NZTA Mode-Shift vs Safety model update

User Guide and background calculations

As part of the NZTA research project "Mode-shift impacts on safety" (RR #728, Koorey *et al.,* 2024), an Excel spreadsheet-based model was developed to enable mode-shift scenario testing for various situations. The original model (v3) has subsequently been further updated to include additional features; this memo documents the underlying features and calculations used in this latest model version (v4).

The model allows users to select a combination of region and demographics, and adjust the future mode usage for this combination. From this, the potential road-safety outcomes will be calculated, both in total numbers of Deaths & Serious Injuries (**DSIs**), and DSIs by exposure (per person-kilometre or per hour travelled).

The data used in the model comes from two key sources:

- the Ministry of Transport Household Travel Survey (**HTS**) data from 2015/16 to 2021/22 (i.e. 7 years) for travel usage
- the Ministry of Health (**MoH**) hospital admission data from 2017/18 to 2022/23 (i.e. 6 years) for serious casualty numbers (deemed as those staying in hospital at least one day)

1 Model overview

The following images (Figure 1 to Figure 3) illustrate the front-end tabs of the spreadsheet tool:

Figure 1: FrontEnd tab of the model – Existing mode usage/DSIs

Figure 2: FrontEnd tab of the model – Future mode usage/DSIs

*Note: the values below are **absolute** percentage point changes*

FUTURE mode usage

	Updated Base %	Change ->	New %Trips	Estimated New '000 Trips/yr	Estimated '000 PKT/yr	Average '000 VKT/yr	Average VKT Pct Diff	Average '000 hrs/yr	
Cars/Light Vehs	55.0% - 49.6%	(Abs %)	49.0% - 43.6%	317,992 - 345,594	2,289,514 - 3,041,187	2,211,915	-31.8%	599,729	Cars/Light Vehs
Trucks	0.4% - 0.4%	+ 0.0% =	0.4% - 0.4%	2,400 - 2,934	10,753 - 16,064	12,678	+1.3%	2,619	Trucks
Motorcycles	0.4% - 0.4%	+ 0.0% =	0.4% - 0.4%	2,312 - 2,825	24,217 - 36,175	30,196	+2.0%	9,494	Motorcycles
Buses	6.4% - 6.8%	+ 1.5% =	7.9% - 8.3%	51,417 - 65,698	273,487 - 427,102	36,622	+96.3%	110,653	Buses
Trains	3.3% - 3.3%	+ 1.0% =	4.3% - 4.3%	27,622 - 33,934	458,538 - 688,487	6,944	+210.2%	254,818	Trains
Ferries	0.4% - 0.4%	+ 1.0% =	1.4% - 1.4%	9,266 - 11,325	89,230 - 133,294	5,891	+234.1%	45,896	Ferries
Cycles/E-bikes	4.9% - 5.6%	+ 1.0% =	5.9% - 6.6%	38,079 - 52,507	132,975 - 224,106	178,541	+290.4%	54,489	Cycles/E-bikes
Wheeled Devices	0.2% - 0.3%	+ 0.5% =	0.7% - 0.8%	4,249 - 6,098	5,531 - 9,703	7,617	+1193.7%	1,742	Wheeled Devices
Pedestrians	29.2% - 33.4%	+ 1.0% =	30.2% - 34.4%	195,889 - 272,583	148,921 - 253,277	201,099	+42.1%	37,210	Pedestrians
Overall travel change (trips):	0.0%	=======>	649,226 - 793,498	3,433,166 - 4,829,395	2,691,503	-23.1%	1,116,650	TOTAL

