Public Health Monograph Series
No. 37
ISSN 1178-7139

TECHNICAL REPORT FOR BODE^3 ACTIVE TRANSPORT AND PHYSICAL ACTIVITY MODEL

Version 1.1

Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme (BODE^3)

Technical Report: Number 18

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First version: November 2018

A technical report published by the Department of Public Health,
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ISBN 978-0-9951070-2-1

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List of acronyms used in report

BODE^3	Burden of Disease Epidemiology, Equity and Cost-Effectiveness
CHD	Coronary Heart Disease
COPD	Chronic Obstructive Pulmonary Disease
GBD	Global Burden of Disease
GHG	Greenhouse Gas
HTS	Household Travel Survey
ICD	International Classification of Diseases
LRTI	Lower Respiratory Tract Infection
PAAT	Physical Activity and Active Transport
MSLT	Multi-State Life Table
MVPA	Moderate and Vigorous Physical Activity
MET	Metabolic Equivalent of Task
NZ	New Zealand
NZBDS	New Zealand Burden of Disease Study
NZHS	New Zealand Health Survey
PIF	Population Impact Fraction
PM2.5	Fine Particulate Matter (less than 2.5µm in diameter)
QALY	Quality Adjusted Life Year
RR	Relative Risk
TMREL	Theoretical Minimum Risk Exposure Level
WHO	World Health Organization

Overview and purpose

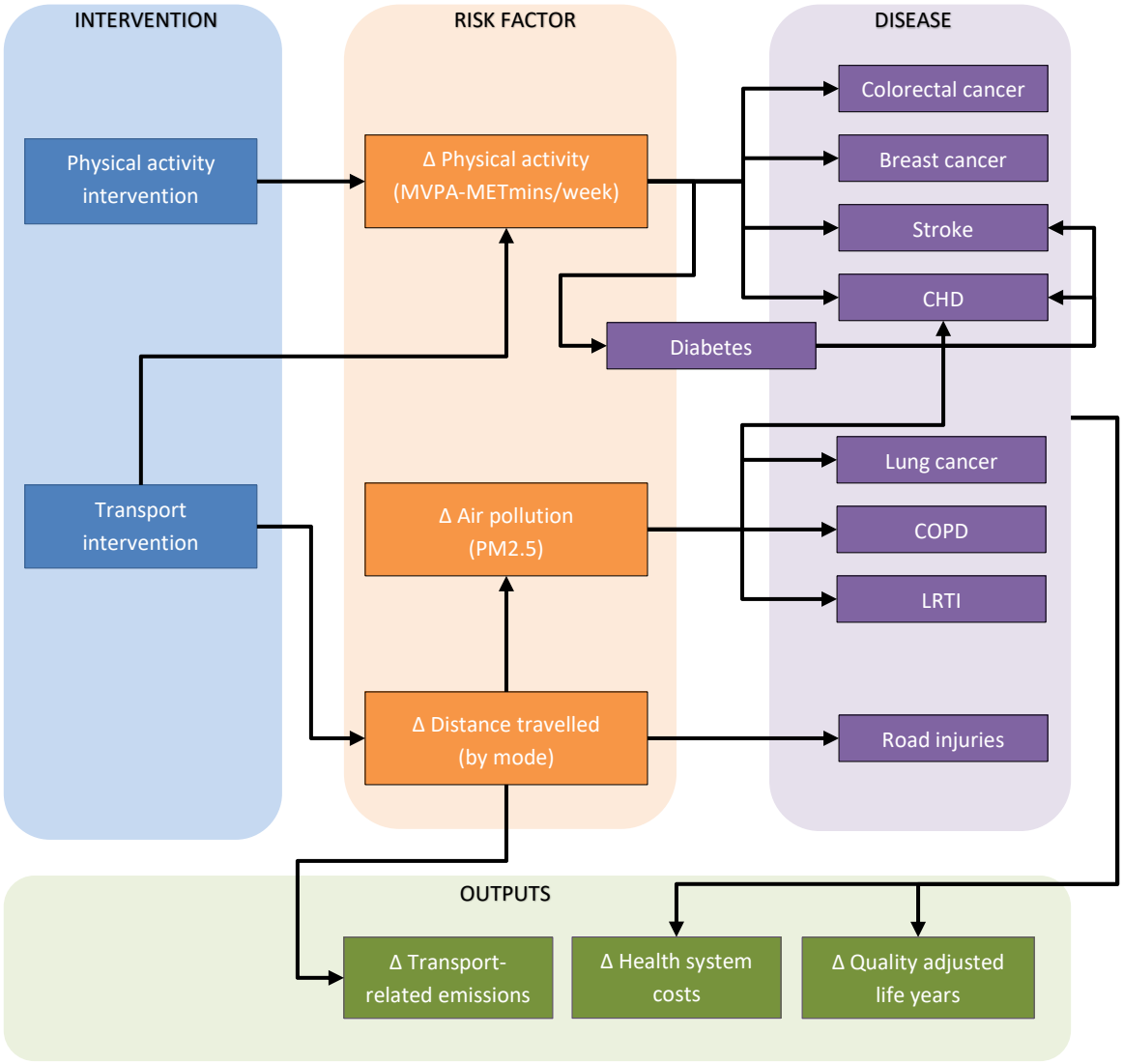
This Technical Report provides the documentation on the Burden of Disease Epidemiology Equity and Cost Effectiveness (BODE^3) physical activity/active transport (PAAT) model. The PAAT model is closely related to the DIET model – the epidemiological inputs for shared diseases are shared between the two models. Full details of how these were derived are available in the DIET Technical Report[1], with epidemiological inputs available on the BODE^3 website[2]. In this document, we primarily outline additions to and differences between the PAAT model and the DIET model.

Broadly, the PAAT model estimates changes in transport related behaviour using data from the NZ Household Travel Survey. Changes in transport behaviour result in changes in distance travelled (by mode) and change in physical activity, which are fed into a multi-state life table (MSLT) model. Alternatively, changes in physical activity arising from interventions that exclusively target physical activity (e.g. green prescriptions) can be modelled directly through the MSLT end of the model. The MSLT model closely resembles the DIET MSLT model, with the addition of disease states for conditions related to transport. There are three risk factors in the PAAT model that influence health outcomes: change in moderate and vigorous physical activity (MVPA-METmins/week[i]); change in transport (total distance travelled by mode); and change in air pollution (average annual PM2.5 concentration). These risk factors influence eight disease outcomes (coronary heart disease (CHD), stroke, diabetes, colorectal cancer, breast cancer, lung cancer, chronic obstructive pulmonary disease (COPD), lower respiratory tract infection (LRTI)) and road injuries, via pathways illustrated in Figure 1. The MSLT model is used to estimate the health impacts, costs, and equity impacts of physical activity and transport interventions.

This Technical Report is organised in three parts. Part I describes how interventions are parameterised in the PAAT model, including how baseline and intervention data were derived for physical activity and transport behaviour. Part II describes the relationship between the risk factors (i.e. physical activity, transport behaviour, air pollution) and diseases included in the model. Part III describes the MSLT structure and the calculation of disease-specific parameters included in the model.

[i] Measure of minutes per week of moderate and vigorous physical activity scaled to reflect activity intensity. Further details are given below.

Figure 1: Physical activity model conceptual diagram



Defining and measuring physical activity

The World Health Organization defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure"[3]. Ideally, the epidemiological data and our models would capture the impact of changes in any physical activity and would be able to quantify the health impacts of different types of activities (e.g. differences in the relative risk (RR) relationships for different activity types and activity intensities). Unfortunately, modelling the impact of changes in overall physical activity on health is limited by measurement of physical activity. The data available on physical activity in New Zealand captures walking, moderate and vigorous activity[4]. Whilst estimates of total physical activity are possible at the individual level (e.g. using accelerometers), it is only recently that this has become feasible to implement at a scale sufficient to derive population level estimates of exposure (e.g. Doherty et al 2017[5]).

Incomplete assessment of physical activity exposure at the population level has also influenced assessment of the risk associated with physical activity. Studies that have measured the RR

associated with physical activity only capture a fraction of total activity in their exposure assessment. For example, of the 35 studies included in Global Burden of Disease (GBD) meta-analysis of the dose-response relationship between physical activity and CHD, 14 exclusively measured recreational physical activity, only seven included measures of household physical activity, and 11 measured commuting related physical activity[6]. As exposure assessment is limited to certain types of physical activity (usually to higher intensity activities such as recreational sport), meta-analysis of the RRs for physical activity are more accurately described as RRs associated with moderate and high intensity physical activities.

The PAAT model is designed to capture the impact of changes in moderate and vigorous physical activity, expressed as a change in MET (metabolic equivalent of task) minutes per week of moderate and vigorous activity. A MET is the ratio of work metabolic rate to a standard resting metabolic rate, where one MET is equivalent to sitting quietly[7]. WHO definitions state that moderate activities include those with MET values between three and six, and vigorous activities include those with a MET value greater than six[3]. The MET values associated with different activities have been documented as part of the Compendium of Physical Activities[7].

Using the definition of "MET minutes per week of moderate and vigorous physical activity" (henceforth MVPA-METs) within the PAAT model utilizes the most complete population level physical activity data available in NZ (from the Health Survey), paired with published RR estimates derived from similar methods of exposure assessment (i.e. self-report questionnaires across selected domains of physical activity).

The main limitation of this approach is that it does not capture possible health impacts associated with increasing total physical activity below the moderate-to-vigorous threshold. Emerging evidence suggests that reducing sedentary time by increasing light activity may reduce risk of mortality and morbidity (e.g. [8-11]). RR estimates for sedentary time and light activity relate to specific population groups and the evidence is not yet generalizable enough to include in a NZ model. In addition, there are currently no population level estimates of sedentary time and light activity in NZ. The decision to restrict the modelled definition of physical activity to MVPA-METs will be reviewed and could be amended in future versions of the PAAT model if relevant inputs became available.

Baseline physical activity data

The New Zealand Health Survey (NZHS) 2011/12 was used to estimate baseline physical activity prevalence. The 2011/12 survey included 12,370 randomly selected adults aged 15 years and over[4]. The NZHS includes the New Zealand Physical Activity Questionnaire Short Form, which consists of questions on the amount of time spent engaging in moderate and vigorous physical activities, and brisk walking[4]. Respondents are provided with examples of moderate and vigorous activities, but no data on the type of physical activities done by individual respondents is collected.

