

# Health consequences of transport patterns in New Zealand's largest cities

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## ABSTRACT

**AIM:** Transport is a well-known determinant of health, through physical activity, air pollution and injury pathways. New Zealand has a highly car-dominated transport system, but cities differ in the amounts of walking, cycling and public transport use, reflecting different urban planning priorities over time.

**METHODS:** Using the Integrated Transport and Health Impacts Model, adapted for New Zealand, we quantified the likely changes in health and greenhouse emissions if Auckland, Hamilton, Tauranga, Christchurch and Dunedin Cities had the same mode share for cycling, walking, public transport and car use as Wellington City, which currently has the highest levels of sustainable travel.

**RESULTS:** All cities modelled would have better health, due to a reduction in morbidity and mortality from injury and air pollution and through increased levels of physical activity, if their transport systems resembled Wellington's. Carbon emissions from light passenger transport would fall also. The magnitude of these effects varies considerably by city.

**CONCLUSION:** Transport funding in recent decades that has prioritised private car use has had detrimental effects on the health of New Zealanders. New Zealand requires better accounting of and accountability for the health and carbon impacts of decisions on transport projects, at both local and national levels.

Transport is an important determinant of health and health inequalities, acting primarily through road injury, air pollution and lack of physical activity (PA).<sup>1</sup> The transport sector is also the fastest growing contributor to carbon emissions locally and internationally;<sup>2,3</sup> and climate change is described as the biggest global health challenge of the next century.<sup>4</sup>

Increasing people's use of sustainable modes of transport (walking, cycling and using public transport) meets multiple policy objectives: improving health; reducing congestion; increasing economic productivity and helping to achieve internationally agreed carbon emission targets. Overseas, some cities, in Europe and Canada for example, have boosted active travel by coordinating transport and land-use policies and investing heavily in provision of suitable infrastructure.<sup>5,6</sup> However, New Zealand has a car-dominated transport environment, with the highest car ownership

rate in the OECD, and there is no sign of substantial change.<sup>7</sup> Policy settings continue to preferentially fund infrastructure that promotes car use.<sup>8</sup> Levels of walking to work halved from 14 to 7% between 1971–2013, and levels of cycling to work declined from 4.3 to 2.9% in the same period.<sup>9</sup>

There are, however, differences in transport patterns between the larger New Zealand cities. For example, in Wellington City the proportion of trips taken by cycling, walking and public transport is 35% compared to Hamilton City where walking, cycling and public transport mode share is 17%.<sup>9</sup> These differences are important: urban planning and transport policies implemented in the different cities have, over time, led to Wellington City having a more sustainable transport system, with the highest rate of active transport and public transport use in New Zealand. This paper sets out to quantify the consequences of the current transport environment in the

six largest cities in New Zealand. Specifically, we will examine what the health and carbon impacts would be if the other five largest cities in New Zealand had the same transport profile as those of the most sustainable city.

## Methods

### Integrated Transport and Health Impacts Model

We used the Integrated Transport and Health Impacts Model (ITHIM).<sup>10–12</sup> It is based on the World Health Organization's comparative risk assessment methodology; providing a means of estimating the health impacts of transport scenario(s) of varying levels of active transport, private motor vehicle and public transport use. ITHIM consists of three components: a physical activity model, an air quality model and an injury model. The results from these three components are combined to estimate deaths, years of life lost (YLL), years of life lived with disability (YLD) and disability-adjusted life years (DALY). The details of these models and how they have been adapted for this study are explained below.

#### Physical activity model

The PA component of ITHIM (which is relevant to people 15 years and over only) compares the distributions of PA in the different scenarios. PA levels are converted into a standardised unit (metabolic equivalent task (MET) hours per week). On this basis it is possible to estimate the PA-related disease outcomes (for example dementia, depression, cardiovascular disease, breast and colon cancer, diabetes) using published estimates of relative risks.<sup>12</sup> In line with common practice, a non-linear relationship between PA level and health outcomes is assumed, in this case a square root function.<sup>12</sup> This accounts for diminishing health returns at higher levels of PA.