FUTURE mode DSIs/yr   **Casualty rates**

	Estimated DSIs/yr	Abs Difference	Est. Risk per Bn P.kms	Ave Pct Diff	Est. Risk per Bn hrs	Ave Pct Diff	
Cars/Light Vehs	34.8 - 44.5	-55.6% - -43.1%	15.2 - 14.6	-25.8%	67.6 - 65.1	-25.8%	Cars/Light Vehs
Trucks	0.4 - 0.6	-42.8% - -17.2%	35.5 - 34.4	-31.2%	181.6 - 176.0	-31.2%	Trucks
Motorcycles	16.5 - 25.7	-44.9% - -13.8%	679.4 - 710.6	-31.0%	2,160.7 - 2,260.2	-31.0%	Motorcycles
Buses	0.6 - 0.9	-3.6% - +42.1%	2.4 - 2.2	-40.2%	7.4 - 7.0	-40.2%	Buses
Trains	0.8 - 1.1	+27.1% - +58.2%	1.8 - 1.5	-54.1%	4.2 - 3.4	-54.1%	Trains
Ferries	0.0 - 0.0	N/A - N/A	- - -	N/A	- - -	N/A	Ferries
Cycles/E-bikes	25.8 - 37.4	+22.7% - +78.3%	193.8 - 167.1	-60.7%	634.9 - 547.5	-60.7%	Cycles/E-bikes
Collisions	15.0 - 19.6	-12.4% - +14.3%	113.1 - 87.5	-73.3%	370.4 - 286.9	-73.3%	Collisions
User only	10.7 - 17.8	+180.0% - +365.1%	80.7 - 79.6	-4.4%	264.5 - 260.7	-4.4%	User only
Wheeled Devices	1.2 - 1.9	-90.4% - -84.8%	217.2 - 196.4	-99.0%	950.0 - 859.0	-99.0%	Wheeled Devices
Collisions	0.7 - 1.0	+4.4% - +54.8%	125.9 - 106.3	-89.7%	550.4 - 465.1	-89.7%	Collisions
User only	0.5 - 0.9	-95.7% - -92.6%	91.4 - 90.1	-99.5%	399.6 - 393.9	-99.5%	User only
Pedestrians	117.9 - 185.5	-10.7% - +40.6%	791.7 - 732.5	-18.3%	4,278.7 - 3,958.9	-18.3%	Pedestrians
Collisions	17.8 - 23.6	-34.8% - -13.8%	119.6 - 93.0	-45.0%	646.6 - 502.5	-45.0%	Collisions
User only	100.1 - 162.0	-4.4% - +54.8%	672.1 - 639.6	-11.3%	3,632.1 - 3,456.4	-11.3%	User only
TOTAL	198.0 - 297.7	-28.2% - +8.0%	57.7 - 61.6	-2.3%	214.9 - 226.9	-13.6%	TOTAL

Figure 3: Settings tab of the model

MODE SHIFT MODEL v4

Facility Settings

*Note: the values below are **proprtionate** percentage changes*

*Note: the values below are **absolute** percentage point changes*

Improve Facilities/LoS?

Improve Bus ped'n access?   YES
Decrease ped'n DSIs by: -3.2% - -4.9%

Area: **Wellington**
Age Group: **All AGES**
Gender: **All GENDERS**
Ethnicity: **All ETHNICITIES**

Improve Train ped'n access?   YES
Decrease ped'n DSIs by: -2.2% - -3.2%

Speed Management   for Wellington streets/roads

Enter details below for new sections of road with speed management

Current Spd Lim	Roads (km) at Spd Lim	Change (km)	New Spd Lim	Traf. Calming?
100	14.7	0.0	80	NO
80	75.5	0.0	60	NO
70	32.8	0.0	60	NO
60	58.2	50.0	50	YES
50	677.6	500.0	40	YES
40	419.1	100.0	30	YES
50	677.6	500.0	30	YES
		0.0		
		0.0		
		0.0		
		0.0		
		0.0		
		0.0		
		0.0		
		0.0		

Improve Cycle Network for Wellington
Existing Network Length (km):   281.23

Additional Cycle Facilities:
Painted cycle lanes (km)   50
Separated infrastructure (km)   30
N'hood Greenways (km)   30
Go Dutch?*   NO

Assumes all cycleways meets full best practice guidance

Increase (prop) cycling trips by: +60.7% - +80.9%
Decrease cycling DSIs by: -3.7% - -5.1%

Improve Ped'n LoS by: +5%
Increase (prop) ped'n trips by: +4% - +6%
Decrease ped'n DSIs by: -4% - -6%

Network road length changes ->   **OK - no inconsistencies**

First/Last-Mile Trips with extra PT
Increase (prop) car trips by: +2.0% - +3.7%
Increase (prop) bike/scoot trips by: +3.9% - +6.4%
Increase (prop) ped'n/scoot trips by: +15.6% - +29.7%
Increase (prop) bus trips by: +6.7% - +12.3%

Decrease road and active mode DSIs by: -8.5% - -8.6%
Increase (abs) pedestrian trips by: +0.8% - +1.2%
Increase (abs) cycling/wheeled device trips by: +1.3% - +1.7%
Increase (abs) PT trips by: +1.9% - +2.9%

The **Instructions** tab explains details further. Key features to note include:

- The model spreadsheet file is an Excel template (***.xltx**) file. Copies of it can be edited and then saved as a different standard Excel (*.xlsx) file. The original template file will remain unchanged.
- The **FrontEnd** and **Settings** tabs are where all inputs and outputs are presented – these are the *only* tabs the end-user is required to interact with. There are separate (hidden) back-end tabs that hold processed data and perform the bulk of the underlying calculations.

- The model can present data either for all of New Zealand, for specific Tier 1 or Tier 2 cities[1], or for all Tier 1 or Tier 2 cities combined.

- The model can also investigate data for specific demographic sub-groups (age, gender or ethnicity); however, only *one* of these sub-groups can be selected at any one time, due to dataset limitations.

