.14	0.12	6.6
Total annual attributable deaths						2166.7
Inactive adult population						1,922,375
Value of Statistical Life[4] (2018 $)						4,340,000
Per capital annual value of physical activity (2018 $)						**$4,891**

1. Ministry of Health, *Mortality 2016 Data tables* (2019)
2. Market Economics Limited, *The Costs of Physical Inactivity – Toward a regional full-cost accounting perspective* (2013)
3. Ministry of Health, 2017. *Annual Data Explorer 2016/17: New Zealand Health Survey.* URL: https://minhealthnz.shinyapps.io/nz-health-survey-2016-17-annual-update (accessed Aug-2019)
4. Ministry of Transport, *Social cost of road crashes and injuries 2018 update* (2018)

Table 4.3: Morbidity Attributable to Physical Inactivity

Item	Value
YLD total[1]	585,908
PAF % from mortality estimations	7%
YLD inactive	40,449.9
Inactive adult population	1,922,375
YLD value	103,828
Per capital annual value of physical activity (2018 $)	**$2,184**

1. Institute for Health Metrics and Evaluation (IHME), *GBD Results Tool*. URL: http://ghdx.healthdata.org/gbd-results-tool (accessed Aug-2019)

4.1.2 Attributable health system costs

The availability of new data allowed for the update of the attributable health system costs related to physical inactivity. The most recent study (Market Economics, 2013) assessed hospitalisation data from the Ministry of Health's inpatient data set (National Minimum Data Set).

- The data set contains all the discharge records from all public hospitals run by the District Health Boards (DHBs).
- The study accessed and assessed patient records for the eight diseases that can be attributed to physical inactivity as shown in Table 4.2.
- Co-morbidity was considered so that no double counting of diseases and cost occurred.

The national expenditure of health system costs was updated in this review using the consumers price index (CPI) for 2018. The updated value suggests health system costs of $694 million, which is equivalent to $361 annually for each inactive person.

4.1.3 Lost output

Lost output costs associated with physical inactivity were estimated during this review with the results shown in Table 4.4.

Table 4.4: Estimated Lost Output Costs

Item	Value
YLD total	40,449.9
Inactive population	1,922,375
YLD per inactive person	0.021
Average annual income[1]	44,800
Per capital annual value of physical activity (2018 $)	**$943**

1. Statistics New Zealand, Dataset: Income by region, gender, age groups and ethnic groups (2019)

4.1.4 Summary of health benefits

The total benefits produced by the use of active mode transport is summarised in Table 4.5.

Table 4.5: Total Estimated Economic Benefits of health improvements

Method	Value
Increasing Healthy Life Quality and Expectancy	$4,424
Health system cost savings	$361
Lost output	$943
Total benefits from converting an inactive person per year (2018 $)	**$5,728**

Table 4.6 states the values and assumptions used to convert the total benefit per inactive person per year value of $5,728 into a per km value.

Table 4.6: Assumptions on Speeds and Travel Duration per Trip

Active mode type	Average speed (km/h)	Travel time duration (hr)	Distance per day (km)	Distance per year (km)
Conventional cycling	20.0	0.5	10.0	2,500
Walking	5.0	0.5	2.5	625
Electric assisted cycling	30.0	0.5	15.0	3,750

The derived health benefit values for the active modes are shown in Table 4.7. These values are based on the current EEM approach of taking the average of the Beca (2007) value and the mid-point of the Genter et al. (2008) value.

It is recommended that the derived health benefit value per new user is capped. This will ensure that the total derived benefit does not exceed the total estimated economic health benefit for converting an inactive person to an active person.

Table 4.7: Derived Health Benefit Values, on a per km basis

Active mode type	Health benefits for new user ($/km)	Maximum annual benefit per new user (2018 $)
Conventional cycling	$2.22	$2,750
Walking	$4.44	$1,375
Electric assisted cycling	$1.03	$2,060

4.1.5 Discussion on proposed values

This review uses a contingent valuation method and reflects a 'willingness to pay' to avoid loss of life and illness or disability. Some of the strengths and weaknesses of this approach are summarised below:

- The contingent valuation method adopted utilises values of statistical life originally developed for road safety.
- These values were developed in the 1990s based on a willingness to pay survey to avoid injury and death from vehicle crashes.
- It has been shown that people would be less willing to pay to prevent a fire related fatality than a road fatality (Market Economics, 2013). This suggests that the willingness to pay is lower when there is greater personal responsibility involved. Therefore, the willingness to pay to avoid death or injury from physical activity may be lower given that there is an element of personal choice to exercise.
- We recommend that the value of statistical life for road safety continue to be used until there are better options available.

An alternative method to the contingent valuation is the human capital method. This method assesses the impact on lost earnings for the remainder of a working life. There are a number of arguments against the use of this method including that it is biased against retired, unemployed, and those unable to work. As such this method has not been adopted in this review.

Over 80% of the total deaths (shown in Table 4.2) related to diseases associated with physical inactivity in New Zealand occurred in the age group of people aged 65 years and above. Excluding people aged 65 years and above resulted in the total benefits being reduced by almost 90%. As the original 1991 study on the value of statistical life for road safety did not differ significantly by age, we recommended that people aged 65 years and above continue to be included when calculating the total economic benefit.

There are arguments for and against the inclusion of indirect health costs. The following discussion is a direct quote from the Pharmac, 2015 report:

- *Sickness or treatment that results in inability for the patient or caregiver to work incurs a cost to individuals and employers in terms of replacement of sick workers, training the replacement, and lower levels of productivity.*
  - Counter-arguments: *The actual production loss for society from sickness is likely to be much smaller than the estimated value of potential production lost. For short-term absences, a person's work may be covered by others or made up by the sick person on their return to work. For long-term absences, an individual's work can be covered by someone drawn from the unemployed, albeit with friction costs (hiring, induction, upskilling costs, etc). Therefore, while absence from work may cost the individual or employer, it may not cost society very much.*
    There are also ethical concerns with including lost productivity in analyses as costs rather than reductions in quality of life, as these costs tend to bias against those who are not in the paid labour force – particularly children, homemakers, retired people, the unemployed, and those unable to work because of disability, frailty or disease, including cognitive and psychological impairment. Incorporating differential earning levels will also result in valuing one group of individuals more than another, which is politically and ethically contrary to egalitarian values. It would also result in health care interventions being more likely to be directed towards well-paid working people.