We converted individuals' time spent engaging in brisk walking, moderate, and vigorous activities to total MVPA-MET minutes per week. Brisk walking was assigned a MET value of 3.0, moderate activities a MET value of 4.5, and vigorous activities a MET value of 6.5. MET values assigned to different activities were consistent with those used in estimates of RRs associated with physical activity[12]. We summed up the total MVPA-MET minutes per week for each individual, and then calculated the proportion of the population that fell into each of the following categories:

- <30 MVPA-METmins/week
- 30-300 MVPA-METmins/week
- 300-600 MVPA-METmins/week
- 600-1,800 MVPA-METmins/week
- 1,800-3,000 MVPA-METmins/week
- 3,000-8,000 MVPA-METmins/week
- 8,000+ MVPA-METmins/week

We fitted a lognormal distribution to smooth the proportions derived from the NZHS. These distributions were used to calculate the mean and standard deviation of MVPA-METmins/week within each of the above categories by age, sex, and ethnicity.

Baseline active transport data

We used the Household Travel Survey (HTS) to derive estimates of the total distance travelled annually by mode (pedestrian, cyclist, motorbike, and motor vehicle), age group, sex, and ethnicity. Total distance travelled (and changes in distance travelled under interventions) were imported into the MSLT model. The HTS was also used to estimate changes in MVPA-METmins/week for transport interventions, but was not used to estimate baseline physical activity levels as it only contained information on transport behavior.

We used HTS data from 2003 to 2014 over which time around 43,000 households were invited to participate (with higher numbers of households invited from 2008/09 onwards)[13,14]. All household members were asked to complete a diary of their travel over two days. The HTS provides information on the purpose, mode, distance, and duration of each trip made by an individual. The HTS also records a number of socio-demographic variables including age, sex, and ethnicity. The mean age of the sample was 37 years (SD 23 years), 51% of the sample were female, and 11% identified as Māori. Weights are available at the person and trip level that enable the user to estimate transport behavior for the NZ population as a whole from the HTS sample. We excluded children (<15years) and non-completers from the analysis. All analyses on the Household Travel Survey dataset were conducted in R (version 3.4.3).

Baseline estimates of total distance travelled by mode were calculated by summing the distances of all trips made by each mode and applying weights provided by the Ministry of Transport to obtain estimates of total annual distance travelled by mode. We derived total distances by mode separately by sex, age, and ethnicity. This was necessary to estimate changes in injury rates following an intervention, as injuries will be influenced both by the distances travelled within a group and by the total distance travelled by other modes; the first reflects risk of injury to an individual and the second reflects the risk they impose on others. Further detail on how changes in distance travelled influence injury rates is provided later in this report.

Intervention impacts

The PAAT was designed to model two different types of interventions: interventions that change physical activity directly and interventions that change physical activity by means of changing transport behavior. The first was modelled by estimating effect sizes (change in MVPA-METs) from the literature and entering these directly into the MSLT model in Excel, the second was modelled in

R using the HTS to estimate changes in MVPA-METs and changes in distance travelled. Change in distance travelled by mode and change in MVPA-METmins/week from the HTS simulation (by age, sex, and ethnicity) and associated uncertainty were imported into the MSLT model.

1.01.1. Interventions that change physical activity directly

Interventions that change physical activity directly include any interventions where previous research was used to change population level MVPA-METmins/week. Examples include green prescriptions (i.e. GP prescribing PA to patients) and increasing uptake of pedometers in mobile technologies. Values for change in MVPA-METmins/week are entered directly into the model with their corresponding uncertainty intervals by sex, age group (<20, 20-40yrs…etc.), and ethnicity (Māori, Non-Māori); and in the future deprivation level.

The PAAT model can also be used to assess the health impacts of hypothetical changes in MVPA-MET distribution (e.g. meeting physical activity guidelines) using the same mechanism of entering the change in MVPA-METmins/week. To prevent unrealistic increases in MVPA-METs for those with high baseline levels of activity under extreme scenarios, the model has an upper limit of 8000[ii] MVPA-METmin/week value that can be achieved under the intervention.

1.01.2. Interventions that change transport behavior

We estimated the overall impact of shifts in transport behavior on physical activity by estimating intervention impacts for individuals in the HTS and then averaging across the HTS sample as a whole to obtain the change in physical activity at the population level.

Firstly, we used the trip level data in the HTS to determine which trips would shift to a different mode under the intervention scenario. For all trips where the mode changed under the intervention, we calculated the change in duration and associated change in MVPA-METmins. We summed MVPA-METmin changes across all trips for an individual and then estimated weekly change in MVPA-METmins.

For example, an individual who switched a 0.8km car trip to walking would gain 33 MVPA-METmins and the trip would take them around 11minutes (assuming walking speed of 4.4kph and MET value 3 for walking). If the trip took 3mins to drive, the change in duration would be 8mins. Assuming travel for the two observed days is representative of the week, this would result in a physical activity increase of 115.5METmins/week (16.5MVPA-METmin change per day). The associated time cost would be 28minutes additional travel time per week. The change in travel time outcome was used to examine the feasibility of different interventions and we could restrict analyses to trip switches that minimized impacts on total travel time.

We assumed that changes in transport-related physical activity did not impact on physical activity from other domains (e.g. leisure, occupational). Existing evidence suggests that active transport is associated with higher levels of total physical activity[15], and that recreational physical activity levels do not differ between those who commute actively compared to those who do not[16]. In NZ, those who use active modes of transport are more likely to meet physical activity recommendations than those who do not[17], suggesting that physical activity accumulated from transport is additional to

[ii] This reflects the value used in the Global Burden of Disease

physical activity accumulated in other domains. However, much of the evidence on the association of active transport with total physical activity levels comes from cross-sectional studies rather than intervention studies. This means it is unclear whether ***changes*** in transport-related activity would ***change*** physical activity in other domains, especially if switches to active transport incur a substantial time cost. Parameters in the model could be updated to include intervention impacts on physical activity across different domains as and when high quality evidence of these impacts becomes available.

Within the HTS intervention simulation, we allowed uncertainty around speeds by mode and MET values for walking and cycling. As with previous BODE work (e.g. [18]), we followed the generic approach of applying a standard deviation of +/- 20% for speeds as we deemed these to be highly uncertain.

Table 1: Household Travel Survey Simulation Parameter Distributions

Parameter	Distribution	Value	Uncertainty	Notes
Walking speed	Normal	4.4km/hr[14]	20%	Applied at the individual level for each run of the model
Cycling speed	Normal	10.5km/h[a]	20%	
Walking METs	Normal	3.0[b,7]	20%	
Cycling METs	Normal	3.5[c, 7]	20%	
[a] Based on current cyclist speed calculated from the HTS [b] Most comparable compendium description: walking, 2.5 mph, level, firm surface [c] Most comparable compendium description: bicycling, leisure, 5.5 mph				

Distance and MVPA-METmins/week changes under the intervention scenarios modelled at the individual level in R were imported into the Excel MSLT model. The absolute average change in MVPA-METmins/week in the intervention scenario was applied to the whole population in the Excel MSLT. In practice, this consisted of adding the intervention increase in physical activity to the baseline physical activity level within each category of baseline activity. For example, if an intervention resulted in a 10MVPA-METmin/week increase in physical activity, then those in the lowest physical activity category (under 30MVPA-METmins/week) would gain 10MVPA-METmins/week under the intervention scenario. The same change (10MVPA-METmins/week) would be applied to every other category of baseline physical activity up to and including the category with the highest levels of physical activity at baseline (i.e. over 8000MVPA-METmins/week). The health impacts associated with simulated changes in distance and MVPA-METmins/week were calculated within the Excel MSLT model, assuming independence between baseline MET values and change in METs under the intervention.

For transport-related interventions, we assumed changes in distance travelled and MVPA-METmins/week to be permanent (i.e. to apply for the remainder of the 2011 cohort's lifetime). For physical activity only interventions (e.g. green prescriptions), the model allows specification of the annual decay in the intervention impact. We modelled an exponential rate of decay; the magnitude of decay is determined as part of intervention specification.

1.01.3. Transport emissions calculations

We calculated changes in transport-related emissions associated with changes in transport patterns for transport-related interventions as a secondary output. Whilst the majority of outputs in our models give values for the impact of the intervention for the lifetime of the NZ adult population alive in 2011, emission results represent the difference in household transport emissions in the first year of the intervention. Technological improvements have resulted in rapid changes in emissions associated with different types of vehicle (e.g. the development of electric cars with minimal direct emissions). It was beyond the scope of the project to estimate long-term changes in factors such as uptake of electric vehicles, improvements in the efficiency of conventional motors, and changes in dietary patterns. We did not include emissions associated with healthcare provision or with changes in the life expectancy of the modelled cohort, and therefore the modelled emissions represent a sub-set of the total emissions associated with modelled interventions.

For car journeys, we assigned a kgCO2e/km value to car trips based average emissions values gathered from the Ministry for the Environment[19]. These include the direct emissions associated with vehicular travel, but not indirect emissions associated with the manufacture of the vehicle. As there were no NZ specific emissions factors for motorbikes or public transport, we sourced estimates of emissions from the 2016 Government GHG Conversion Factors for Company Reporting in the UK[20]. Motorbikes were assigned the average motorbike emission factor for the UK (0.12 kg CO_2e). The HTS does not provide detail on mode for local public transport trips (i.e. whether journeys made by bus, rail, or ferry). We assigned all local public transport trips the emissions factor for local buses (0.10 kg CO_2e/passenger km[20]), as buses are the dominant mode of public transport in NZ[21]. However, it is worth noting that alternative forms of public transport may have even lower emissions (e.g. 0.05 kg CO_2e/passenger km for light rail and tram[20]).

Pedestrian and cycling trips were assigned emissions factors of 0.195kgCO_2e/km and 0.094 kgCO_2e/km respectively. Pedestrian and cycling emissions are based on the additional food energy ("fuel") required to offset the increased energy expenditure and maintain a constant body weight and use existing methods[22]. First, we estimated current energy requirements per minute from FAO data on per capita energy supply[23]. Energy supply data were used to counteract the presence of underreporting known to be a problem in dietary surveys. Whilst this will overestimate the actual energy intake that would be required to compensate for additional physical activity, it is a more representative measure of the emissions associated with the provision of additional energy from the agricultural system. Second, we estimated the additional energy required per minute of walking and cycling by dividing current energy requirements by an average MET value for a predominantly inactive lifestyle (MET = 1.5) and then multiplying this by the MET values for walking and cycling. We multiplied the excess energy intake for walking and cycling by the time taken to travel one kilometre to estimate excess energy intake per kilometre. Finally, the excess energy intake was multiplied by average emissions per kilocalorie of the current NZ diet, calculated by dividing the reported average per capita emissions by reported average energy intake[24]. The standard deviation around the emissions factors was set to 20% of the estimated emissions factor.