METs from walking and cycling are derived from the New Zealand Household Travel Survey for age and sex groups. Physical activity METs from other sources are not available for the New Zealand population, so we assumed people in the cities studied have the same non-travel PA levels as people in the Bay Area of California, US (these data have been utilised in the ITHIM model previously). Differing effects of PA

on diseases by age and sex are taken into account by using baseline disease burden data for each age-sex group, and adjusting relative risks for specific age-sex groups where this is supported by the literature. Baseline disease and injury burden were obtained from New Zealand figures in the Global Burden of Disease (GBD) study.<sup>13</sup> City measures of disease and injury burden have been derived by applying national rates to the city populations across the same age and sex categories as provided by the GBD study.

Physical activity levels for baseline (the five 'least sustainable' cities) and counterfactual scenario (the 'most sustainable' city) and disease-specific risk ratios are used to calculate fractions for each disease that may be attributed to the difference in PA between the baseline and counterfactual scenario. Attributable fractions are then applied to the baseline burden of disease for each age-sex group within each city to estimate differences in deaths, YLLs, YLDs and DALYs between baseline and scenario. Numbers are summed over the age and sex groups used in the ITHIM model to give total change in disease burden.

#### Road injury model

The model to describe effects on road injury burden originally developed for ITHIM is based on risk, distance and speed limit to generate estimates of injury for each scenario. New Zealand lacks sufficient data on distances by road type (a proxy for speed limit) so the formulae in ITHIM have been modified to work with the available data. This means that changes in exposure to risk of injury are assumed to occur evenly across all road types in this study. The total number of deaths, YLLs, YLDs and DALYs for any given scenario relative to the respective values at baseline are summed over the age and sex groups used in the ITHIM model. As per the ITHIM model, these equations incorporate a 'safety in numbers' function whereby the risk of injury increases less than linearly with increases in exposure to motor vehicle traffic.<sup>12,14</sup>

#### Air quality model

The air quality model is based on estimated changes in concentrations of particulate matter of 2.5 micrometre diameter or less (PM<sub>2.5</sub>) as a result of differences in the vehicle kilometres travelled

(VKT) between the baseline and scenario. The baseline PM<sub>2.5</sub> levels for each New Zealand city are modelled estimates and were obtained from a national PM<sub>2.5</sub> model created by the National Institute of Water and Atmospheric Research (NIWA) for the Ministry for the Environment (Unpublished data, NIWA 2017). Due to technical limitations in New Zealand's air quality monitoring, this study has used a linear model based on vehicle emissions and air shed modelling in the Bay Area, US. The EMFAC2007 and the Multi-Pollutant Evaluation Methods were used to estimate changes in PM<sub>2.5</sub> levels from changes in VKT.<sup>15–17</sup> The changes in PM<sub>2.5</sub> are applied to estimate changes in the burden of air pollution-related diseases (for example lung cancer and acute respiratory infection) using established dose-response relationships from the World Health Organization.<sup>18,19</sup>

### Carbon dioxide emissions

Carbon emissions changes were then estimated on the basis of published government estimates of emissions derived from fossil fuels consumed annually by passenger vehicles nationally. A mean level of emissions per vehicle kilometre travelled (VKT) for the entire passenger fleet was estimated by dividing total emissions estimated for this sector by total VKT nationally. The light passenger fleet was estimated to have travelled approximately 31 billion km and generated 7.3115 million tonnes of CO<sub>2</sub> during 2013. The mean level of emissions was therefore calculated to be 0.000236

tonnes per km for the light passenger vehicle fleet. This figure was then used to estimate changes in emissions, based on changes in vehicle kilometres travelled, between the baseline and scenario.

### Scenario

The scenario we modelled assumed the other five largest cities in New Zealand (Auckland, Tauranga, Hamilton, Christchurch and Dunedin) had the same transport profile as Wellington City. This is modelled by applying the per capita daily travel times and distances for Wellington City to the population and disease burden distributions of the other five cities. All New Zealand travel data were drawn from the New Zealand Household Travel Survey 2008–2014 provided by the Ministry of Transport.<sup>20</sup>

## Results

Table 1 shows baseline information on each of the six New Zealand cities included in the scenario. This shows the existing differences in mode share, with Wellington having the highest level of walking (27.5% of trips) and public transport (6.2% of trips), and Christchurch having the highest cycling mode share (3.1%). It also shows the existing differences in PM<sub>2.5</sub> exposure, with Christchurch having the highest levels (annual average 11.3mcg/m<sup>3</sup>), although it is important to note that motor vehicle emissions are only one of a number of sources of air pollution in each city. Auckland has the highest level of multiple car ownership, with 55% of households owning two or more vehicles.