As there are no conclusive view on the level of lost output value that should be included, and acknowledging both the argument for and against this inclusion, we recommend that the lost output value derived in Section 4.1.3 be halved for the purpose of this assessment. This has a negligible effect on the health benefit value.

4.1.6 Recommended health benefit values

Based on the above considerations, the recommended health benefits are summarised in Table 4.8.

Table 4.8: Recommended Health Benefit Values, on a per km basis

Active mode type	Health benefits for new user ($/km)	Maximum annual benefit per new user (2018 $)
Conventional cycling	$2.20	$2,500
Walking	$4.40	$1,250
Electric assisted cycling	$1.00	$2,000

4.2 Demand estimation methods

Based on the literature review and several workshops, the following procedure has been developed to calculate the active mode demand estimation as shown in Figure 4.1.

The following demand estimation methodology is intended as a general procedure only. Further refinement of this procedure is recommended once more detailed research into active mode demand estimation is completed by Waka Kotahi.

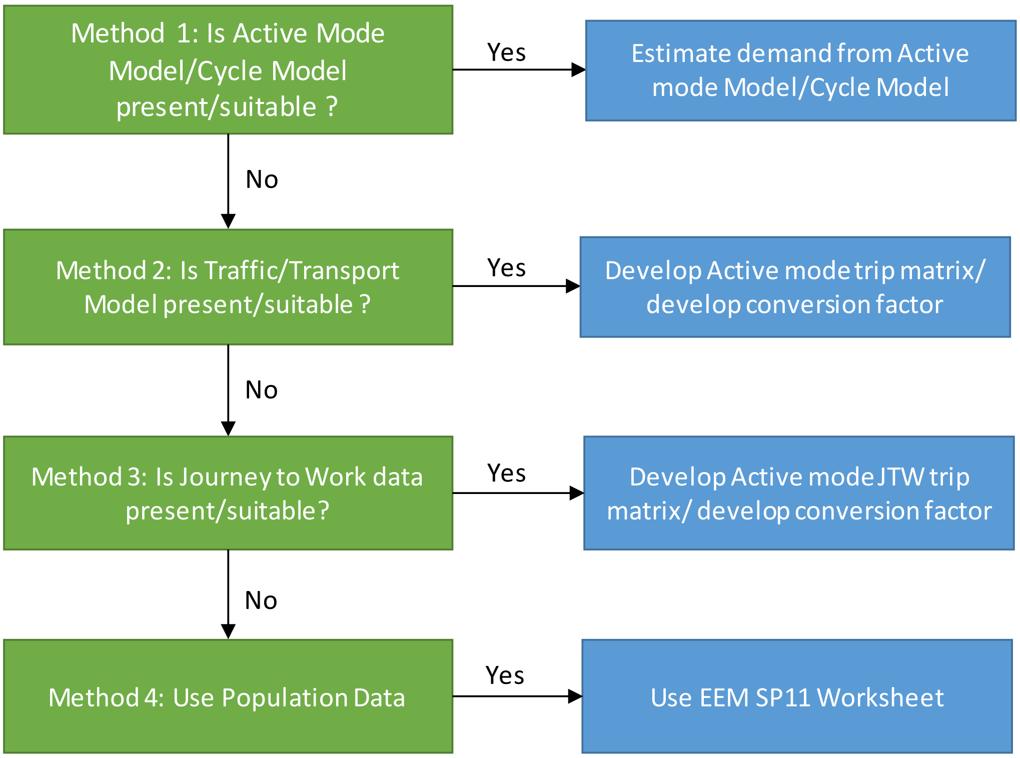

Figure 4.1: Demand Estimation Methods Procedure

Method 1:

Main city centres may have an active mode model or cycle model. These models are often based on the principles of trip generation, trip distribution, trip assignment, adjacent land use conditions, and the overall transport network. Human behaviour and other travel characteristics are included to estimate future travel patterns. Other active mode models are simplified versions of the regional transport model.

Active mode demands can be obtained from the active mode models of the region. Developed models are generally responsive to network or facility changes so can be used to assess demand for various project options.

Method 2:

In the absence of an active mode model, active mode demands can be estimated from the regional transport model. A proportion of vehicular trips is converted to active mode trips based on the origin-destination of the trip, trip length, and quality of route.

The following methodology can be used to estimate active mode demands from a regional transport model. It should be noted that the above methodology is a very high-level initial attempt for a quick estimation method of zone-zone cycle trips based on the trip distance and requires further study.

Step 1 (Develop Base Year Curve):

Develop a base trip distribution curve (active mode share vs. trip distance) from Census data or adopted from another city. The base trip distribution curve can be developed from journey to work data (available in “Commuter View” at the Stats NZ website) for the specific region or other available local data.

Separate distribution curves are required for to estimate the demand for individual modes such as walking and cycling.

A sample chart of cycle trip distribution curve is shown in the Figure 4.2 below.