For each trip, we calculated the carbon dioxide equivalent value of the trip by multiplying the emissions factor by the trip distance. For car journeys, we then divided the total emissions by the number of people in the vehicle. Where unspecified, we assumed the respondent was the only person in the vehicle for car journeys. We applied trip weights provided in the HTS to generate the

total emissions at baseline and under each transport intervention scenario. Our estimate of total baseline emissions reflects emissions from the following trip modes: pedestrian, car/van driver, car/van passenger, cyclist, and local public transport. Trips made by the above modes accounted for 98% of all trips in the dataset. We were unable to estimate the emissions contribution of "Other household travel", "Non-local public transport", and "Non-household travel" to total baseline emissions owing to the lack of detail on the mode of these trips. Our estimates are an underestimate of total transport related emissions as they only include emissions relating to household transport and do not include emissions associated with commercial transport (e.g. emissions of heavy good vehicles). We report dietary emissions associated with walking and cycling separately to vehicular emissions to allow easier comparison of our interventions with the existing literature, which only includes emissions associated with motorised vehicles.

Risk factor distributions

There are three risk factors in the PAAT model that influence health outcomes: change in physical activity (MVPA-METmins/week); change in transport (total distance travelled by mode); and change in air pollution (average annual PM2.5 concentration). Change in physical activity and total distance travelled by mode was estimated separately by sex (male and female), ethnicity (Non-Māori and Māori), and age group (<20years, 20-40years, 40-60years, 60-80 years, 80+years). Changes in air pollution were calculated for the population as a whole.

2.01.1. Relative risks

In the PAAT model, changes in the distribution of risk factors resulting from interventions influence disease incidence through potential impact fractions (PIFs) for physical activity and air pollution, and through a risk ratio for road injuries. PIFs are calculated separately for each risk factor to disease incidence relationship using the RR shift method[25], replicating the methods used in the DIET model[1].

Uncertainty around the RRs was assumed to follow a lognormal distribution. We applied the Barendregt (2010)[26] correction method to all RRs to ensure that the mean effect size remained equal to the point estimate of the RR and that the width of the confidence interval around the RR was retained. This differed from the DIET model where scaling of the parameters prior to entry into the model was not required due to the use of Ersatz to run the model, specifically the use of the ErRelativeRisk function.

2.01.2. Physical activity

In the PAAT model, increases in physical activity (MVPA-METmins/week) reduce the risk of CHD[12], stroke[12], diabetes[12], colorectal cancer[6], and breast cancer[6] incidence. We used estimates of the RR of disease based on physical activity from two meta-analyses: Kyu et al[6] and Wahid et al[12]. These were the only two meta-analyses that we identified that provided continuous dose-response relationships, as opposed to categorical estimates (e.g. for low, medium, and high physical activity categories based on population tertiles).

The Kyu et al[6] estimates were derived for the Global Burden of Disease study and include a broad range of different health outcomes. This meta-analysis estimates RRs associated with activity levels from 0-8000MVPA-METmins/week. Whilst Kyu et al[6] allow for a continuous dose-response curve across the range of MVPA-MET levels modelled, the dose-response curve is linear at low levels of

physical activity. However, dose-response relationships (for cardiovascular diseases and diabetes) observed in literature show the greatest benefits of a unit shift in PA accrue to those with the lowest baseline levels of PA[12]. Linearization of the dose-response curve is likely to bias effect estimates towards the null for small shifts in physical activity levels in populations (like NZ), where baseline physical activity levels are low. The Wahid et al[12] meta-analysis accounted for a non-linear dose response relationship between PA and rates of CHD, stroke, and diabetes. Given that many of our modelled interventions result in very small shifts in physical activity (<100MVPA-METmins/week), it is important that the PAAT model accurately captures the health impact of small shifts. This issue is less pronounced for breast cancer and colorectal cancer where the impact of changes in physical activity is much smaller and flatter, as demonstrated in the continuous dose-response curves given in Kyu et al.

It is worth noting that the Kyu et al and Wahid et al meta-analysis differed in their adjustment for changes in BMI. The Wahid et al study provided separate estimates of RRs with and without adjustment for BMI. In the Kyu et al meta-analysis, the majority (but not all) of the included studies had adjusted for BMI but some bias may remain from the few studies that did not adjust for BMI. Where available, we used BMI adjusted RR estimates in the PAAT model.

(i) BMI impact

Increases in physical activity result in increased energy expenditure, and could result in weight loss if there was incomplete compensation of energy intake. As discussed in relation to emissions, we assumed that increased energy expenditure would be compensated by increased food intake.

Reviews of the effect of active transport interventions on body weight are inconclusive[27,28]. Those who walk and cycle are reported to be lighter than people who travel by car. However, most studies have been cross-sectional, which means it is unclear whether people shifting to active transport lose weight as a result or are lower weight for other reasons (i.e. confounding). Few longitudinal studies have tackled this question, and those that have do not include comprehensive assessments of other changes in individual circumstances that may confound the observed relationship[29-31]. Whilst some capture major life events (e.g. moving house, new job), none capture changes in dietary patterns or changes in neighbourhoods – factors that could influence both active transport and dietary patterns.

At present, the PAAT model is not designed to estimate the impacts of physical activity interventions that have impacts on BMI. In the future, the PAAT model will be combined with the BODE^3 DIET model to allow assessment of physical interventions that do change BMI. Further methodological work is necessary prior to implementation of the combined model. However, the current DIET model can be used to examine the maximum health impacts of changing BMI from selected interventions.

(ii) MET values

Across the different data sources used in the PAAT model, there was variation in the MET values that were assigned for different types of activity (see table below). We will examine the impact of the variation in MET values assigned in sensitivity analyses.

	Walking	Light activity	Moderate activity	Vigorous activity	Notes

Kyu et al[6]		-	4	8	Where type of activity was not listed, country-specific centile values were calculated and those were mapped to MET values
Wahid et al[12]		2.5	4.5	6.5	Inactive assigned a value of 1.5
Household Travel Survey	3				Conversion of HTS assumed speed to MET value based on the compendium of physical activities[7]
PAAT model	3	-	4.5	6.5	We also prepared scenario analyses with different MET values to test the sensitivity of modelled results to MET value assumptions

2.01.3. Road injuries

The PAAT model includes the impact of changes in transport behavior on road injury rates. Previous studies have demonstrated that changes in active transport may have deleterious health impacts in some population groups due to increases in injuries (e.g. modelled health impacts of the London bicycle hire scheme had negative health impacts for younger women[32]). The inclusion of road injuries within the model enabled us to assess whether improvements in health from increased physical activity in active transport intervention scenarios were outweighed by increases in road injuries or vice versa.

We calculate changes in distance travelled, by mode, age, sex, and ethnicity from the HTS. The distance travelled by mode within each population group influence the risk of being a victim ($_v$) – if a particular sub-group had no motorbike travel, then no one in that group would be a motorbike victim. The distance travelled within each sub-group contributes to total distance travelled by each mode, which influences the risk to victims from different 'hitter' ($_h$) modes – if there were no motorbikes on the roads there would be no instances of pedestrian victims hit by motorbike 'hitters'. The impact of changes in distance on injury rates depends on baseline injury rates for each victim-hitter combination (B_{vh}), which we derived as part of the model building procedure.

In addition, meta-analysis of changes in transport behavior has demonstrated a safety-in-numbers effect for both pedestrians and cyclists, whereby increases in pedestrians and cyclists result in a less than proportional increase in the number of injuries[33]. To determine the impact of interventions on road injuries we calculate the intervention mortality and YLD rates for each victim mode (I_v) by combining impacts across each victim-hitter ($_{vh}$) combination. Intervention rates are calculated from baseline rates (B_{vh}), distance travelled (D) by mode ($_{p, c, mb, mv}$), and mode-specific coefficients representing the safety-in-numbers effect (E) derived from meta-analysis of multivariate modelling studies[33]. The overall formula for calculating the change in rates is adapted from Woodcock et al[34]:

$$I_v = \sum_{h=p,c,mb,mv} B_{vh} \left(\frac{D_{Iv}}{D_{Bv}}\right)^{E_v} \left(\frac{D_{Ih}}{D_{Bh}}\right)^{E_h}$$

The ratio of intervention to baseline rates is then calculated and applied in the same way that PIFs are used for the non-communicable disease impacts.

We captured the uncertainty around the safety-in-numbers coefficient using the reported mean and variance from the meta-analysis[33] to parameterize the beta distribution. Disease rates were normally distributed using a standard deviation (SD) of +/-5% of the baseline injury rate. Uncertainty around the change in distance travelled reflected estimates of the uncertainty around baseline distance travelled in the HTS data, as our scenarios involved switching the mode of trips that are currently being made with no additional trips added or existing trips removed.

Additional assumptions

An implicit assumption with risk ratios for road transport injuries is that the interventions do not change other variables that could influence risk of death/hospitalization from road injuries (e.g. speed, nature of pedestrian crossings, cycle lane availability, helmet-wearing prevalence). We also assume that the severity distribution of injuries would not be changed by the modelled interventions. In addition, due to small numbers of road traffic injuries in New Zealand (particularly when split by mode), we grouped data between 2006 and 2013, but do not account for trends in mode-specific deaths or hospitalizations that may have occurred over this seven-year time period (i.e. trends in victim-hitter mode combinations).

2.01.4. Air pollution

Baseline exposure to fine particulate matter air pollution (PM2.5) was based on population-weighted exposure estimates for New Zealand from GBD[35], with the same exposure assigned to all age groups, males and females, and both Māori and Non-Māori populations. Uncertainty around the exposure was normally distributed with a standard deviation based on confidence intervals reported in GBD[35].

We used RR estimates from the Global Burden of Disease study to model the impact of changes in fine particulate matter resulting from changes in transport behaviors on CHD, lung cancer, COPD, and LRTI[36]. We assumed that uncertainty around the RRs for PM2.5 concentration was fully correlated (R=1.0) between different age groups as it seemed implausible to draw a high RR value for one age group and a very low RR value for an adjacent age group.

Intervention changes in air pollution exposure were calculated based on changes in the distance travelled by motor vehicles. Road transport accounts for 11% of total PM2.5 in New Zealand[37]. We assumed the road transport component of PM2.5 component would change proportionally to the change in distance travelled under intervention scenarios. This can be expressed as:

$$E^I = E^B + \left(E^B * PM_{2.5}^{Road} * \Delta Dist\right)$$

Where E^I represents intervention exposure, E^B represents baseline exposure, $PM_{2.5}^{Road}$ represents the fraction of the exposure that is due to road transport, and $\Delta Dist$ represents the percentage change in the distance travelled by motorized vehicles under the intervention scenario. We applied a beta distribution with 20% uncertainty around the proportion of PM2.5 resulting from road transport.

Theoretical minimum risk exposure levels

The theoretical minimum risk exposure level (TMREL) is a theoretically possible level of risk factor exposure that minimizes overall risk, allowing us to quantify how much of the disease burden could be lowered by shifting the population to this 'theoretically possible' minimum risk level[38]. Applied to a single risk factor, shifting the population distribution to the TMREL gives the maximum envelope of health gains that could be achieved by addressing this risk factor.