**Table 1:** Baseline information on each city.

	Population <sup>a</sup>	Households with two or more vehicles (%) <sup>a</sup>	Trips walking (annual %) <sup>b</sup>	Trips cycling (annual %) <sup>b</sup>	Trips by public transport (annual %) <sup>b</sup>	PM <sub>2.5</sub> (annual mean mcg/m <sup>3</sup> ) <sup>c</sup>	Light vehicle CO <sub>2</sub> emissions (tonnes/year) <sup>d</sup>	Transport-related injury (annual deaths (DALYs)) <sup>e</sup>
Auckland City	1,493,210	55	16.1	0.5	3.3	4.8	2,150,000	146 (8,407)
Tauranga City	119,830	51	14.1	2.1	1.3	5.1	190,000	12 (611)
Hamilton City	150,180	49	13.8	1.2	1.9	6.3	253,000	15 (878)
Wellington City	197,460	36	27.5	1.3	6.2	3.5	227,000	20 (1,184)
Christchurch City	356,750	53	18.9	3.1	3.3	11.3	447,000	37 (2,028)
Dunedin City	123,540	46	23.5	1.3	1.4	7.5	153,000	13 (737)

Sources: <sup>a</sup>Statistics New Zealand, Census of Population and Dwellings 2013, <sup>b</sup>Ministry of Transport, New Zealand Household Travel Survey 2008–2014, <sup>c</sup>NIWA, <sup>d</sup>Ministry of Transport, The New Zealand 2015 Vehicle Fleet: Data Spreadsheet, <sup>e</sup>adapted from Institute of Health Metrics and Evaluation, Global Burden of Disease study, 2013.

Table 2 shows the impacts on health and greenhouse gas emissions if Auckland, Tauranga, Hamilton, Christchurch and Dunedin had the same transport mode share patterns as Wellington City. All cities would have improved health, with a reduction in morbidity and mortality due to injury, air

pollution and increased levels of PA. The magnitude of the health impacts varies by city. For example, Hamilton currently has low levels of active transport and PT use, and the city would have around 52 fewer deaths per year and 1,000 DALYs avoided if it had the same mode share as Wellington.

**Table 2:** Annual health and GHG emissions impacts if each city had the same transport patterns as Wellington.

		<b>Physical activity</b>	<b>Injury</b>	<b>Air pollution</b>	<b>Total</b>
<b>Auckland</b>	Premature deaths	-41.2	-15.1	-1.0	-57.3
	YLL	-534.8	-764.0	-12.8	-1,311.6
	YLD	-169.1	-102.0	0.0	-271.2
	DALYs	-703.9	-866.0	-12.9	-1,582.8
	Light vehicle CO <sub>2</sub> emission change tonnes/year (% reduction from baseline)	-	-	-	-433,778 (-20)
<b>Tauranga</b>	Premature deaths	-46.5	-1.8	-1.3	-49.7
	YLL	-599.6	-81.7	-17.5	-698.8
	YLD	-183.8	-16.8	-0.1	-200.6
	DALYs	-783.4	-98.5	-17.5	-899.4
	Light vehicle CO <sub>2</sub> emission change tonnes/year (% reduction from baseline)	-	-	-	-52,210 (-27)
<b>Hamilton</b>	Premature deaths	-47.2	-2.9	-1.5	-51.7
	YLL	-620.9	-148.1	-20.1	-789.1
	YLD	-195.8	-21.5	-0.1	-217.4
	DALYs	-816.7	-169.6	-20.2	-1,006.5
	Light vehicle CO <sub>2</sub> emission change tonnes/year (% reduction from baseline)	-	-	-	-79,960 (-32)
<b>Wellington</b>	Reference	-	-	-	-
<b>Christchurch</b>	Premature deaths	-29.1	-1.5	-0.4	-31.0
	YLL	-298.8	-79.3	-5.3	-383.4
	YLD	-95.1	-16.4	0.0	-111.5
	DALYs	-393.9	-95.8	-5.3	-495.0
	Light vehicle CO <sub>2</sub> emission change tonnes/year (% reduction from baseline)	-	-	-	-36,789 (-8)
<b>Dunedin</b>	Premature deaths	-12.3	-0.4	-0.3	-13.1
	YLL	-193.3	-20.9	-4.4	-218.6
	YLD	-63.4	-2.2	0.0	-65.6
	DALYs	-256.7	-23.1	-4.4	-284.2
	Light vehicle CO <sub>2</sub> emission change tonnes/year (% reduction from baseline)	-	-	-	-10,395 (-7)