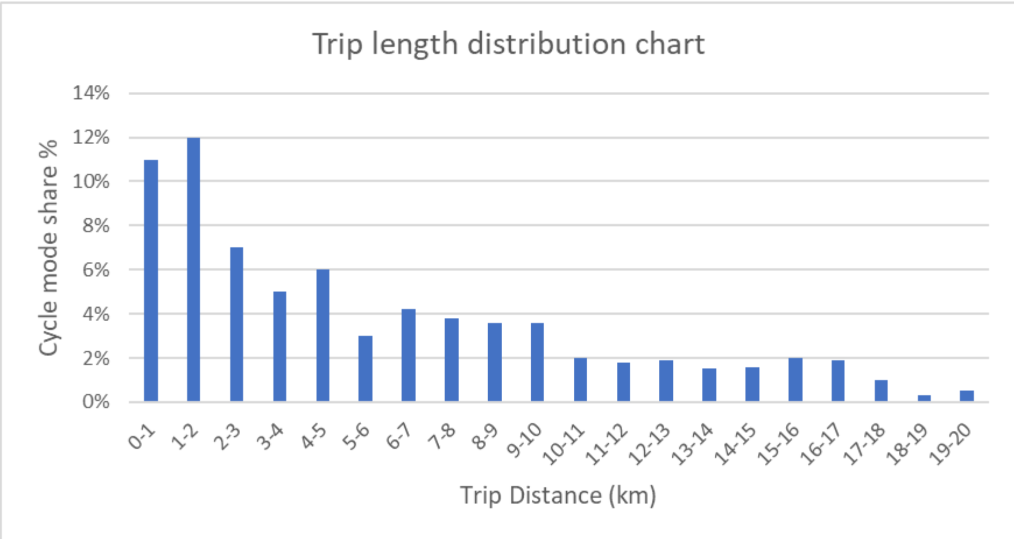

Figure 4.2: Hypothetical trip length distribution chart showing cycle mode share against trip distance

Step 2 (Define Catchment Area):

Define a catchment area and zones based on the areas being served by the project.

Step 3 (Get Transport Model Trip Distance and Demand Matrices):

From the regional transport model, obtain zone to zone trip distance and demand matrices for each zone within the catchment area.

Step 4 (Develop Base Year Active Matrix):

Apply a best fit curve to the active mode share % vs. trip distance. The zone-zone active mode share percentage is then determined. The active mode share % multiplied by the demand matrix will give the active mode trip demand.

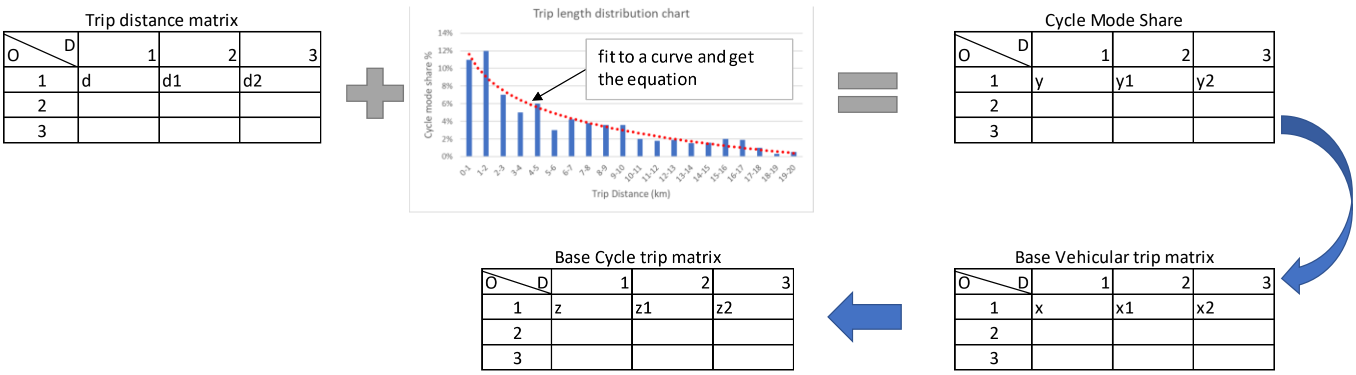

Figure 4.3: Zone-zone cycle trip estimation from regional transport model

Step 5 (Simplified Assignment and Calibration):

The zone-zone active matrix can be aggregated to a simplified sector-sector matrix and manually assigned to the existing network.

It is preferable to calibrate the base curve (Step 1) by comparing the manually assigned active trips and local observed data. In this way the model will better represent trip purposes within the catchment area and zones of the project. For example, if the base curve is developed from Census journey to work data, travel patterns will be more likely to represent commuter type trips.

Step 6 (Develop Future Curve and Active Matrix):

An option curve is required to estimate the number of active trips after facility development. This curve is normally determined using data from other comparative studies.

Figure 4.4 shows a hypothetical option curve compared to the base curve based on a project that improves overall route quality. The future cycle mode share percentage is multiplied by the forecasted demand matrix (obtained from the forecast year transport model) to estimate the future year active trips.

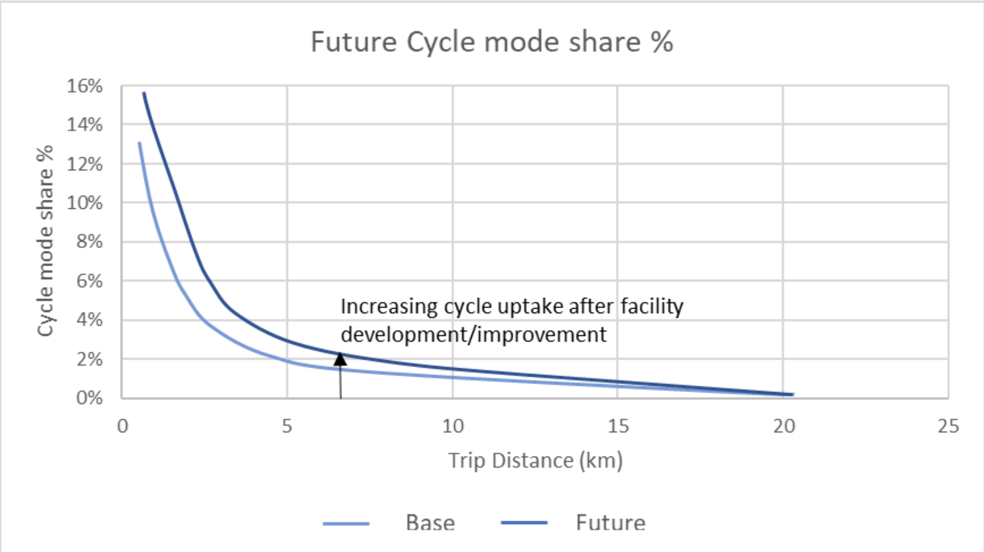

Figure 4.4: Hypothetical future option cycle mode share vs. trip distance

Method 3:

In the absence of both active and transport regional models, journey to work data can be used to estimate active demands.