2.01.5. Physical activity

The TMREL specified for physical activity in GBD was ≥8000MVPA-METmins/week[39]. Unlike other risk factors, the TMREL for physical activity is far in excess of population recommendations (NZ physical activity guidelines equate to 675MVPA-METmins/week). Due to the discrepancy between population recommendations and the GBD TMREL for physical activity, we allowed specification of the TMREL as part of intervention specification. This allows us to look at the impact of interventions relative to different overall 'envelope' values: the GBD physical activity envelope and the envelope of reaching NZ recommendations.

2.01.6. Air pollution

The TMREL for air pollution was parameterized as a PM2.5 concentration uniformly distributed between 2.5 and 5.9μg/m^3, consistent with the GBD TMREL[39]. The non-zero TMREL for air pollution reflects the fact that some level of fine particulates is naturally occurring and therefore the exposure to air pollution cannot reach zero. In contrast, road injury rates could theoretically reach zero (if there was no road transport) and therefore the (implicit) TMREL for road injuries was zero. In the PAAT model, this meant that setting the intervention scenario to zero distance travelled for all modes led to zero road injury rates.

Model structure

Mirroring the MSLT model structure of the DIET model, the PAAT model is composed of a series of independent[iii] disease-state life tables that are linked to the main life table. Full detail on the MSLT model structure is available in the DIET Technical Report. As in the DIET model, the main life table represents everyone that is alive in the population in a particular age, sex, and ethnic group. Age-specific all-cause mortality and morbidity rates are applied to the cohort until the maximum age of 110 after which any remaining people in the population are assumed to die. Changes in risk factor distribution result in changes in cause-specific incidence rates on individual disease sheets; these result in changes in disease-specific mortality and morbidity, which are fed into the main life table where they influence overall mortality and morbidity rates. Where diseases (or injuries) are acute (i.e. duration typically less than the one-year time-step of the model), we model the impact of risk factor changes directly on morbidity (YLDs) and mortality associated with the disease/injury in burden of diseases analyses. These changes are then fed back into the main life table in the same way as with the chronic diseases.

The diseases and injuries included in the PAAT model are CHD, stroke, type 2 diabetes, lung cancer, colorectal cancer, breast cancer, COPD, LRTI, and transport injuries. All the included diseases apart from COPD, LRTI and transport injuries are also present in the DIET model and are modelled using

[iii] Apart from diabetes, which is linked into the CHD and stroke disease life table – see 0

the same epidemiological inputs (i.e. incidence, prevalence, case fatality rates, disability weights, and trends). Epidemiological inputs for COPD (incidence, mortality, prevalence rates, trends and disability weights) and LRTI (mortality and YLD rates) were sourced from the BODE^3 Tobacco MSLT model[18], and are available online[2]. Briefly, disease rates were sourced from national collections of health data and then processed using DisMod II to ensure coherence.

Disease specific morbidity rates were obtained by dividing prevalent years lived with disability (pYLD) from the New Zealand Burden of Disease Study (NZBDS)[40] (projected forward to 2011), by the count of prevalent cases from DisMod II processing. For example, the pYLDs associated with CHD in 55-64 year old non-Māori males were 1,321 in 2006. Applying trends in incidence and case fatality, and changing population size, pYLDs were projected to be 1,533 in 2011. This value was then divided by the 17,326 prevalent cases of CHD estimated using DisMod II, to determine a CHD morbidity rate of 0.088 for 55-64 year old non-Māori males. Epidemiological inputs for transport injuries are described in more detail below.

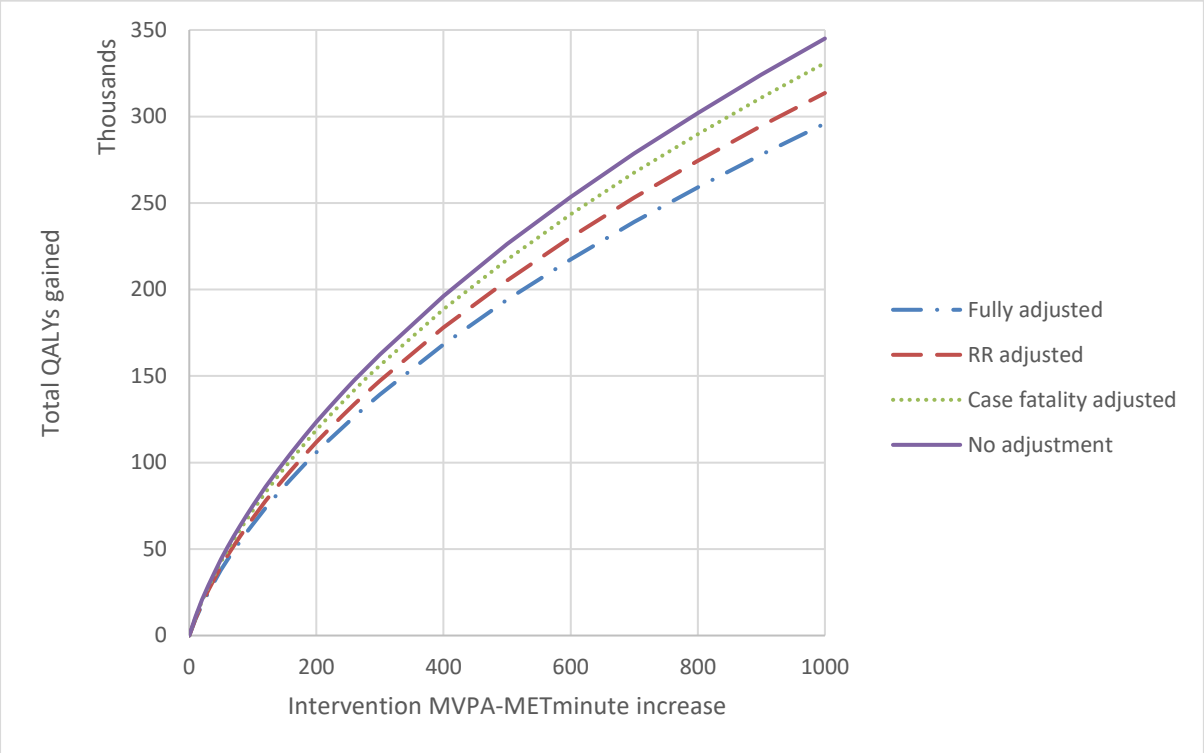
Diabetes as a risk factor and disease

Diabetes status influences the risk of CHD and stroke[41,42]. This means that changes in diabetes prevalence that result from changes in risk factors may have knock on impacts on CHD and stroke disease rates, even in the absence of a direct association between a risk factor and CHD and stroke. As in the DIET model, changes in diabetes prevalence rates under intervention scenarios were converted to a PIF. The PIF for diabetes was combined multiplicatively with PIFs for other risk factors to generate the overall PIF for CHD and stroke.

As a result of incorporating diabetes as a risk factor for CHD and stroke, we also needed to scale the RRs for the impact of PA on CHD and stroke to avoid double-counting impacts mediated through diabetes. This was necessary as RR estimates for CHD and stroke at different PA levels did not adjust for diabetes status. We calculated adjusted RRs using the GRG nonlinear method of optimization using the Excel Solver add-in, assuming that the total fraction of CHD and stroke attributable to physical activity is a sum of the fraction attributed to physical activity directly and the fraction attributable indirectly via diabetes. Case fatality rates for diabetes were also scaled to account for the excess deaths due to CHD and stroke in diabetics. Further details and formulas on the diabetes adjustment are included in the DIET Technical Report[1].

We ran scenario analyses to examine the impact of the diabetes adjustment for a range of increases in MVPA-METmins/week. Figure 2 shows the impact of the two diabetes adjustments for a range of increases in physical activity. Adjusting diabetes case fatality rates and RR estimates for CHD and stroke resulted in a 16% reduction in QALY gains compared to the unadjusted model. The absolute difference between the adjusted and unadjusted models increases with increasing intervention effect size.

Figure 2: QALY gains for increases in physical activity, with and without adjustments in diabetes



LRTI

LRTI is included as a disease in the BODE^3 Tobacco MSLT model[18]. Epidemiological data on LRTI (mortality and YLD rates) from the Tobacco MSLT model were imported into the PAAT model. The PIF for LRTI from air pollution was applied to mortality and YLD rates in the PAAT model to obtain a change in mortality and YLD rates. This differs from other diseases where PIFs were applied to incidence. As with other diseases, changes in mortality and YLD rates in LRTI flowed through to the main life table, influencing the overall mortality and disability rates in the total population.

Transport injuries

Transport injuries have not been modelled in existing BODE^3 MSLT model. This section describes in detail how the epidemiological parameters (mortality and disability rates) relevant to transport injuries were derived for the PAAT model. In the PAAT model, changes in pedestrian, cyclist, motorbike, and motor vehicle mortality and disability rates were combined to give overall changes in mortality and morbidity rates for transport injuries. As with the chronic conditions included in the model, these overall changes in mortality and morbidity rates were linked to the main life table. We used ICD 10 codes (Australian modifications) and included the same ICD code groupings as those included in GBD.

(iii) Data sources

Transport injury rates were calculated using data from the New Zealand Burden of Disease Study (NZBDS), Health Tracker, and the GBD Results Tool[43]. The Health Tracker data on mortality covered calendar years from 2007-2012 (inclusive), with data on hospitalizations spanning financial years 2006/07 to 2012/13. Differences in ICD coding prior to 2006 meant that it was not possible to look

back further than 2006. Hospitalizations that occurred during the time period of interest and that ended prior to 1/1/2014 were included so as to not inadvertently exclude individuals injured during the time period of interest but who remained in hospital beyond the end of the 2012/13 financial year (i.e. beyond 30th June 2013). We assumed a statistical cure time of one year for road injuries.

ICD coding assumptions

Transport related ICD codes were categorized according to the mode of the victim (i.e. pedestrian, cyclist, motorbike, motor vehicle). For the majority of diseases included in BODE^3 MSLT model, only primary diagnoses of particular disease states are included. However, for transport related injuries, the primary diagnostic code relates to the nature of injury sustained (e.g. fracture of skull) whilst secondary codes relate to the mode of injury (e.g. pedestrian hit by motor vehicle in transport accident) and therefore we included individuals where any diagnostic code was a relevant transport injury ICD code.

We used the first transport-related ICD code assigned to an individual for a (victim) mode where there were multiple, transport related ICD codes. For example, “a pedestrian hit by motor vehicle in transport accident” and “pedestrian hit by motor vehicle in non-transport accident” were ascribed to same event if occurring within 28 days of first event. However, if the same individual was listed as a “cyclist hit by motor vehicle in transport accident” within 28 days of the “pedestrian hit by motor vehicle in transport accident” ICD code then these would be coded as two separate events.