- Most front-end inputs use drop-down lists to select specific subgroups or locations for investigation, as well as potential changes to mode share, overall travel, or improvements to transport infrastructure. There are some fields that allow direct editing of values, e.g. additional kms of cycleways or lengths of roads (km) with changed speed limits.

- Prior to specifying any potential changes in future mode usage, if any other measures have already increased the base % mode-share (e.g. due to improved speed management or active/public transport mode measures), these increases will be highlighted in colour in the "***Updated Base %***" column.

- **Motor vehicle modes** are split into "cars & light vehicles", trucks, buses, and motorcycles. As well as buses, there are also separate **public transport modes** for trains and ferries. **Active transport modes** are split into cycles (incl. e-bikes), pedestrians, and other "wheeled devices" (incl. e-scooters, skateboards, mobility scooters, etc). The latter modes have also been split into casualties from crashes involving motor vehicles and those not involving motor vehicles (e.g. slip/trip or hit object) – see section 2.6 for more details.

- The model includes checks for when values are zero or not available, to avoid divide-by-zero errors in the results presented.

Once a geographic urban area and (if desired) a demographic group has been selected, modal usage statistics (up to +10% absolute mode shift in non-car modes) and total overall travel (up to +/- 20% relative change) can be adjusted to generate a future scenario. Other adjustments can also be made, including:

- cycling facilities can be added to adjust the cycling mode share and improve safety outcomes
- pedestrian quality of service can be adjusted to adjust the walking mode share and improve safety outcomes
- public-transport access can be enhanced to improve safety outcomes for those walking to public-transport services.
- speed limits can be adjusted to introduce more lower speed areas

Once a future scenario has been set, new DSI statistics are generated (in terms of total numbers and risk per person-kilometre and per hour travelled) for the selected location and demographic breakdown, using the crash-prediction models derived from the existing crash statistics and relationships identified in the sections below. Many of the calculated values are presented a **range of estimated (low-high) values**; the parameters used to test these are described in section 2.9.

2   Explanation of model calculations

Travel mode usage in the model is measured using both vehicle-kms travelled (VKT) and person-kms travelled (PKT). The latter reflects the fact that more than one person may be in a particular vehicle (refer to discussion in section 0). So, for example, one bus might travel a trip of 10 km (resulting in a VKT of 10), but if it contains an average of 15 passengers then it has a PKT of 150.

As a starting point, the model assumes a straight linear relationship between travel mode VKT and resulting DSI numbers (e.g., a doubling of VKT would lead to a doubling of DSIs) before other factors described in the following sub-sections are introduced.

Broadly speaking, for each travel mode analysed, the estimated change in the number of DSIs with a change in mode shift has been calculated in the following manner:

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[1] Tier 1 and Tier 2 are classifications used for cities in New Zealand, based on their size and relative growth. Tier 1 cities are Auckland, Hamilton, Tauranga, Wellington and Christchurch. Tier 2 cities are Whangārei, Rotorua, New Plymouth, Napier-Hastings, Palmerston North, Nelson-Tasman, Queenstown, and Dunedin.

$$[Predicted\ DSIs] = [Existing\ DSIs] \times [Future\ VKT] / [Existing\ VKT] \times \pi_j\,[Infra_j] \times f(Marginal\text{-}Crash\text{-}Rate)$$

where:

$\pi_j\,[Infra_j]$ = a multiplicative combination of factors to improve crash rates, associated with improvements to active mode and public transport infrastructure, and speed management, as described in sections 2.3, 2.4 and 2.8

f(Marginal-Crash-Rate) = a correction of the marginal crash rate, based on changes to relevant travel mode volumes, as described in section 2.1.

Prior to any further self-determined changes to future VKT volumes, the existing VKT volumes of car, bike or scooter, pedestrian and bus trips are also initially increased when they form part of a trip-chain with any increases in public-transport usage, as described in section 2.2.

Where there are no existing crash rates currently available for a particular travel mode (e.g. absence of a train service or wheeled devices in a city), or mode usage is very small (i.e. <0.1%), the average DSI casualty rates per billion person-kms or billion hours for modes in all Tier 1 cities have been used as the default rates for any future mode increases.

2.1 Marginal crash risks

Transport mode crash numbers do not typically operate linearly relative to usage. It is important therefore that the relative risk of each travel mode is adjusted to allow for likely changes when volumes change – this also includes adjusting for any concurrent changes in interacting travel mode usage levels as well.