This method of demand estimation is similar to Method 2. The main difference is that the commuter trip matrix is developed at the Census Area Unit (CAU) level instead of the vehicle trip matrix at zone level.

Step 1 (Develop Base Year Curve):

Utilise the same method described as in Method 2.

Step 2 (Define Catchment Area):

This is same as Method 2 except that the catchment area consists of the relevant CAU to be served by the project.

Step 3 (Obtain journey to work data and develop journey to work total matrix):

Journey to work data can be obtained from Commuter View on the Stats NZ website. Commuter View provides the number of individuals commuting in and out of a CAU in the form of desire lines. A snapshot of the interactive tool is shown in Figure 4.5.

The number of the commuters can be obtained from the associated tables shown in Figure 4.6. The table view data can be configured to represent an origin-destination matrix. This allows the journey to work trip total matrix at the CAU level to be defined for the project catchment area.

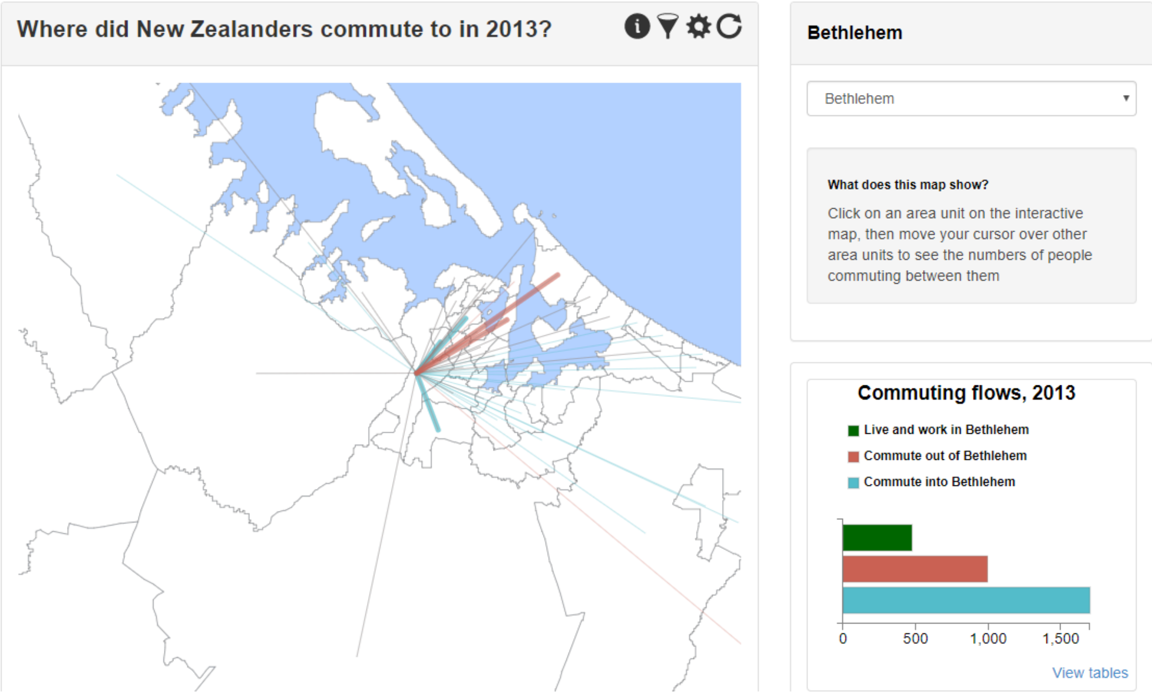

Figure 4.5: Example of Commuter View journey to work data as Interactive map

Bethlehem, (536514)

Area unit code	Area unit name	Type of flow	2006	2013
536615	Aongatete	in	9	18
536831	Arataki	in	9	27
536831	Arataki	out	21	18
537100	Bellevue	in	27	66
537100	Bellevue	out	12	6
536513	Bethlehem East	in	111	129
536513	Bethlehem East	out	6	6
537301	Brookfield	in	54	108
537301	Brookfield	out	15	18
536203	Doncaster	in	..	9
537500	Gate Pa	in	21	48
537500	Gate Pa	out	..	18
536517	Gravatt	in	6	21
536517	Gravatt	out	..	6
537601	Greerton	in	18	45
537601	Greerton	out	57	78
537900	Hairini	in	42	96
537400	Judea	in	12	33
537400	Judea	out	33	42
536630	Kaimai	in	42	87

Figure 4.6: Example of Commuter View journey to work data

Step 4 (Develop Base Year Commuter Active Matrix):

This step is similar to Method 2. The estimated active demand at the CAU level is likely to represent the commuter active trip matrix, instead of the total active trip matrix, as the input demand is sourced from journey to work data.

Step 5 (Matrix Expansion and Simplified Assignment and Calibration):

Estimated commuter active matrices can be expanded to include Home Based Education (HBE) trips. The locations of education centres such as schools or tertiary institutions should be identified within the catchment area of the proposed facility.

HBE active trips can be estimated using Census population data categorised by school age and school roll. Therefore, HBE trips can be added to the origin and destination CAUs appropriately. If there are no education centres within the catchment area, the HBE active trips can be ignored.

In a similar way to Method 2, the estimated active matrices at the CAU level can be aggregated to a simplified sector system and manually assigned to the network. Calibration of the model is recommended through the use of local data so that other trip purposes can be captured.

Step 6 (Develop Future Curve and Active Matrix):

The future year option curve and active matrix can be developed in a similar way as described in Method 2. However, there will not be an estimate of the forecast year trip matrix due to the absence of a regional transport model. Instead, an assumed growth factor (agreed with the model owner) should be applied to the base year commuter active matrix.

Method 4:

This is the current method used to determine an estimate of cyclist demand. This method makes use of the Waka Kotahi SP11 Walking and cycling facilities spreadsheet.

In particular instances where the population catchment approach in SP11 is not sufficient or appropriate, the comparison method should be used. The comparison method has been discussed in the Section 3.2.2 and involves a comparison of the proposed cycle facility with a similar cycle facility whose demand is already known.