(iv) Mortality and disability rates

Ethnicity- and mode-specific mortality rates were calculated by scaling the NZBDS ethnicity-specific rates by the mode-specific rates from GBD. The NZBDS data provided road injury rates by ethnicity for 2006. We obtained mode-specific data for 2006 and 2011 for New Zealand from the GBD Results Tool. We assumed that that proportions of deaths by mode did not vary by ethnicity and scaled the NZBDS mortality rates accordingly, as per the equation below.

$$Mortality\ rate_{M,eth,2011} = NZBDS_{eth,2006} * \frac{GBD_{M,2011}}{GBD_{A,2011}} * \frac{GBD_{M,2011}}{GBD_{M,2006}}$$

To obtain ethnicity- and mode-specific disability rates, we followed the same procedure as for the mortality rates with the exception that we used GBD data for 2005, 2010, and 2015 as estimates of YLD rate for intermediate years were not available from the GBD Results Tool. We assumed a linear change in rates between years of data available.

To estimate the risk ratio for changes in distance, we further sub-divided mortality and YLD rates by hitter mode to give rates for each victim-hitter combination (e.g. pedestrian hit by motor vehicle, cyclist hit by motorbike). The victim-hitter mode matrix was used exclusively to derive the rate ratios for intervention impacts by victim-mode (as described in 2.01.3). The full cause matrix is provided in the Appendix. To sub-divide mortality and YLD rates, we first calculated total deaths and hospitalisations for each victim-hitter combination, using data from 2006 to 2013 to avoid bias from instability around small values within a year. We averaged counts of deaths for calendar years from 2007-2013, hospitalisation counts were averaged for financial years 2005/07 to 2012/13. Proportions of deaths (from counts) from each victim-hitter combination were then applied to

(victim) mode specific mortality rates to sub-divide mortality rates. Proportions of hospitalisations were similarly applied to YLD rates.

Costs

The inclusion of a different package of diseases compared to the DIET model meant that we needed to recalculate disease specific and healthy costs as part of building the PAAT model. Disease-specific costs for incidence, prevalence, and last 6 months of life were derived as per the DIET model Technical Report[1]. Briefly, healthy costs captured costs and person time prior to any diagnosis and post last statistical cure time (i.e. a person was classified as healthy at the time-points that they were absent of all modelled conditions). Disease-specific costs were divided into incidence (first year), prevalence (subsequent years), and mortality (last six months of life if dying from that disease) costs.

Cost offsets due to changes in injury rates and LRTI were derived by combining mortality costs and costs per YLD; mortality costs were obtained in the same way as for the other diseases. We calculated a cost per YLD from the total YLDs and total excess incidence and prevalence costs associated with the conditions. Costs were scaled to account for health expenditure not captured in Health Tracker, and to avoid double counting costs attributed to individuals who may simultaneously reside in multiple disease states. Further details on the calculation of disease costs in BODE^3 MSLT model is given in BODE^3 Technical Report 15[44]. For road injuries, we derived costs separately for each victim mode.

Trends

For the diseases included in the DIET model, we used the same trends. For LRTI and COPD we used the trends from the Tobacco model (see [18]). For injuries, we calculated trends in mortality and YLD rates using linear regression of the log of GBD injury rates (by mode and sex) from 1990 to 2015. The values assigned to injury trends based on the regression models are displayed in the table below.

	YLD rate	Mortality rate
Pedestrian	-0.03	-0.05
Cyclist	-0.03	-0.04
Motor bike	-0.05	-0.06
Motor vehicle	-0.02	-0.04

Time lags

Changes in risk factor distributions do not necessarily impact on disease rates immediately – e.g. it takes time for changes in physical activity to influence incidence rates of breast cancer. As highlighted in the DIET model technical report, it may take many years for changes in risk factor prevalence to influence disease rates. Assuming that changes in disease incidence are immediate could (grossly) overestimate the health impacts of modelled interventions. We look across multiple years to estimate the impact on disease prevalence and account for the delay between change in risk factor prevalence and change in incidence rates. Diseases are classified as having short[iv] or long[v]

[iv] CVD, stroke, type 2 diabetes

[v] Lung cancer, colorectal cancer, breast cancer, COPD

time lags. For short lag diseases, we average the PIF for the previous 5 years; for long lag diseases we look back and average the PIF from between 10 and 20 years ago. For injuries and LRTI, we assume that changes in distance travelled do have an immediate impact on injury rates. In addition, we assign uncertainty around the start and end of the look back periods (SD 20%, normal distribution).

Model analysis

For each intervention, the model is run 2,000 times using Monte Carlo simulation. Probabilistic uncertainty is included around the same parameters as previous models: intervention effect sizes, intervention costs, and selected baseline parameters. Modelling of the impact of active transport interventions is conducted in R and all other modelling is undertaken in Microsoft Excel® using custom-built macros in Visual Basic (VBA) for uncertainty analysis. This differs from the DIET[1] and Tobacco[18] models that use the Ersatz add-in for Excel to conduct uncertainty analyses. In each model run, the VBA macro loops through each age group for both ethnicities and prints the results to a macro output sheet. The results for all groups are summed to give the total change in DALYs and net cost offsets under the intervention.

I. References

1. Cleghorn CL, Blakely T, Nghiem N, Mizdrak A, Wilson N. Technical Report for BODE3 Intervention and DIET MSLT Models. 2017. http://www.otago.ac.nz/wellington/otago670797.pdf.
2. Burden of Disease Epidemiology E, and Cost-Effectiveness Programme;. Disease Inputs used for Multi-State Life Table Modelling. In: Burden of Disease Epidemiology E, and Cost-Effectiveness Programme;, editor. Version 1.0 ed; 2019.
3. World Health Organisation. Global recommendations on physical activity for health, 2010.
4. Ministry of Health. The Health of New Zealand Adults 2011/12: Key findings of the New Zealand Health Survey. Wellington, 2012.
5. Doherty A, Jackson D, Hammerla N, et al. Large Scale Population Assessment of Physical Activity Using Wrist Worn Accelerometers: The UK Biobank Study. *PLoS One* 2017; **12**(2): e0169649.
6. Kyu HH, Bachman VF, Alexander LT, et al. Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. *BMJ* 2016; **354**: i3857.
7. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of Physical Activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise* 2000; **32**(9).
8. Powell C, Herring MP, Dowd KP, Donnelly AE, Carson BP. The cross-sectional associations between objectively measured sedentary time and cardiometabolic health markers in adults - a systematic review with meta-analysis component. *Obes Rev* 2017.
9. LaMonte MJ, Buchner DM, Rillamas-Sun E, et al. Accelerometer-Measured Physical Activity and Mortality in Women Aged 63 to 99. *J Am Geriatr Soc* 2017.
10. Dohrn IM, Sjostrom M, Kwak L, Oja P, Hagstromer M. Accelerometer-measured sedentary time and physical activity-A 15 year follow-up of mortality in a Swedish population-based cohort. *J Sci Med Sport* 2017.
11. Swindell N, Mackintosh K, McNarry M, et al. Objectively Measured Physical Activity and Sedentary Time Are Associated With Cardiometabolic Risk Factors in Adults With Prediabetes: The PREVIEW Study. *Diabetes Care* 2017.
12. Wahid A, Manek N, Nichols M, et al. Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. *J Am Heart Assoc* 2016; **5**(9).
13. Ministry of Transport. (2003-2014) Travel Survey - information for researchers. 2015. http://www.transport.govt.nz/research/travelsurvey/travelsurvey-method/ (accessed 13th Dec 2017).
14. Ministry of Transport. 25 years of New Zealand travel: New Zealand household travel 1989–2014. Wellington, 2015.
15. Wanner M, Gotschi T, Martin-Diener E, Kahlmeier S, Martin BW. Active transport, physical activity, and body weight in adults: a systematic review. *Am J Prev Med* 2012; **42**(5): 493-502.

16. Sahlqvist S, Song Y, Ogilvie D. Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. *Prev Med* 2012; **55**(3): 206-11.
17. Shaw C, Keall M, Guiney H. What modes of transport are associated with higher levels of physical activity? Cross-sectional study of New Zealand adults. *Journal of Transport & Health* 2017; **7**: 125-33.
18. Blakely T, Cobiac LJ, Cleghorn CL, et al. Health, Health Inequality, and Cost Impacts of Annual Increases in Tobacco Tax: Multistate Life Table Modeling in New Zealand. *PLOS Medicine* 2015; **12**(7): e1001856.
19. Ministry for the Environment. Summary of emissions factors for the Guidance for Voluntary Greenhouse Gas Reporting - 2016, 2016.
20. Department for Business Energy and Industrial Strategy. Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors. London: United Kingdom, 2016.
21. Ministry of Transport. Transport volume : Public transport volumes. 2017. http://www.transport.govt.nz/ourwork/tmif/transport-volume/tv020/.
22. Mizdrak A, Cobiac L, Cleghorn CL, Woodward A, Blakely T. Fuelling active transport – an exploration into diet-related emissions associated with walking and cycling. *Under Review*.
23. Food and Agriculture Organisation of the United Nations. Food Balance Sheets: Food Supply (kcal/capita/day). Rome, Italy, 2016.
24. Drew JM. Healthy and sustainable eating patterns for New Zealand: University of Otago; 2017.
25. Barendregt JJ, Veerman JL. Categorical versus continuous risk factors and the calculation of potential impact fractions. *J Epidemiol Community Health* 2010; **64**(3): 209-12.
26. Barendregt J. The effect size in uncertainty analysis. *Value in Health* 2010; **13**(4).
27. Brown V, Moodie M, Mantilla Herrera AM, Veerman JL, Carter R. Active transport and obesity prevention - A transportation sector obesity impact scoping review and assessment for Melbourne, Australia. *Prev Med* 2017; **96**: 49-66.
28. Saunders LE, Green JM, Petticrew MP, Steinbach R, Roberts H. What are the health benefits of active travel? A systematic review of trials and cohort studies. *PLoS One* 2013; **8**(8): e69912.
29. Foley L, Panter J, Heinen E, Prins R, Ogilvie D. Changes in active commuting and changes in physical activity in adults: a cohort study. *Int J Behav Nutr Phys Act* 2015; **12**: 161.
30. Martin A, Panter J, Suhrcke M, Ogilvie D. Impact of changes in mode of travel to work on changes in body mass index: evidence from the British Household Panel Survey. *J Epidemiol Community Health* 2015; **69**(8): 753-61.
31. Mytton OT, Panter J, Ogilvie D. Longitudinal associations of active commuting with body mass index. *Prev Med* 2016; **90**: 1-7.
32. Woodcock J, Tainio M, Cheshire J, O'Brien O, Goodman A. Health effects of the London bicycle sharing system: health impact modelling study. *BMJ* 2014; **348**: g425.
33. Elvik R, Bjørnskau T. Safety-in-numbers: A systematic review and meta-analysis of evidence. *Safety Science* 2017; **92**: 274-82.
34. Woodcock J, Givoni M, Morgan AS. Health impact modelling of active travel visions for England and Wales using an Integrated Transport and Health Impact Modelling Tool (ITHIM). *PLoS One* 2013; **8**(1): e51462.
35. Brauer M, Freedman G, Frostad J, et al. Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013. *Environ Sci Technol* 2016; **50**(1): 79-88.
36. Forouzanfar MH, Alexander L, Anderson HR, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet* 2015; **386**(10010): 2287-323.
37. European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR). NEW_v4.3_PM2.5_EM_hindcast_ref(14072014081043) ed; 2010.
38. Forouzanfar MH, Alexander L, Anderson HR, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet* 2015.
39. Global Burden of Disease 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388**: 1659-724.
40. Ministry of Health. Health Loss in New Zealand: A report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study, 2006–2013. Wellington: Ministry of Health, 2016.