Typically, most crash-prediction models used assume a key relationship between traffic 'exposure' (i.e., the amount of relevant at-risk traffic present) and the resulting number of crashes (or related metrics, such as the number of casualties or total crash costs) (Elvik *et al.*, 2009). Models for two different conflicting travel modes often feature two separate VKT values for each mode, each with a different exponent coefficient, multiplied together, that is:

$$[Crash\ metric] = \boldsymbol{b_0} \times [VKT_1]^{\boldsymbol{b1}} \times [VKT_2]^{\boldsymbol{b2}}$$

where *[VKT$_1$]* and *[VKT$_2$]* are the total VKTs for each mode, and $\boldsymbol{b_0}$, $\boldsymbol{b_1}$, and $\boldsymbol{b_2}$ are coefficients to be determined.

Factors were built into each of the future-crash-rate estimates to account for likely changes in risk. These used coefficients determined following a review of the various traffic models described in the relevant literature, and summarised in Table 1.

Table 1: Assumed crash-prediction model coefficients

Travel mode	VKT variables	Main mode *b1*	Motor vehicle *b2*	Sources and section of report where cited
Motor vehicles	*[M.Veh Mode VKT]^{b1}* × *[All motor traffic VKT]^{b2}*	**0.8**	**0.8**	• ViaStrada (2022), section 7.2
Cycling	*[Cycle VKT]^{b1}* × *[Adjacent traffic VKT]^{b2}*	**0.2**	**0.4**	• ViaStrada (2022), section 7.2 • NZ Transport Agency (2018), section 7.1 and 7.2 • Turner *et al.* (2009), section 5 • Turner *et al.* (2006), section 6
Pedestrian	*[Pedestrian VKT]^{b1}* × *[Adjacent traffic VKT]^{b2}*	**0.4**	**0.6**	• ViaStrada (2022), section 7.2 • NZ Transport Agency (2018), section 4.2 • Turner *et al.* (2006), section 6
Trains	*[Train VKT]^{b1}* × *[Adjacent traffic VKT]^{b2}*	**0.4**	**0.3**	• NZ Transport Agency (2018), section 6.5

The above coefficients were determined by inspecting a selection of relevant studies for each model type and assessing appropriate best-estimate values. These coefficients could be adjusted to test other values; however, it is likely that some would need to vary greatly to get a big difference in the resulting marginal costs.

It is notable that in all cases the model exponents are less than 1 – that is, a doubling of VKT would lead to **less** than a doubling in crashes. This illustrates the "safety-in-numbers" effect commonly found in most crash relationships.

Note that the b_2 coefficient is applied to the *combined* total change of VKT in all motor vehicles (VKT_{MV}), namely cars and light vehicles, trucks, motorcycles and buses. This reflects the fact that it is likely that all adjacent motor traffic contributes to the relative crash risk of other modes.

The effect on the resulting crash rates can be calculated thus for each mode M with a VKT of VKT_M:

$$[DSIs_{New}] = [DSIs_{Existing}] \times ([New\ VKT_M] / [Existing\ VKT_M])^{b1} \times ([New\ VKT_{MV}] / [Existing\ VKT_{MV}])^{b2}$$

For example, if cycling VKT increased by 50% (relative), while motor-vehicle VKT is reduced by 3%, then the resulting change in cycle DSI numbers would be $(1.50 / 1.00)^{0.2} \times (0.97/1.00)^{0.4} = 1.07$ higher. However, because cycle VKT have increased by 50%, the effective change in the cycle DSI rate per VKT would be $(1.07 / 1.50) = 0.71$ or a **29%** reduction.

2.2   Trip chains associated with public transport

Trip chaining occurs when a person's journey comprises using multiple travel modes along the way. This is particularly a common issue with public-transport trips, where the travel to and from the public-transport leg ("first-mile"/"last-mile" trips) may be made by other travel modes, such as driving and walking, but potentially also by cycles and other wheeled devices and even buses feeding into ferry or train trips.

HTS data analysis was undertaken to establish trip-chaining patterns for New Zealand public-transport trips across the country. A particularly useful component was to analyse the relative use of modes *supporting* public-transport trips, in terms of relative distances travelled, to predict the increase in "first/last-mile" modes, such as walking and cycling, when use of buses, trains or ferries increases.

For example, every additional kilometre of **bus** travel undertaken in Auckland is likely to be associated with an average of an extra 0.19 km driven, 0.01 km cycled, and 0.07 km walked. Similarly, every additional kilometre of **train** travel undertaken in Wellington is likely to see an average of an extra 0.15 km driven, 0.04 km using a bus, 0.01 km cycled, and 0.05 km walked. Therefore, the base VKT amounts for travel by car & light vehicles, buses, cycles, and walking are adjusted accordingly to take these into account.

Although not strongly reflected in the HTS data yet, there is growing evidence that wheeled devices such as e-scooters are likely to also feature in first/last-mile journeys associated with public transport. For example, in their review of micro-mobility use in Auckland, Martin *et al*. (2021) cited evidence that one in five users said they currently rode shared e-scooters to and from public-transport stations. It is likely that these trips may be replacing both existing walking and cycling trips to and from public transport, and possibly other traditional linking modes, such as driving and busing. Therefore, for now, we have made an assumption that **20%** each of the increased VKT attributed to cycling and walking to and from public transport should be added to wheeled devices instead.