The proportion of the population of the CAU near the existing facility and the proportion of the population near the new facility can be multiplied with the cycle trips of the existing facility to assess the cycle trips of the new facility. The ratio of the cycle to work counts for both CAU should be compared.

Another comparison approach is through the use of before and after studies. The ratio of the count before the facility is developed can be used to determine the demand of the new facility. Suggested comparison methods include:

- Cycle count of new facility = (Population of CAU of new facility/Population of CAU of existing facility) X Cycle count of existing facility
- Cycle count of new facility = (Bicycle Work trips of CAU of new facility/Bicycle Work trips of CAU of existing facility) X Cycle count of existing facility
- After cycle count of new facility = (Before cycle count of new facility/Before cycle count of existing facility) X After cycle count of existing facility

4.2.1 Electric assisted modes

As discussed in Section 3.3, the uptake of electric bicycles and electric scooters is increasing. One of the main reasons is the distance that users can travel on electric assist active modes. On conventional cycles, the average distance travelled was up to about 5km. On electric bicycles, individuals can comfortably travel up to 15km. This is primarily due to higher speed, less physical effort, and greater cargo carrying capacity. However, electric bicycles come with higher capital cost and are likely to be constrained to higher income households, commuters within urban environments and recreational users.

As discussed earlier in Section 3.3.2, typical distances covered by electric scooter users using shared platform devices is typically around 1.6km (average). Users have indicated that trips are mostly for recreational, social, and running errand purposes.

There is an increasing need to estimate the demand of the electric assisted active modes. Some cities are in the process of incorporating electric bicycles and/or electric scooters into their active mode strategic models or their transport models. The following example describes a method to include electric assist active modes and estimate the demand.

- A horizontal shift 'x' of the base trip distribution curve is recommended. A horizontal shift is recommended as electric bicycles can travel further, faster which translates into higher usage at the same distance.
- The magnitude of the horizontal shift of the curve depends on the expected uptake of electric bicycles within the project area.
- The magnitude should account for the increased capabilities and attractiveness to buyers while also reflecting any barriers that currently exist within the market.

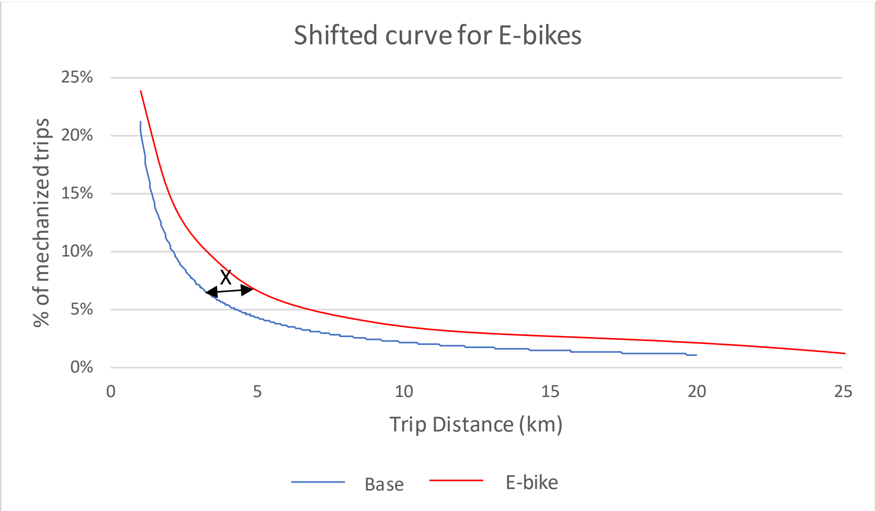

Figure 4.7: Hypothetical shifted curve for conventional bicycles (Base) and electric bicycles (E-bike)

In the case of electric scooters, a number of walking, public transport and driving trips may be diverted to shared electric scooters. A diversion factor can potentially be used to calculate the number of estimated electric scooter trips in a similar fashion to the electric bicycle curve shown in Figure 4.7.

There are currently some Waka Kotahi research projects that aim to further develop demand estimation for the active modes and the electric assisted modes.

To our knowledge, Tauranga City Council is also in the process of updating its traffic model. This will include the incorporation of the electric assisted modes based on some of the methods described during this review. The update is expected to be finalised in early 2020. We recommended that Waka Kotahi and its research teams follow up with the Tauranga City Council in early 2020 such that their findings can be incorporated into the EEM, if deemed appropriate.

4.3 Key gaps and opportunities

This review has identified gaps and opportunities that can be further explored. This section summarises these and provides recommendations for further consideration. Each recommendation has been assessed for its priority for delivery (from a time and resourcing perspective), based on the relative ease of implementation (easy, medium or hard) as well as corresponding benefits (high, medium or low):

- 1st Priority: Quick win providing high benefits for low effort
- 2nd Priority: Quick win providing relatively low benefits but for minimum effort
- Strategic: High benefits with high effort required
- Low Priority: Low benefits with high effort required

Table 4.9: Key gaps, opportunities, and recommendations from the review

Item	Description	Recommendation	Priority
Age groups	There is strong evidence that regular physical activity provides great health benefits to the two age groups of adults aged between 18-64 and in older adults who are 65 years and above (WHO, 2010). The document further elaborates that inactivity is more common in older adults, hence they are more likely to gain major health benefits compared to the other age groups. There is also emerging research that suggests that the uptake of electric bicycles in older age groups can have other health benefits not confined to physical health alone. For instance, the ability to use electric bicycles has resulted in larger life space that could have significant mental health benefits.	Fund research on assessing the mental health benefits for consideration as part of the health benefit framework.	2nd priority
Mental health/ well-being	The New Zealand Government has established mental health as a key priority. Sport NZ conducted an Active NZ survey to assess the correlation between mental well-being and physical activity participation (Richards et al., 2017). Recreation physical activity undertaken for at least 150 minutes per week can result in improved mental well-being. However, 270 minutes per week was the optimal duration of physical activity to gain improved mental well-being benefits (Richards et al., 2017). A recent research paper published by the University of Auckland, (Wild, 2018) suggested that cyclists are the happiest commuters and there is consistent evidence showing that cyclists have the highest levels of mode satisfaction compared to modes such as walking, public transport, or driving. Cyclist commute satisfaction can be		