41. Peters SAE, Huxley RR, Woodward M. Diabetes as a risk factor for stroke in women compared with men: a systematic review and meta-analysis of 64 cohorts, including 775 385 individuals and 12 539 strokes. *The Lancet* 2014; **383**(9933): 1973-80.
42. Peters SAE, Huxley RR, Woodward M. Diabetes as risk factor for incident coronary heart disease in women compared with men: a systematic review and meta-analysis of 64 cohorts including 858,507 individuals and 28,203 coronary events. *Diabetologia* 2014; **57**: 1542–51.
43. Global Burden of Disease Study. Global Burden of Disease Study 2015 (GBD 2015) Results. 2016. http://ghdx.healthdata.org/gbd-results-tool.
44. Kvizhinadze G, Nghiem N, Atkinson J, Blakely T. Cost off-sets used in BODE3 multistate lifetable models. 2016. https://www.otago.ac.nz/wellington/otago619391.pdf.

II. Appendices

Physical activity baseline distribution

				Age group					
	Ethnicity	Sex	Physical activity category (MVPA-METmins/week)	15-24	25-34	35-44	45-54	55-64	65+
Proportion	Non-Maori	Male	0 <= 30	0.06	0.07	0.08	0.08	0.10	0.18
			>30 to <=300	0.19	0.20	0.21	0.22	0.22	0.32
			>300 to <=600	0.20	0.18	0.17	0.17	0.19	0.18
			>600 to <=1800	0.35	0.34	0.38	0.38	0.31	0.24
			>1800 to <=3000	0.13	0.14	0.11	0.08	0.11	0.07
			>3000 to <=8000	0.06	0.06	0.06	0.07	0.07	0.02
			>8000	0.00	0.00	0.00	0.00	0.00	0.00
		Female	0 <= 30	0.10	0.11	0.10	0.10	0.11	0.27
			>30 to <=300	0.29	0.30	0.29	0.30	0.28	0.29
			>300 to <=600	0.25	0.22	0.24	0.22	0.21	0.20
			>600 to <=1800	0.28	0.31	0.31	0.31	0.32	0.20
			>1800 to <=3000	0.07	0.05	0.05	0.06	0.06	0.02
			>3000 to <=8000	0.01	0.01	0.02	0.01	0.02	0.01
			>8000	0.00	0.00	0.00	0.00	0.00	0.00
	Maori	Male	0 <= 30	0.06	0.08	0.08	0.09	0.17	0.18
			>30 to <=300	0.19	0.17	0.16	0.21	0.14	0.25
			>300 to <=600	0.13	0.18	0.18	0.14	0.16	0.23
			>600 to <=1800	0.39	0.34	0.38	0.33	0.36	0.26
			>1800 to <=3000	0.11	0.12	0.11	0.16	0.16	0.08
			>3000 to <=8000	0.11	0.10	0.09	0.06	0.02	0.01
			>8000	0.00	0.00	0.01	0.00	0.00	0.00
		Female	0 <= 30	0.10	0.16	0.13	0.16	0.14	0.27
			>30 to <=300	0.30	0.25	0.25	0.24	0.32	0.31
			>300 to <=600	0.26	0.20	0.20	0.20	0.24	0.19
			>600 to <=1800	0.25	0.30	0.30	0.33	0.23	0.21
			>1800 to <=3000	0.07	0.05	0.09	0.03	0.05	0.03
			>3000 to <=8000	0.02	0.02	0.02	0.04	0.01	0.00
			>8000	0.00	0.00	0.00	0.00	0.00	0.00
Category means	Non-Maori	Male	0 <= 30	22	22	22	21	21	18
			>30 to <=300	167	161	161	157	151	126
			>300 to <=600	431	430	430	429	428	420
			>600 to <=1800	993	1,000	991	991	993	958
			>1800 to <=3000	2,262	2,270	2,263	2,266	2,269	2,255

			>3000 to <=8000	4,236	4,306	4,257	4,282	4,321	4,258
			>8000	10,052	10,150	10,089	10,127	10,187	10,148
		Female	0 <= 30	22	21	22	22	21	17
			>30 to <=300	152	146	151	152	147	114
			>300 to <=600	422	422	422	423	424	416
			>600 to <=1800	936	943	941	946	957	940
			>1800 to <=3000	2,227	2,236	2,232	2,235	2,246	2,247
			>3000 to <=8000	4,035	4,096	4,063	4,085	4,160	4,213
			>8000	9,812	9,904	9,851	9,880	9,987	10,107
	Maori	Male	0 <= 30	22	21	22	19	19	18
			>30 to <=300	163	158	166	144	143	128
			>300 to <=600	432	431	432	429	428	421
			>600 to <=1800	1,013	1,013	1,005	1,009	1,001	967
			>1800 to <=3000	2,278	2,280	2,271	2,284	2,279	2,261
			>3000 to <=8000	4,362	4,390	4,304	4,450	4,413	4,298
			>8000	10,215	10,259	10,139	10,356	10,313	10,195
		Female	0 <= 30	22	20	20	20	20	17
			>30 to <=300	147	137	139	140	132	111
			>300 to <=600	422	423	424	423	419	415
			>600 to <=1800	943	967	975	960	941	936
			>1800 to <=3000	2,235	2,257	2,262	2,251	2,240	2,245
			>3000 to <=8000	4,087	4,254	4,288	4,208	4,142	4,209
			>8000	9,889	10,125	10,164	10,062	9,987	10,107
Category SD	Non-Maori	Male	0 <= 30	0.02	0.03	0.03	0.03	0.03	0.04
			>30 to <=300	0.19	0.21	0.21	0.21	0.21	0.17
			>300 to <=600	0.02	0.02	0.02	0.02	0.02	0.03
			>600 to <=1800	0.34	0.34	0.35	0.34	0.36	0.48
			>1800 to <=3000	0.34	0.34	0.35	0.34	0.34	0.42
			>3000 to <=8000	2.72	2.87	2.92	2.83	2.95	3.31
			>8000	3.79	3.95	4.06	3.91	4.03	4.49
		Female	0 <= 30	0.03	0.04	0.03	0.03	0.04	0.05
			>30 to <=300	0.24	0.23	0.22	0.20	0.23	0.14
			>300 to <=600	0.03	0.03	0.03	0.02	0.02	0.04
			>600 to <=1800	0.59	0.56	0.53	0.50	0.51	0.53
			>1800 to <=3000	0.57	0.53	0.51	0.47	0.48	0.46
			>3000 to <=8000	3.70	3.67	3.42	3.24	3.54	3.44
			>8000	5.44	5.28	4.98	4.68	5.00	4.70
	Maori	Male	0 <= 30	0.06	0.06	0.07	0.08	0.13	0.19
			>30 to <=300	0.44	0.42	0.54	0.47	0.70	0.78
			>300 to <=600	0.05	0.05	0.06	0.04	0.05	0.11
			>600 to <=1800	0.56	0.60	0.82	0.66	0.99	1.92
			>1800 to <=3000	0.59	0.59	0.83	0.64	0.97	1.70
			>3000 to <=8000	5.40	5.39	7.18	6.01	8.92	13.88
			>8000	7.42	7.28	9.92	7.99	11.99	18.72

		Female	0 <= 30	0.07	0.09	0.10	0.10	0.14	0.22
			>30 to <=300	0.44	0.45	0.50	0.53	0.69	0.55
			>300 to <=600	0.06	0.05	0.04	0.06	0.13	0.20
			>600 to <=1800	1.13	1.03	1.02	1.22	1.94	2.35
			>1800 to <=3000	1.06	0.94	0.95	1.12	1.76	2.00
			>3000 to <=8000	7.29	7.45	7.78	8.58	12.60	14.84
			>8000	10.51	10.20	10.62	11.92	17.77	20.22

Disease groupings included in PA model

Disease	ICD 10
CHD (CHD in Diet)	I200, I201, I208, I209, I210, I211, I212, I213, I214, I219, I220, I221, I228, I229, I230, I231, I232, I233, I234, I235, I236, I238, I240, I241, I248, I249, I250, I2510, I2511, I2512, I2513, I252, I253, I254, I255, I256, I258, I259
Stroke	G450, G451, G452, G453, G454, G458, G459, G460, G461, G462, G463, G464, G465, G466, G467, G468, I600, I601, I602, I603, I604, I605, I606, I607, I608, I609, I610, I611, I612, I613, I614, I615, I616, I618, I619, I620, I621, I629, I630, I631, I632, I633, I634, I635, I636, I638, I639, I64, I650, I651, I652, I653, I658, I659, I660, I661, I662, I663, I664, I668, I669, I679
Diabetes	E1100, E1101, E1110, E1111, E1120, E1121, E1130, E1131, E1140, E1141, E1150, E1151, E1160, E1161, E1170, E1171, E1180, E1181, E1190, E1191, E1200, E1201, E1210, E1211, E1220, E1221, E1230, E1231, E1240, E1241, E1250, E1251, E1260, E1261, E1270, E1271, E1280, E1281, E1290, E1291, E1300, E1301, E1310, E1311, E1320, E1321, E1330, E1331, E1340, E1341, E1350, E1351, E1360, E1361, E1370, E1371, E1380, E1381, E1390, E1391, E1400, E1401, E1410, E1411, E1420, E1421, E1430, E1431, E1440, E1441, E1450, E1451, E1460, E1461, E1470, E1471, E1480, E1481, E1490, E1491
Colorectal cancer	C180, C181, C182, C183, C184, C185, C186, C187, C188, C189, C19, C20, C210, C211, C212, C218
Breast cancer	C50
COPD	J40, J410, J411, J418, J42, J430, J431, J432, J438, J439, J440, J441, J448, J449
Lung cancer	C33, C340, C341, C342, C343, C348, C349
LRTI	J120, J121, J122, J128, J129, J13, J14, J150, J151, J152, J153, J154, J155, J156, J157, J158, J159, J160, J168, J180, J181, J182, J188, J189, J200, J201, J202, J203, J204, J205, J206, J207, J208, J209, J210, J218, J219, J22, J850, J851, J852, J853, J860, J869
Pedestrians Injuries	V01.0 - V04.9, V06.0 - V09.9
Cyclists Injuries	V10.0 - V19.9
Motorbike Injuries	V20.0 - V39.9
Motor vehicle Injuries	V40.0 - V79.9, V87.2 - V87.2, V87.3 - V87.3