2.3   Effects of improvements to walking and cycling levels of service

There are several studies where increased quality of pedestrian and cycling facilities were shown to reduce crash rates and the severity of crashes. As well as safety impacts, the quality of infrastructure is also associated with higher levels of active mode use such as cycling.

While there are numerous pedestrian or cyclist "level of service" tools, few have been developed for evaluating more than a single corridor (e.g., a neighbourhood, city or nation), and most are not quantitative in their outputs. Two recent models were developed for evaluating Council urban active-mode networks and have been further refined with data from other cities to estimate the mode shift

resulting from changes in infrastructure that improves Pedestrian Level of Service (PLOS) and Cycling Quality of Service (CQOS).

2.3.1   Cycling quality of service (CQOS) model

Work was undertaken to determine CQOS scores for different urban areas, and the resulting impact on cycling usage levels and (provisionally) cycle safety risks. The resulting model allows one to assess the effect of hypothetically adding additional cycling infrastructure to any major city in New Zealand (in terms of kilometres of facility).

To establish the level of cycling provision on and off the road network, two datasets (NZTA MegaMaps for road attributes, and OpenStreetMap for cycling provision) were combined using a GIS process to assign a facility type (from OSM) to each road segment (MegaMaps), with completely off-road paths being added to the dataset.

Auckland Transport's [CQOS tool](#) was then used to determine the quality of service of each road segment, based on three of its five principles directly relating to safety. CQOS was scored between 1 (best possible provision) and 4 (worst possible provision). Generally, separated cycleways rated better than on-road cycle lanes, which rated better than no facility at all.

To find a CQOS score for an entire urban area, the CQOS for each street segment was multiplied by its length, and then divided by the total network length, finding an average CQOS score. To account for the 'network effect', a combined metric was used, multiplying the inverse average CQOS score of cycling infrastructure by the percentage of the network that has cycling infrastructure.

A relationship between the combined CQOS metric and cycling mode share was obtained and is shown in Figure 4. While still warranting further investigation and refinement, the R-squared value of 0.38 is considered acceptable for use in the research model. The relationship suggests that for each 1% (0.01) increase in coverage-weighted CQoS there would be a **0.70%** (absolute) increase in cycling mode share.

Figure 4: Coverage-weighted cycling quality of service vs cycling mode share
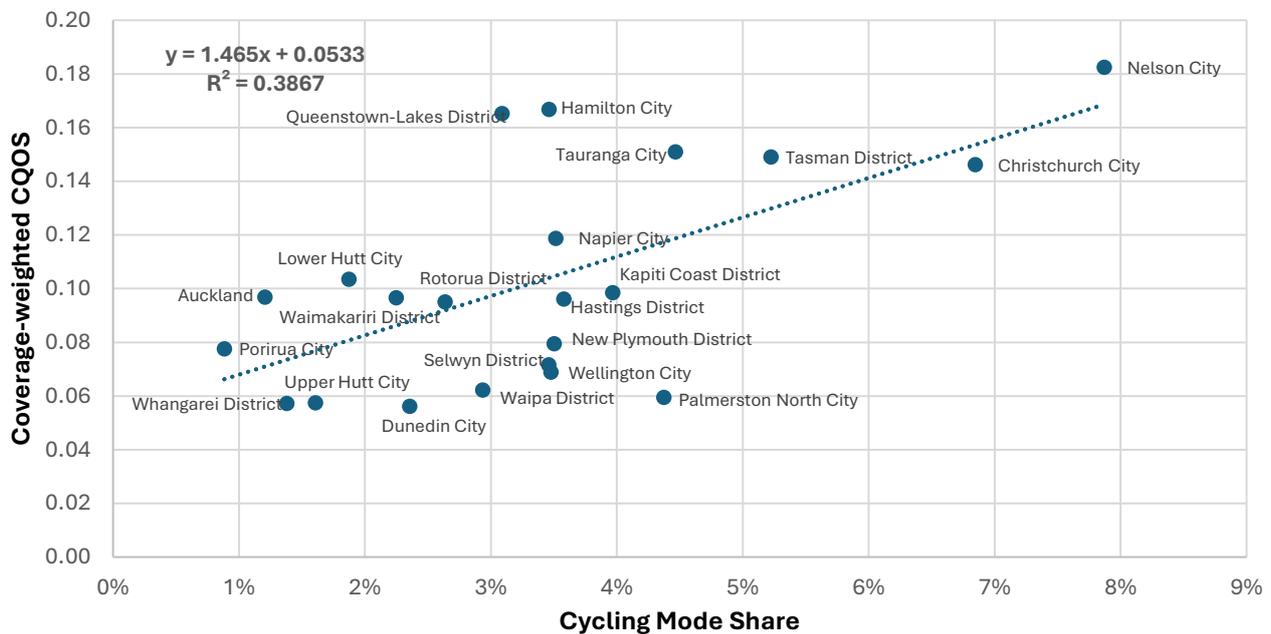
For testing the effect of future cycleway provision, the user of the model tool can enter the length of added cycling infrastructure by three types:

- separated infrastructure (including shared paths and separated cycleways)
- on-road cycle lanes
- neighbourhood greenways

To assess the impact of this, an assumed CQOS is assigned to the added cycling infrastructure by its type. This assumed CQOS is derived from the national average CQOS for that facility type, rounded down slightly as it is assumed that newer cycling infrastructure will be, on average, higher quality than what exists today. A 'go Dutch' option has also been added, to allow users to see the impact of higher infrastructure quality on mode share. This option assumes a higher CQOS level for all facility types. Assumed CQOS scores for added infrastructure are shown in Table 2 (scored 1 to 4, where 1 is best provision).

Table 2: CQOS scores for different cycle facility types and 'go Dutch' options

Option selection	Separated infrastructure	Cycle lanes	Neighbourhood greenways
Standard quality of service	1.6	2.3	1.8
'Go Dutch' quality of service	1.2	1.6	1.0

The length of the facility at a given CQOS is then added to the total length of cycling network, providing both a new average CQOS value for cycling infrastructure, and a new value for the proportion of the network that has cycling infrastructure (the total network length is assumed to remain the same, i.e., all new facilities are assumed to be built on the existing road network). The relationship established between the combined CQOS metric and the Census cycling mode share (Figure 4) is then applied to the new network parameters, where the projected increase in cycling mode share is added to the existing measured cycling mode share.

Other research elsewhere has attempted to estimate the safety effect of introducing different types of cycle facilities to existing networks. Based on that literature, Table 3 suggests estimates of DSI reductions that can be applied to any expanded cycle networks.

Table 3: Estimated safety effects of different cycle facility types

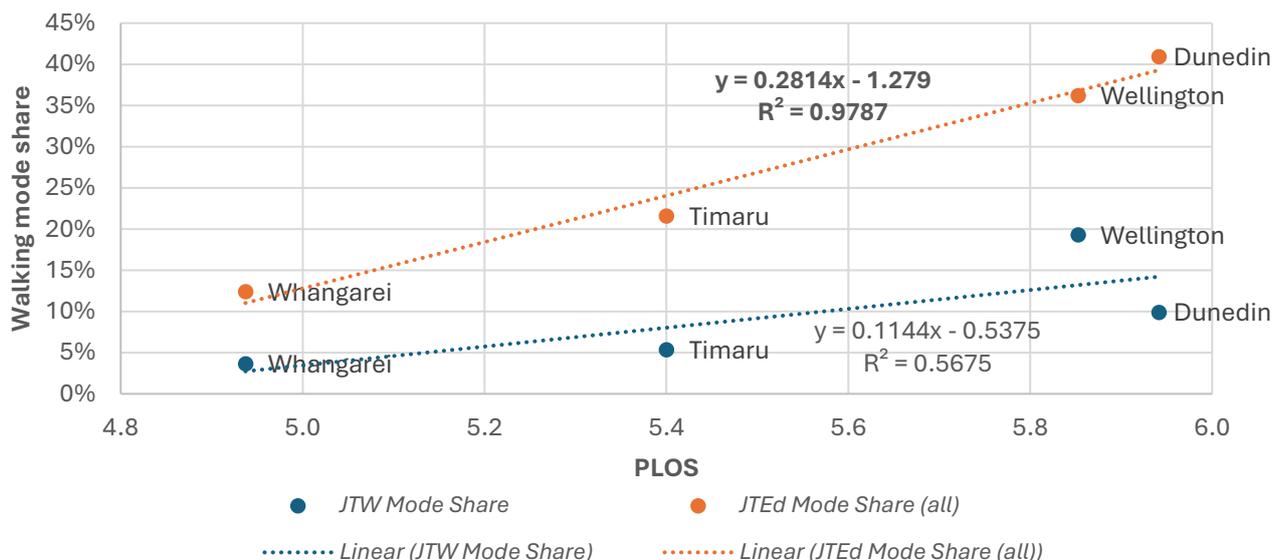| Option selection	Separated infrastructure	Cycle lanes	Neighbourhood greenways
Standard quality of service	0.70	0.90	0.80
'Go Dutch' quality of service	0.50	0.80	0.50

The relative additional length of each type of cycle facility can be combined to form a weighted crash reduction factor (with the assumption that the existing cycle network has a factor of 1.0 reflecting the existing cycle crash numbers). This can then be applied to the existing cycle crash rate for the network to determine a future crash rate.