Item	Description	Recommendation	Priority
	attributed by a high degree of commuting control, sensory stimulation, 'feel better' effect of moderate intensity exercise, and social interaction. Moderate-intensity exercise provides the most satisfaction to the majority of people by improving mood and increasing mental alertness. Cycling also increases opportunities for social interaction which increases social trust, feelings of familiarity, and affection for the local neighbourhood and other people. Cycling can be defined as a 'place-making activity'. Psychological and social pleasures of cycling and other active modes are to be further explored to examine how active modes can affect the quality of life. Currently, mental health and well-being are difficult to quantify as there are no set metrics to measure this factor. QALY and DALY are potential metrics which could be used to quantify mental health benefits. This is an emerging area and requires further research to establish a significant correlation between mental health and active modes. This emerging area will assist decision makers in developing initiatives and legislation with the intention of promoting active mode transport to provide further health benefits		
Ethnicity trends and benefits	Correspondence with University of Auckland's School of Population Health has indicated that the indigenous population are more disease prone and are likely to benefit the most from increased physical activity. This is not unique to New Zealand and has also been observed internationally. The Lancet's study found strong evidence of poorer health and social outcomes of indigenous people than for non-indigenous populations in over 23 countries and 28 populations, including in New Zealand (Anderson et al., 2016). Discussions indicate that it is inappropriate and impractical to segregate the value of health by ethnicity. This is due to the fact that the implementation of active mode projects is typically for an area with a wide variety of demographics. There may be value in funding further research into the health benefits associated with increased active mode transport for specific ethnic groups.	Ensure that equity distributional impacts will be reported in the Business Case process. Specifically, this should be reported in the proposed Appraisal Summary Table that is being developed through the Waka Kotahi and Ministry of Transport Investment Decision Making Framework (IDMF) review.	1st priority
		Fund research to further understand and assess the health benefits gained among specific ethnicity groups through the use of active mode and electric active mode transport.	2nd priority

Item	Description	Recommendation	Priority
Access to electric bicycles	This review has found that electric bicycles are deemed expensive and are potentially only affordable to higher income households. Given the potential health benefits associated with electric bicycles and the poorer health conditions found in lower socio-economic groups, it may be worthwhile to investigate the benefits and viability of improving access to electric bicycles to the populations. Correspondence with the Nga Tangata Microfinance Trust, which provides fair financial assistance to lower socio-economic groups, has indicated that options are limited when a low-income family needs to seek credit for vehicle purchase. People are often found to be charged excessive interest rates and higher costs for the purchase of a sub-standard vehicle that is prone to maintenance issues.	Assess any potential vehicle ownership and operating cost savings for the low socio-economic groups through incentives and/or financial assistance (eg as part of vehicle purchase feebate scheme)	Strategic
Electric scooter physical activity level	Currently, there is a lack of research regarding the physical activity levels achieved by electric scooter users. The MET levels associated with using electric scooters is unknown. There is also a lack of information on the number of privately-owned electric scooters in New Zealand.	Carry out or monitor any international research regarding physical activity levels achieved by electric scooter users.	Low priority
Use characteristics	Currently, there is limited information on: • Trip purpose and characteristics of privately-owned electric scooters and electric bicycles. Further understanding user traits will enhance the ability to estimate their demand and refine the health benefit valuation. • Count data of electric assisted active modes (ideally by ownership type) would be useful to develop a local growth profile. Understanding the type of ownership may be important to establish and capture the emergence of certain uses (eg postal, courier delivery, food delivery) which may have an impact on health benefits. User groups of the cycling and electric assisted modes (particularly electric bicycles). There is currently limited information whether these activities are done evenly across all population groups (by age, gender, ethnicity). More data would enable challenges to be identified and managed.	Establish the monitoring of these activities with local authorities.	Strategic

Item	Description	Recommendation	Priority
Air pollution/ emission costs	Active mode users exposed to air pollution in urban centres may result in adverse health consequences. This impact should be considered as the economic spillover externality for motorised vehicles and as such this cost should be incorporated within the cost of emission.	Quantify health impact as part of the vehicle emission costs.	2nd priority
Import data	Import data for bicycles are inclusive of all types of bicycles including children bicycles. Further segregation will improve the ability to better understand emerging trends in the market. Similarly, for the electric assisted modes, electric scooters, electric mopeds, and electric bicycles are all lumped together under a single import code. Segregation of these will provide a better ability to investigate trends of these distinct modes in the future.	Waka Kotahi to explore with NZ Customs on ability to introduce sub-codes for the import categories of bicycles and the electric assisted modes.	Strategic
Other projects	We are aware that a few Waka Kotahi projects have some overlap with this review. These include further research into the demand estimation methods for the active modes and a shift to non-traditional modes of travel (with a focus on electric assisted modes). Tauranga City Council is also in the process of updating its traffic models and this includes incorporation of the electric assisted modes.	It is recommended that the demand estimation framework from this review be used as a starting point to estimate the demand of active modes. It is recommended that Waka Kotahi follow up with Tauranga City Council in early 2020 to determine if their work can inform the initial EEM guidance. Ideally this would occur prior to completion of the Waka Kotahi research projects that are due for completion in late 2020.	1st priority

5. RECOMMENDATIONS

Following our review, it is recommended that the following health benefit values be incorporated in the EEM. It is recommended that the health benefit value per new user is capped such that they do not exceed the total estimated health benefits for converting an inactive person to an active person.

Table 5.1: Recommended health benefit values, on a per km basis

Active mode type	Health benefits for new user ($/km)	Maximum annual benefit per new user (2018 $)
Conventional cycling	$2.20	$2,500
Walking	$4.40	$1,250
Electric assisted cycling	$1.00	$2,000

This review has not found any research or evidence on the level of physical activity provided by electric scooters and as such it is recommended that health benefits for electric scooters will not apply until further research can substantiate the level of physical activity for this mode of travel.

A demand estimation procedure for the active modes, including the electric assisted modes, has been developed and illustrated in Figure 5.1.