Road injury ICD code cause matrix

	"Hitter"				
Victim	Pedestrian	Cyclist	Motorbike	Motor vehicle	Other
Pedestrian		V01.0, V01.1, V01.9	V02.0, V02.1, V02.9	V03.0, V03.1, V03.9, V04.0, V04.1, V04.9	V06.0, V06.1, V06.9, V09.0, V09.1, V09.2, V09.3, V09.9
Cyclist	V10.0, V10.1, V10.2, V10.3, V10.4, V10.5, V10.9	V11.0, V11.1, V11.2, V11.3, V11.4, V11.5, V11.9	V12.0, V12.1, V12.2, V12.3, V12.4, V12.5, V12.9	V13.0, V13.1, V13.2, V13.3, V13.4, V13.5, V13.9, V14.0, V14.1, V14.2, V14.3, V14.4, V14.5, V14.9	V15.0, V15.1, V15.2, V15.3, V15.4, V15.5, V15.9, V16.0, V16.1, V16.2, V16.3, V16.4, V16.5, V16.9, V17.0, V17.1, V17.2, V17.3, V17.4, V17.5, V17.9, V18.0, V18.1, V18.2, V18.3, V18.4, V18.5, V18.9, V19.0, V19.1, V19.2, V19.3, V19.4, V19.5, V19.6, V19.8, V19.9
Motorbike	V20.0, V20.1, V20.2, V20.3, V20.4, V20.5, V20.9, V30.0, V30.1, V30.2, V30.3, V30.4, V30.5, V30.6, V30.7, V30.9	V21.0, V21.1, V21.2, V21.3, V21.4, V21.5, V21.9, V31.0, V31.1, V31.2, V31.3, V31.4, V31.5, V31.6, V31.7, V31.9	V22.0, V22.1, V22.2, V22.3, V22.4, V22.5, V22.9, V32.0, V32.1, V32.2, V32.3, V32.4, V32.5, V32.6, V32.7, V32.9	V23.0, V23.1, V23.2, V23.3, V23.4, V23.5, V23.9, V24.0, V24.1, V24.2, V24.3, V24.4, V24.5, V24.9, V33.0, V33.1, V33.2, V33.3, V33.4, V33.5, V33.6, V33.7, V33.9, V34.0, V34.1, V34.2, V34.3, V34.4, V34.5, V34.6, V34.7, V34.9	V25.0, V25.1, V25.2, V25.3, V25.4, V25.5, V25.9, V26.0, V26.1, V26.2, V26.3, V26.4, V26.5, V26.9, V27.0, V27.1, V27.2, V27.3, V27.4, V27.5, V27.9, V28.0, V28.1, V28.2, V28.3, V28.4, V28.5, V28.9, V29.0, V29.1, V29.2, V29.3, V29.4, V29.5, V29.6, V29.8, V29.9, V35.0, V35.1, V35.2, V35.3, V35.4, V35.5, V35.6, V35.7, V35.9, V36.0, V36.1, V36.2, V36.3, V36.4, V36.5, V36.6, V36.7, V36.9, V37.0, V37.1, V37.2, V37.3, V37.4, V37.5, V37.6, V37.7, V37.9, V38.0, V38.1, V38.2, V38.3, V38.4, V38.5, V38.6, V38.7, V38.9, V39.0, V39.1, V39.2, V39.3, V39.4, V39.5, V39.6, V39.8, V39.9
Motor vehicle	V40.0, V40.1, V40.2, V40.3, V40.4, V40.5, V40.6, V40.7, V40.9, V50.0, V50.1, V50.2, V50.3, V50.4, V50.5, V50.6, V50.7, V50.9, V60.0, V60.1, V60.2, V60.3, V60.4, V60.5, V60.6, V60.7, V60.9, V70.0, V70.1, V70.2, V70.3, V70.4, V70.5, V70.6, V70.7, V70.9	V41.0, V41.1, V41.2, V41.3, V41.4, V41.5, V41.6, V41.7, V41.9, V51.0, V51.1, V51.2, V51.3, V51.4, V51.5, V51.6, V51.7, V51.9, V61.0, V61.1, V61.2, V61.3, V61.4, V61.5, V61.6, V61.7, V61.9, V71.0, V71.1, V71.2, V71.3, V71.4, V71.5, V71.6, V71.7, V71.9	V42.0, V42.1, V42.2, V42.3, V42.4, V42.5, V42.6, V42.7, V42.9, V52.0, V52.1, V52.2, V52.3, V52.4, V52.5, V52.6, V52.7, V52.9, V62.0, V62.1, V62.2, V62.3, V62.4, V62.5, V62.6, V62.7, V62.9, V72.0, V72.1, V72.2, V72.3, V72.4, V72.5, V72.6, V72.7, V72.9	V43.0, V43.1, V43.2, V43.3, V43.4, V43.5, V43.6, V43.7, V43.9, V44.0, V44.1, V44.2, V44.3, V44.4, V44.5, V44.6, V44.7, V44.9, V53.0, V53.1, V53.2, V53.3, V53.4, V53.5, V53.6, V53.7, V53.9, V54.0, V54.1, V54.2, V54.3, V54.4, V54.5, V54.6, V54.7, V54.9, V63.0, V63.1, V63.2, V63.3, V63.4, V63.5, V63.6, V63.7, V63.9, V64.0, V64.1, V64.2, V64.3, V64.4, V64.5, V64.6, V64.7, V64.9, V73.0, V73.1, V73.2, V73.3, V73.4, V73.5, V73.6, V73.7, V73.9, V74.0, V74.1, V74.2, V74.3, V74.4, V74.5, V74.6, V74.7, V74.9	V45.0, V45.1, V45.2, V45.3, V45.4, V45.5, V45.6, V45.7, V45.9, V46.0, V46.1, V46.2, V46.3, V46.4, V46.5, V46.6, V46.7, V46.9, V47.0, V47.1, V47.2, V47.3, V47.4, V47.5, V47.6, V47.7, V47.9, V48.0, V48.1, V48.2, V48.3, V48.4, V48.5, V48.6, V48.7, V48.9, V49.0, V49.1, V49.2, V49.3, V49.4, V49.5, V49.6, V49.8, V49.9, V55.0, V55.1, V55.2, V55.3, V55.4, V55.5, V55.6, V55.7, V55.9, V56.0, V56.1, V56.2, V56.3, V56.4, V56.5, V56.6, V56.7, V56.9, V57.0, V57.1, V57.2, V57.3, V57.4, V57.5, V57.6, V57.7, V57.9, V58.0, V58.1, V58.2, V58.3, V58.4, V58.5, V58.6, V58.7, V58.9, V59.0, V59.1, V59.2, V59.3, V59.4, V59.5, V59.6, V59.8, V59.9, V65.0, V65.1, V65.2, V65.3, V65.4, V65.5, V65.6, V65.7, V65.9, V66.0, V66.1, V66.2, V66.3, V66.4, V66.5, V66.6, V66.7, V66.9, V67.0, V67.1, V67.2, V67.3, V67.4, V67.5, V67.6, V67.7, V67.9, V68.0, V68.1, V68.2, V68.3, V68.4, V68.5, V68.6, V68.7, V68.9, V69.0, V69.1, V69.2, V69.3, V69.4, V69.5, V69.6, V69.8, V69.9, V75.0, V75.1, V75.2, V75.3, V75.4, V75.5, V75.6, V75.7, V75.9, V76.0, V76.1, V76.2, V76.3, V76.4, V76.5, V76.6, V76.7, V76.9, V77.0, V77.1, V77.2, V77.3, V77.4, V77.5, V77.6, V77.7, V77.9, V78.0, V78.1, V78.2, V78.3, V78.4, V78.5, V78.6, V78.7, V78.9, V79.0, V79.1, V79.2, V79.3, V79.4, V79.5, V79.6, V79.8, V79.9, V87.2, V87.3

Health system costs

		Excess incidence (2011 NZD)							$/YLD				
	Age	Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Male	0	41,906	18,794	-	45,759	12,278	20,263	2,590	157,967	56,983	82,947	38,773	554,646
	1-4	41,906	18,794	-	45,759	12,278	20,263	2,590	157,967	56,983	82,947	38,773	72,660
	5-9	41,906	18,794	-	45,759	12,278	20,263	2,590	58,003	38,584	164,173	22,009	19,119
	10-14	41,906	18,794	-	45,759	12,278	20,263	2,590	38,204	46,267	138,878	23,056	9,981
	15-19	41,906	18,794	-	45,759	12,278	20,263	2,590	54,655	35,688	106,943	70,705	11,935
	20-24	41,906	18,794	-	45,759	12,278	20,263	2,590	38,205	20,521	68,761	36,076	8,116
	25-29	41,906	18,794	-	45,759	12,278	20,263	2,590	15,950	19,007	42,692	19,368	9,145
	30-34	41,906	18,794	-	45,759	12,278	20,263	2,590	12,610	15,335	31,594	10,368	12,591
	35-39	41,906	18,794	-	45,759	12,278	20,263	2,590	9,380	17,254	28,842	8,650	11,073
	40-44	41,906	18,794	-	45,759	12,278	20,263	2,590	11,586	18,557	23,883	8,722	12,426
	45-49	31,670	15,808	-	32,750	12,315	13,013	2,117	8,745	17,129	24,058	7,928	16,776
	50-54	31,670	15,808	-	32,750	12,315	13,013	2,117	9,988	15,553	21,921	8,154	13,344
	55-59	31,670	15,808	-	32,750	12,315	13,013	2,117	8,927	11,496	16,144	6,494	11,408
	60-64	31,670	15,808	-	32,750	12,315	13,013	2,117	13,703	16,688	18,696	11,834	13,656
	65-69	24,423	13,432	-	26,988	11,102	10,247	2,394	13,103	14,286	9,332	12,953	12,118
	70-74	24,423	13,432	-	26,988	11,102	10,247	2,394	33,123	8,743	8,425	13,740	13,150
	75-79	14,912	9,580	-	20,460	8,953	8,070	2,611	18,484	15,709	5,952	12,923	11,465
	80-84	14,912	9,580	-	20,460	8,953	8,070	2,611	23,941	5,591	4,320	10,864	15,003
	85-89	7,932	5,816	-	14,436	6,892	6,834	3,164	23,941	5,591	4,320	10,864	12,038
	90-94	7,932	5,816	-	14,436	6,892	6,834	3,164	23,941	5,591	4,320	10,864	12,038
	95+	7,932	5,816	-	14,436	6,892	6,834	3,164	23,941	5,591	4,320	10,864	12,038