In contrast, Dunedin, with higher existing levels of active transport and a smaller population, would have fewer deaths (13 per year) and DALYs avoided (about 200 annually) than Hamilton, but would still be better off under the 'Wellington' scenario. In most cities, the majority of modelled health gains were from reductions in diseases associated with lack of physical activity, however, small gains were seen from reductions in air pollution and injury-related morbidity and mortality. In Auckland, the majority of the reduction in premature deaths was due to the benefits of physical activity. However, the largest contributor to the reduction in DALYs was avoided injury. This is due to the relatively large reduction in time driving in Auckland under the 'Wellington' scenario and the fact that road injuries tend to involve younger people, so result in more years of life lost than diseases associated with physical inactivity.

All cities would reduce carbon emissions from light passenger transport as a result of the mode shift. Auckland would reduce emissions by 430,000 tonnes per year (about a 20% reduction) and Dunedin the least by about 10,000 tonnes per year.

## Discussion

### Summary of findings

The modelling suggests if Auckland, Tauranga, Hamilton, Christchurch and Dunedin had the same cycling, walking and public transport (PT) mode share as Wellington there would be considerable health and carbon gains. The health gains are predominately through increased physical activity, and, to a lesser extent, as a result of reduced air pollution and injury deaths. Depending on the city, light vehicle carbon emissions would be between seven and 32% lower, as a result of reduced car travel.

### Policy and practice implications

This modelling shows that the economic land-use planning and transport policies that have been put in place in many cities around New Zealand over the preceding decades have disadvantaged the health of their populations (and the planet). For example, if local and national governments had put in place policies and infrastructure around transport and land use in Tauranga that resulted in a similar mode share as Wellington, there would be around 50 fewer premature deaths

per year (which is about four times larger than the effect of preventing all road injury deaths in Tauranga).

The health benefits of the scenarios primarily arise due to the increased PA of walking, cycling and the trips associated with each end of PT use. Physical activity levels in New Zealand are low: fewer than half of adults meet New Zealand PA guidelines (which should be considered a bare minimum for health).<sup>21</sup> These modelling results are consistent with the growing body of observational evidence. International studies show that taking up cycling and walking for transport leads to increased levels of PA, reductions in BMI and diabetes, and lower levels of sick leave.<sup>22–25</sup> People who cycle for transport have lower mortality than those who do not.<sup>26</sup> The longitudinal associations between taking up public transport use and increasing PA are less well studied,<sup>27,28</sup> but there are strong grounds for making more PA from walking and cycling a policy priority.

The net reduction in injury deaths and morbidity in all scenarios may appear surprising given the well-known differences in injury risk between modes, in particular the higher risk of death when cycling compared to driving.<sup>9</sup> However, firstly, the safety in numbers effect applies, whereby as more people cycle, the risk per person of injury and death decreases, possibly due to drivers being more aware of cyclists.<sup>29</sup> Secondly, these scenarios have people reducing driving through a combination of increased walking, cycling and use of public transport. This shift away from the car results in an overall reduction in road traffic deaths, as public transport in particular is far safer than driving. Reduced driving also reduces the exposure of cyclists and pedestrians to cars, and crashes involving cars are the commonest cause of severe injury for these groups. Moving towards a more sustainable transport system should be considered a key component of reducing the road toll, which after a long period of decline in New Zealand is now increasing again.<sup>30</sup>

The reductions in carbon emissions in the scenario reported in this paper occur primarily as a result of trips being shifted from private cars to public transport (Wellington has the highest mode share of PT in New Zealand), with resultant

decreases in VKT and thus carbon emissions. These journeys are generally longer distance than those able to be shifted to bike or foot, thus the carbon emissions savings for shifting car trips to public transport are estimated to be greater. This is consistent with previous New Zealand modelling, which showed that shifting from private car to active transport modes only modestly reduced greenhouse gas emissions, although accompanied by large health benefits.<sup>31</sup> The carbon emission reductions estimated here are indicative rather than precise. The short urban trips that would be replaced by other modes in the scenario modelled tend to be less fuel efficient than longer trips; hence emission reductions may be underestimated.<sup>32</sup> Additionally, this modelling does not account for any emissions generated if any additional PT required used fossil fuels rather than renewable energy. However, it is evident that investing in high-quality PT will be essential to meet New Zealand's carbon reduction targets of 50% by 2050.<sup>33</sup>