2.3.2   Pedestrian level of service (PLOS) model

A separate, less detailed analysis has been undertaken looking at the effect on usage of journey to work and education and study walking trips (from the 2018 Census data) compared with the relative PLOS in four New Zealand cities.

Figure 5 shows the resulting relationship. Although the sample is limited, the correlations are reasonably strong. Ideally over time, a large sample of data points would be collected, and other potential factors also incorporated (e.g., terrain and climate).

Figure 5: Relationship between journey to work or study walking share and pedestrian level of service

On the chart: $y = 0.2814x - 1.279$, $R^2 = 0.9787$ (JTEd trendline); $y = 0.1144x - 0.5375$, $R^2 = 0.5675$ (JTW trendline). Axes: Walking mode share (vertical, 0%–45%), PLOS (horizontal, 4.8–6.0). Data labels: Dunedin, Wellington, Timaru, Whangarei. Legend: JTW Mode Share; JTEd Mode Share (all); Linear (JTW Mode Share); Linear (JTEd Mode Share (all)).

Note: JTW = journey to work; JTEd = journey to education and study

The findings suggest that for every 0.1 improvement in PLOS there is a **2.81%** (absolute) increase in journey-to-education walking trips and a **1.14%** increase in journey-to-work trips. HTS data for 2015-21 indicates that the numbers of these walking trips are roughly even (about 52% and 48%, respectively), so a trendline interpolated *halfway* between the two in the figure is assumed as representative of the growth in pedestrian trips overall. If the PLOS values around the mid-point of the dataset are assumed as a base (i.e., 5.4), then every 5% relative improvement in this score (i.e. 0.27) would see about a **5%** (absolute) increase in walking trips.

At present, no clear research has been identified that shows a relationship between PLOS and changes to pedestrian crash risk. However, it would seem logical that an improvement in walking conditions should also result in a corresponding improvement in pedestrian safety. As a conservative estimate for the model at this point, it has been assumed that every 5% improvement in PLOS would correspond to a **5%** reduction in pedestrian DSI risk.

2.4   Effect of improvements in pedestrian access to public transport

Additional public-transport trips can lead to additional risks for other more vulnerable travel modes that connect to these services. Therefore, ideally efforts should be made to improve the relative safety of these first/last-mile journeys as well.

Previous research from Auckland focussed on the safety of people travelling outside vehicles (ViaStrada, 2021) and identified that a reasonable proportion of total pedestrian injuries involved people trying to access public transport. Not all of these public-transport journey injuries involved a motor vehicle either; many involved a person tripping or slipping when running for the bus or on an uneven surface while catching the bus, or when boarding. The authors hypothesised that improved pedestrian access to public transport may reduce the number of these injuries. Interventions to achieve these safety gains may include those that reduce the likelihood of tripping and falling, such as raised pedestrian crossings, or other raised platform crossing types from the standard safety intervention toolkit (NZ Transport Agency, 2021) where the crossing tripping hazard is effectively mitigated.

Few studies have examined the access modes to public transport, and the percentage decrease in DSIs from improving pedestrian access to public transport. A before and after comparison crash study using a substantial number of bus stops would need to be undertaken to gather statistically meaningful data on the effect that access to public transport has on safety. The level of service or quality of service of each bus stop would need to be quantified.

For the purposes of this model, we have made a simple assumption that *any* pedestrian improvements to accessing train or bus services would improve the DSI risk of those trips by **20%**. These savings have only been applied to the pedestrian trips directly associated with any train or bus journeys.

2.5   Changes in average trip length when changing modes

The previous version of the model assumed that when mode shift occurred, the user travelled the same distance and to the same location. In reality, when changing to an active mode, a user may change their journey length or travel to a different destination that is more convenient (Litman, 2021).

The HTS data (Table 4) shows that the average distance of active mode trips is generally less than that of motor car trips. Of note, active modes (cycle, wheeled device, pedestrian) had a roughly similar average trip duration to trips undertaken in a motor car. These trip durations reinforced the concept that each traveller typically has a roughly fixed "travel time budget" (although public transport users take a bit longer) and will decrease their trip distances if a mode is slower.