		Excess incidence (2011 NZD)							$/YLD				
		Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Female	0	37,881	16,151	38,762	44,249	10,385	23,228	4,269	304,658	65,593	120,457	61,869	548,309
	1-4	37,881	16,151	38,762	44,249	10,385	23,228	4,269	304,658	65,593	120,457	61,869	61,822
	5-9	37,881	16,151	38,762	44,249	10,385	23,228	4,269	90,598	53,973	120,457	30,790	16,024
	10-14	37,881	16,151	38,762	44,249	10,385	23,228	4,269	44,960	28,972	93,637	21,451	28,723
	15-19	37,881	16,151	38,762	44,249	10,385	23,228	4,269	56,118	15,927	64,538	75,858	13,280
	20-24	37,881	16,151	38,762	44,249	10,385	23,228	4,269	42,294	18,423	84,070	43,883	12,094
	25-29	37,881	16,151	38,762	44,249	10,385	23,228	4,269	25,208	16,405	30,404	23,298	10,680
	30-34	37,881	16,151	38,762	44,249	10,385	23,228	4,269	23,734	15,236	36,326	19,030	11,994
	35-39	37,881	16,151	38,762	44,249	10,385	23,228	4,269	24,861	19,718	31,762	22,635	11,407
	40-44	37,881	16,151	38,762	44,249	10,385	23,228	4,269	28,260	17,432	44,599	13,439	10,016
	45-49	29,432	11,704	24,387	30,192	11,196	15,060	1,978	34,499	31,544	82,771	14,747	12,484
	50-54	29,432	11,704	24,387	30,192	11,196	15,060	1,978	23,299	26,462	46,108	13,370	10,659
	55-59	29,432	11,704	24,387	30,192	11,196	15,060	1,978	40,301	22,749	25,704	13,841	10,157
	60-64	29,432	11,704	24,387	30,192	11,196	15,060	1,978	54,371	45,834	62,615	22,271	10,882
	65-69	23,680	9,675	15,760	23,887	9,528	10,177	1,822	65,996	24,366	15,438	28,926	10,188
	70-74	23,680	9,675	15,760	23,887	9,528	10,177	1,822	41,611	16,437	19,595	30,194	14,574
	75-79	14,603	6,925	11,859	18,326	8,769	8,052	2,052	65,322	17,033	19,595	32,116	12,504
	80-84	14,603	6,925	11,859	18,326	8,769	8,052	2,052	33,526	17,033	19,595	20,736	11,920
	85-89	8,127	4,830	6,311	13,329	6,861	6,384	2,610	33,526	17,033	19,595	20,736	12,506
	90-94	8,127	4,830	6,311	13,329	6,861	6,384	2,610	33,526	17,033	19,595	20,736	12,506
	95+	8,127	4,830	6,311	13,329	6,861	6,384	2,610	33,526	17,033	19,595	20,736	12,506

		Excess prevalence (2011 NZD)											
	Age group	Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Male	0	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	1-4	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	5-9	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	10-14	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	15-19	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	20-24	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	25-29	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	30-34	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	35-39	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	40-44	4,606	4,057	-	4,401	4,026	2,857	3,030	-	-	-	-	-
	45-49	5,624	3,245	-	3,783	6,931	3,478	3,209	-	-	-	-	-
	50-54	5,624	3,245	-	3,783	6,931	3,478	3,209	-	-	-	-	-
	55-59	5,624	3,245	-	3,783	6,931	3,478	3,209	-	-	-	-	-
	60-64	5,624	3,245	-	3,783	6,931	3,478	3,209	-	-	-	-	-
	65-69	5,295	3,176	-	3,360	6,023	3,282	3,175	-	-	-	-	-
	70-74	5,295	3,176	-	3,360	6,023	3,282	3,175	-	-	-	-	-
	75-79	3,902	2,823	-	2,651	4,986	2,689	2,704	-	-	-	-	-
	80-84	3,902	2,823	-	2,651	4,986	2,689	2,704	-	-	-	-	-
	85-89	2,243	2,359	-	1,861	3,610	1,989	2,178	-	-	-	-	-
	90-94	2,243	2,359	-	1,861	3,610	1,989	2,178	-	-	-	-	-
	95+	2,243	2,359	-	1,861	3,610	1,989	2,178	-	-	-	-	-

		Excess prevalence (2011 NZD)											
	Age group	Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Female	0	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	1-4	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	5-9	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	10-14	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	15-19	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	20-24	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	25-29	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	30-34	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	35-39	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	40-44	11,832	4,133	5,964	4,651	4,139	3,884	2,816	-	-	-	-	-
	45-49	6,346	4,048	2,728	3,100	6,127	3,516	3,079	-	-	-	-	-
	50-54	6,346	4,048	2,728	3,100	6,127	3,516	3,079	-	-	-	-	-
	55-59	6,346	4,048	2,728	3,100	6,127	3,516	3,079	-	-	-	-	-
	60-64	6,346	4,048	2,728	3,100	6,127	3,516	3,079	-	-	-	-	-
	65-69	4,868	3,388	2,098	2,631	5,585	3,056	3,003	-	-	-	-	-
	70-74	4,868	3,388	2,098	2,631	5,585	3,056	3,003	-	-	-	-	-
	75-79	3,893	2,868	1,960	2,082	4,472	2,548	2,468	-	-	-	-	-
	80-84	3,893	2,868	1,960	2,082	4,472	2,548	2,468	-	-	-	-	-
	85-89	1,364	2,106	1,546	1,577	2,955	1,716	1,881	-	-	-	-	-
	90-94	1,364	2,106	1,546	1,577	2,955	1,716	1,881	-	-	-	-	-
	95+	1,364	2,106	1,546	1,577	2,955	1,716	1,881	-	-	-	-	-

		Excess mortality (2011 NZD)											
	Age group	Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Male	0	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	1-4	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	5-9	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	10-14	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	15-19	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	20-24	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	25-29	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	30-34	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	35-39	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	40-44	34,613	11,737	-	36,035	18,396	18,623	45,505	8,903	9,463	12,552	5,520	42,103
	45-49	26,708	10,175	-	29,461	18,396	16,841	45,505	8,903	9,463	12,552	12,016	42,103
	50-54	26,708	10,175	-	29,461	18,396	16,841	45,505	8,903	9,463	12,552	12,016	42,103
	55-59	26,708	10,175	-	29,461	18,396	16,841	45,505	8,903	9,463	12,552	12,016	42,103
	60-64	26,708	10,175	-	29,461	18,396	16,841	45,505	8,903	9,463	12,552	12,016	42,103
	65-69	24,540	14,563	-	28,260	14,547	16,243	21,281	9,793	10,409	11,058	7,558	17,379
	70-74	24,540	14,563	-	28,260	14,547	16,243	21,281	9,793	10,409	11,058	7,558	17,379
	75-79	19,550	14,138	-	25,074	15,869	11,336	23,215	10,683	11,355	12,063	21,647	18,959
	80-84	19,550	14,138	-	25,074	15,869	11,336	23,215	10,683	11,355	12,063	21,647	18,959
	85-89	14,547	11,027	-	17,184	17,191	9,809	25,150	11,573	12,302	13,068	23,451	20,539
	90-94	14,547	11,027	-	17,184	17,191	9,809	25,150	11,573	12,302	13,068	23,451	20,539
	95+	14,547	11,027	-	17,184	17,191	9,809	25,150	11,573	12,302	13,068	23,451	20,539

		Excess mortality (2011 NZD)											
	Age group	Lung cancer	CHD	Breast cancer	Colorectal cancer	COPD	Stroke	Type 2 Diabetes	Pedestrian injury	Cyclist injury	Motorbike injury	Motor vehicle injury	LRTI
Female	0	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	1-4	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	5-9	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	10-14	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	15-19	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	20-24	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	25-29	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	30-34	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	35-39	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	40-44	32,433	14,598	38,226	31,627	20,832	17,973	47,761	2,984	9,378	5,694	7,611	45,398
	45-49	26,441	17,137	29,461	27,380	20,832	18,503	47,761	2,984	9,378	5,694	5,614	45,398
	50-54	26,441	17,137	29,461	27,380	20,832	18,503	47,761	2,984	9,378	5,694	5,614	45,398
	55-59	26,441	17,137	29,461	27,380	20,832	18,503	47,761	2,984	9,378	5,694	5,614	45,398
	60-64	26,441	17,137	29,461	27,380	20,832	18,503	47,761	2,984	9,378	5,694	5,614	45,398
	65-69	24,700	17,725	25,607	27,834	14,680	14,236	18,737	3,282	10,316	21,689	18,614	17,215
	70-74	24,700	17,725	25,607	27,834	14,680	14,236	18,737	3,282	10,316	21,689	18,614	17,215
	75-79	19,177	13,417	20,604	22,616	16,015	10,207	20,440	3,581	11,254	23,660	20,759	18,780
	80-84	19,177	13,417	20,604	22,616	16,015	10,207	20,440	3,581	11,254	23,660	20,759	18,780
	85-89	14,597	9,101	10,948	14,881	17,349	6,436	22,144	3,879	12,192	25,632	22,489	20,345
	90-94	14,597	9,101	10,948	14,881	17,349	6,436	22,144	3,879	12,192	25,632	22,489	20,345
	95+	14,597	9,101	10,948	14,881	17,349	6,436	22,144	3,879	12,192	25,632	22,489	20,345

Healthy population costs (2011 NZD)				
	Male		Female	
Age group	Not last 6 months of life	Last 6 months of life	Not last 6 months of life	Last 6 months of life
0	5,404	92,068	4,732	84,415
1-4	1,409	36,338	1,220	35,629
5-9	690	36,841	619	29,892
10-14	653	25,745	597	21,684
15-19	657	17,909	919	22,840
20-24	703	10,161	1,234	27,718
25-29	711	14,813	1,349	23,768
30-34	763	15,818	1,490	22,474
35-39	819	15,488	1,350	24,417
40-44	918	21,412	1,129	29,439
45-49	1,062	22,024	1,168	27,355
50-54	1,212	24,507	1,279	29,543
55-59	1,430	25,953	1,434	28,646
60-64	1,764	25,306	1,700	27,210
65-69	2,380	28,365	2,245	25,640
70-74	3,033	25,247	2,747	22,018
75-79	3,685	22,590	3,316	17,090
80-84	4,214	17,752	3,850	12,560
85-89	4,713	15,519	4,286	8,715
90-94	4,875	11,558	4,516	6,179
95+	4,848	8,446	3,976	3,828

III. Version amendments

Version 1.1 (17th June 2019)

- Additional detail added to describe derivation of morbidity rates
- Added reference to BODE^3 Disease Inputs Used for Multi-State Life Table Modelling (version 1) (now publically available online)
- Example of calculation of morbidity rates provided in 'model structure' section (pages 15-16)