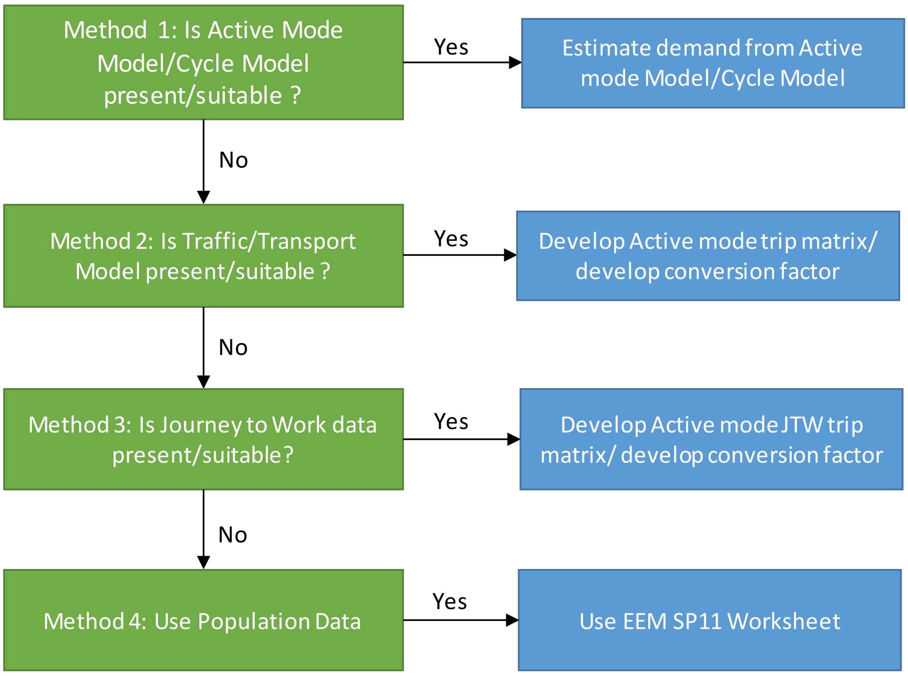

Figure 5.1: Demand Estimation Methods Procedure

The methodology for each of the four methods are detailed in Section 4. Further work and development of key items, mostly for Method 2, is required prior to inclusion into the EEM. Once further work has been completed Waka Kotahi can adopt the procedure and guidance note into the EEM.

The key items that require further work before inclusion into the EEM are:

- further development or guidance on the active mode share vs trip distance distribution curve. This curve is location specific and guidance could potentially surround the type of user and land use characteristics (eg major city, regional towns etc)

- develop a trip distribution curve for the electric assisted modes.

Other key observations and recommendations are outlined in the action plan in Table 5.2. The relative priority of the recommendation is also included and is based on the relative ease of implementation and corresponding benefits.

Table 5.2: Other Key Recommendations

Recommendations	Priority
Ensure that equity distributional impacts will be reported in the Business Case process. Specifically, this should be reported in the proposed Appraisal Summary Table that is being developed through the Waka Kotahi and Ministry of Transport Investment Decision Making Framework (IDMF) review.	1st priority
It is recommended that the demand estimation procedure from this review be used as a starting point to estimate the demand of active modes. It is recommended that Waka Kotahi follow up with Tauranga City Council in early 2020 to determine if their work can inform the initial EEM guidance. Ideally this would occur prior to completion of the Waka Kotahi research projects that are due for completion in late 2020.	1st priority
Fund research on assessing the mental health benefits for consideration as part of the health benefit framework.	2nd priority
Fund research to further understand and assess the health benefits gained among specific ethnicity groups through the use of active mode and electric active mode transport.	2nd priority
Quantify the health impact of air pollution as a part of vehicle emission costs.	2nd priority
Establish the monitoring of active mode and electric assisted active mode activities in conjunction with the local authorities.	Strategic
Assess any potential vehicle ownership and operating cost savings for the low socio-economic groups through incentives and/or financial assistance (eg as part of vehicle purchase feebate scheme).	Strategic
Waka Kotahi to explore with NZ Customs the ability to introduce sub-codes for the import categories of bicycles and the electric assisted modes.	Strategic
Carry out or monitor any international research regarding physical activity levels and associated health benefits achieved by electric scooter users.	Low priority

BIBLIOGRAPHY AND REFERENCES

Anderson I, Robson B, Connolly M et al., (2016). *Indigenous and tribal peoples' health (The Lancet-Lowitja Institute Global Collaboration): a population study*. Lancet. 2016; 388: 131-157

Barclays Research. (2019). *Micromobiltiy: Fast, Cheap and Good Solution for 'Smart Cities'*.

Barnes, G., Krizek, K. (2005). *Estimating Bicycling Demand,* Transportation Research Board

Beca Carter Hollings & Ferner Ltd. (1999). *Development of Procedures for the Evaluation of Cyclist Facilities*, report to Transfund NZ

Beca Infrastructure Ltd. (2007). *Health Benefits of Walking & Cycling*, report for Land Transport New Zealand

Bicycle Industries Australia. (2017). Australian bicycle sales slump. Retrieved from https://www.bikeoz.org/single-post/2017/08/28/Australian-bicycle-sales-slump

BMI Research. (2018). *Industry Trend Analysis - Battery Cathodes To Boost Metals As EV Market Expands.*

Bourne, J.E., Sauchelli, S., Perry, R. et al.(2018). *Health benefits of electrically-assisted cycling: a systematic review.* International Journal of Behavioral Nutrition and Physical Activity.

Bruce, O. (2019). *Why you should pay attention to micromobility*, New Zealand

Celis-Morales C.A., Lyall D.M., Welsh P., et al. (2017). *Association between active commuting and incident cardiovascular disease, cancer, and mortality: Prospective cohort study.* BMJ. 2017;357:j1456. http://dx.doi.org/10.1136/bmj.j1456. doi: 10.1136/bmj.j1456.

Charterian. (2019). Electric Bicycles Market Report Forecast by Industry Outlook, Capital Investment, Opportunities & Trends 2024. Retrieved from http://thecharterian.com/market-research-news/127782/electric-bicycles-market-report-forecast-by-industry-outlook-capital-investment-opportunities-trends-2024/

Christchurch City Council. *Draft micro-mobility discussion paper*; 2019.