### Strengths and weaknesses

The strengths of this paper include using an internationally recognised model, underpinned by a strong evidence base on the health outcomes and a well-recognised methodology.<sup>11</sup> While models inevitably represent a simplification of reality; they do allow us to consider possible alternative futures, or in this case, quantify the impacts of decisions on transport infrastructure made in recent decades.

Our model lacked data on where the New Zealand population derives its PA; we had to use information from California, which may or may not be similar. In addition, air quality modelling relied on sparse New Zealand PM<sub>2.5</sub> monitoring data and used an air shed model and vehicle emissions model developed for the Bay Area, California. As the cities were compared with one another using the same basis to estimate changes in PA and PM<sub>2.5</sub>, our comparisons and scenarios were likely to be robust despite the use of the Californian estimates and models for PA and PM<sub>2.5</sub>.

Our adaptation of the ITHIM model was not able to disaggregate travel according to the speed limit and function of the road, as we did not have data to undertake modelling at this level. This means that the reduction in injuries from change in travel mode to

cycling and walking is likely to be underestimated slightly (ie, it is conservative). This is because when walking and cycling replace car trips, these are likely to be short trips on local roads; thus, the corresponding reduction in driving will likely be on local roads too. A reduction in car traffic on these roads where cyclists and pedestrians are common will have a much larger safety benefit than taking cars off high volume, high speed-limit roads. Our model assumed that there would be proportional reductions in travel from greater uptake of active travel modes that were equal across all road types, which therefore underestimates the injury reductions for vehicle collisions with pedestrians and cyclists.

A number of assumptions have been made in ITHIM to model changes in disease burden due only to changes in active transport and light vehicle PM<sub>2.5</sub> emissions. ITHIM reports changes in disease burden in a single year and does not account for gradual changes in PA and ongoing benefits in subsequent years. External disease trends, changes in non-transport physical activity and changes in population distribution of the cities have also not been accounted for. Additionally, transport emissions that impact health, other than PM<sub>2.5</sub>, have not been included (such as ozone, sulphur dioxide, ultrafine particles). ITHIM also does not measure physical activity-related health impacts in children under 15 years of age due to uncertainties in the relationship between PA and disease in this age group. All of these assumptions are likely to result in underestimation of the health impacts of modelled transport scenarios.<sup>11</sup>

The 'scenario' we modelled has limitations. It reflects the characteristics (including topography) of Wellington, which was used to represent an achievable transportation environment for other New Zealand cities. For example, the scenario required a somewhat improbable outcome of Christchurch reducing its current cycling levels. The scenario we modelled does not represent an aspirational, or even necessarily probable, future transport context. The funding push for urban cycling in New Zealand, after decades of minimal investment, is potentially already leading to a different transport future, whereby New Zealand cities rapidly increase their cycling

rates as infrastructure improves. Local and international evidence shows this is entirely plausible.<sup>34</sup> For example, through a number of policy initiatives, Vancouver City increased cycling trips from 4.4% in 2013 to 6.7% in 2016.<sup>5</sup> Such additional cycling activity would improve health outcomes further, assuming people transfer from inactive modes of transport; however, it would not have any sizeable impacts on carbon emissions.

This model was not able to take into account inequalities in transport use or health outcomes. We know that cities are increasingly geographically segregated along socioeconomic and ethnic lines, across which there are differential health outcomes in New Zealand. The scenarios modelled were unable to take these factors into account in any detail, and this is an area that

needs further work. More importantly, these inequalities need better consideration in transport and land use policy and planning to ensure that environmental injustice, in terms of access to transport and the opportunities that entails, is not entrenched.

## Conclusion

Decisions with regards to the planning of transport and land use need to be recognised by local councils and central Government as not just 'bricks and mortar' or a means of improving efficiency, but as policy that can either improve or harm the health of their constituents. Better accounting and accountability of the health and carbon impacts of decisions around transport projects, in particular, should be implemented at both local and national levels.

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### Competing interests:

Nil.

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