Clifton, K.J., Singleton, P.A., Muhs, C.D., Schneider, R.J. (2015). *Development of a Pedestrian Demand Estimation Tool*, Final Report, National Institute for Transportation and Communities

CONEBI Confederation of the European Bicycle Industry (2017), *European Bicycle Market 2017 Edition Industry & Market Profile (2016 Statistics)*. Retrieved from http://www.conebi.eu/facts-and-figures/

Desyllas, J., Ward, J., Duxbury, E., Smith, A. (2003). *Pedestrian Demand Modelling of Large Cities: An Applied Example from London*, Working Paper series, Paper 62

Eftekhari, A (2017). Lithium-Ion Batteries with High Rate Capabilities. *ACS Sustainable Chemistry & Engineering*. 5 (3): 2799–2816.

Genter, A., Donovan, S., Petrenas, B. and Badland, H. (2008). *Research valuing the health benefits of active transport modes Report 359*, New Zealand Transport Agency

Griffin, G. (2009). *Simple Techniques for Forecasting Bicycle and Pedestrian Demand*, American Planning Association

Guidebook on Methods to estimate Non-Motorized Travel: Supporting Documentation, Federal Highway Administration, U.S. Department of Transportation

Hall C., Hoj T.H., Julian C., Wright G., Chaney R.A., Crookston B., West J. (2019). Pedal-Assist Mountain Bikes: A Pilot Study Comparison of the Exercise Response, Perceptions, and Beliefs of Experienced Mountain Bikers. JMIR Formative Research

Institute for Health Metrics and Evaluation (IHME), GBD Results Tool (2019). Retrieved from http://ghdx.healthdata.org/gbd-results-tool

Jacyna, M., Wasiak, M., Klodawski, M., Gołębiowski, P. (2017). *Modelling of Bicycle Traffic in the Cities using VISUM*, 10th International Scientific Conference Transbaltica 2017: Transportation Science and Technology

Lewis, C., James, E. (1997). *Central Massachusetts Rail Trail Feasibility Study*. Central Transportation Planning Staff, Boston, MA, April.

Lindsay, G., Macmillan, A. & Woodward, A. (2010). *Moving urban trips from cars to bicycles: impact on health and emissions*, Auckland, New Zealand

Malnes, L. *Can cycling with an E-bike improve fitness?* University of Agder; 2016.

Market Economics Limited (2013), *The Costs of Physical Inactivity – Toward a regional full-cost accounting perspective*, New Zealand

McDonald, A., Macbeth, A., Ribeiro, K., Mallett, D., MWH New Zealand (2007), *Estimating Demand for New Zealand Cycling Facilities in New Zealand*, Land Transport New Zealand Research Report 340

Ministry of Health. (2017). Annual Data Explorer 2016/17: New Zealand Health Survey. Retrieved from https://minhealthnz.shinyapps.io/nz-health-survey-2016-17-annual-update

Ministry of Health. (2016). *Annual Update of Key Results 2015/16: New Zealand Health Survey*. Wellington: Ministry of Health

Ministry of Health. (2016). Health Loss in New Zealand 1990-2013*. A report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study*. Wellington: Ministry of Health

Ministry of Social Development, National Health Statistics Reports. (2016). *The Social Report 2016: New Zealand, 2016*. Retrieved from http://socialreport.msd.govt.nz/health/participation-in-physical-activity.html

Neves A, Brand C. *Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel diary approach.* Transportation Research Part A. 2019;123:130-146. https://www.sciencedirect.com/science/article/pii/S0965856417316117. doi: 10.1016/j.tra.2018.08.022.

NZ Herald (2019), Under the radar: Thousands of bicycles stolen every year, very few offenders caught. Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12244671

NZ Transport Agency (2018), *Economic Evaluation Manual*, New Zealand

Pharmac. (2015). Prescription for Pharmacoeconomic Analysis Methods for Cost-Utility Analysis, New Zealand

Pushkarev, B. and Jeffrey M. Zupan. (1971). *Pedestrian Travel Demand*. Highway Research Record 355,

Raser Elisabeth, Dons Evi, Gaupp-Berghausen Mailin, Anaya-Boig Esther, Brand Christian, Clark Anna, et al. *European cyclists' travel behaviour: Differences and similarities between seven European (PASTA) cities.* Journal of Transport & Health. 2018;9:244-252. https://dx.doi.org/10.1016/j.jth.2018.02. 006.

Richards J, Barnes M, Keane A, et al. *Active NZ: Recreational physical activity and mental wellbeing*. 2018

Ryley, T. (2006). *Estimating Cycling Demand for the Journey to Work or Study in West Edinburgh, Scotland*, Transportation Research Board.

Standen, C. (2018). *The value of slow travel: An econometric method for valuing the user benefits of active transport infrastructure* (Doctor of Philosophy's thesis). The University of Sydney Business School, Sydney, Australia

Struijk, Ellen & May, Anne & Beulens, Joline & De wit et al. (2013). Development of Methodology for Disability-Adjusted Life Years (DALYs) Calculation Based on Real-Life Data. PloS one. 8.

e74294. 10.1371/journal.pone.0074294. Wigan, M., Anthony., Paris B. (1998) *Simplified Estimation of Demand for Non-motorized Trails Using GIS*, Transportation Research Board.

Wigan, M., Anthony., Paris B. (1998). *Simplified Estimation of Demand for Non-motorized Trails Using GIS*, Transportation Research Board.

Wild K, Woodward Alistair. *Electric city: E-bikes and the future of cycling in New Zealand.* The University of Auckland. 2018.

Wild K. *Why are cyclists the happiest commuters?*. 2018.

Woods M, Shaw J. (2018) 10,000 electric vehicles on NZ roads. Beehive. Retrieved from https://www.beehive.govt.nz/release/10000-electric-vehicles-nz-roads

World Health Organization. (2010). *Global Recommendations on Physical Activity for Health*. Geneva: World Health Organization.