Table 4: Average trip distance (km) and duration (min) for each mode using data from the HTS (all NZ)

Mode	Average trip distance (km)	Average trip duration (min)
Motor car occupant (car/taxi/van/ute)	9.1	13.4
Truck occupant	11.4	15.1
Motorcycle/motor-scooter/moped rider	9.0	14.6
Bus occupant	8.7	22.7
Train passenger	19.3	31.0
Ferry passenger	19.7	36.5
Cycle (incl. e-bike)	3.8	17.1
Pedestrian mobility device (e.g. wheelchair, mobility scooter)	1.0	9.7
Wheeled device rider (e.g. e-scooter, skateboard, kick-scooter)	2.1	10.7
Pedestrian	0.9	11.6

Average trip distances and durations vary between different areas, and this is reflected in the underlying data, which the model uses. For example, the average bus journey in Auckland is 8.5 km, while in Christchurch it is 7.3 km. Similarly, the average cycle journey in Dunedin is 5.3 km while in Hamilton it is 3.0 km. These figures will be applied to the respective calculations for each urban area

The relative change in average distances is used to determine the change in VKT. This is done by first determining the number of existing trips for each mode by using the total kilometres travelled and average trip length from the HTS. It is assumed that the total number of trips across all modes are conserved unless there is a change in total travel. Therefore, the mode shift is applied to *trips* rather than VKT or PKT.

For example, if 100 VKT of motor car trips (average trip distance 10 km = 10 trips) are replaced by an equal share of walking and cycling trips (average trip distances of 2 km and 5 km respectively, with 5 trips each) then the new amount of active mode trips are 10 VKT (2×5) for walking and 25 VKT (5×5) for cycling. Conversely, if those motor car trips were replaced by train trips (average trip distance 30 km), then the new amount of public transport trips would be 300 VKT (10×30). Note however, that there would be additional adjustments for vehicle occupancy (discussed in section 0) that would affect the calculated PKT values.

2.6   Active mode casualty figures not involving motor vehicles

In the previous version of the model, the casualty figures used for active modes (pedestrians, cyclists, e-scooters, etc.) did not distinguish between those incidents that involved motor vehicles and those incidents that that did not (e.g. slip/trip, hit object, etc.). For this update, these figures were separated by identifying the incidents where the secondary mode involved was listed as 'none'. This implied that no other mode of vehicle was involved when the person was injured and could be assumed to be an active mode incident due to a self-inflicted mistake. These also excluded incidents between users of active modes such as pedestrian vs cyclist or pedestrian vs wheeled device.

The results showed that a significant number of incidents with pedestrians or wheeled devices did not involve a motor vehicle (Table 5). It is possible that these numbers could be even higher when accounting for under-reporting.

Table 5: Casualty data for active modes with no second mode involved

User Mode	No. of Casualties	% of User-only Casualties
Cycle	243	19.5%
Pedestrian	5818	74.8%
Wheeled Device	741	94.6%

Based on these figures, the DSI numbers for each of these modes have been split into **"Collisions"** (with motor vehicles or other users) and **"User only"** (i.e. slips/trips/falls or collisions with objects).

A separate analysis also investigated the overall relative crash rates for cycles and wheeled devices with motor vehicles in Tier 1 cities combined. Typically, the casualty rates were slightly lower per billion kms and slightly higher per billion hours for wheeled devices vs cycles. Therefore, we have assumed that the default crash rate scaling factor for wheeled devices relative to cycles is **1.0**.

2.7   Vehicle occupancy factors to more accurately measure VKT

The previous version of the model did not consider occupancy factors within motor vehicles and public transport vehicle patronage. For example, if two people travelled 10 km in a motor car together (total PKT of 20), the resulting total could imply that each person individually travelled to their destination in two separate motor vehicles (i.e. a total VKT of 20), rather than as a single trip (i.e. a VKT of 10).

The previous model also assumed that when mode shift towards public transport occurred, the VKT attributed to public transport also increased by an equivalent amount. However, while the number of passengers within a scheduled public transport vehicle would increase, it wouldn't have the same impact on VKT. This meant the measure of VKT for vehicle-based modes was overestimated and more accurately reflected the *person-kms* travelled.

2.7.1   Public transport occupancy

Public data available from NZTA (Waka Kotahi) details public transport services and patronage across New Zealand (NZ Transport Agency, 2025). This data was used to determine the nationwide average occupancy per public transport vehicle (buses, trains and ferries) and the total passenger-kms (PKT). The average occupancy data was subsequently used with the PKT data to determine the actual VKT across public transport trips and is summarised in Table 6.

Table 6: Average occupancy of PT vehicles per service-km for each urban area

Urban Area	Average occupancy per service-km		
	Bus	Train	Ferry
Auckland	6.86	56.71	45.76
Christchurch	7.83	#N/A	12.90
Hamilton	5.40	41.27	#N/A
Tauranga	5.88	#N/A	#N/A
Wellington	9.45	81.75	18.70
Dunedin	5.29	#N/A	#N/A
Napier/Hastings	5.27	#N/A	#N/A
Nelson/Tasman	6.19	#N/A	#N/A
New Plymouth	8.27	#N/A	#N/A
Palmerston North	4.50	#N/A	#N/A
Queenstown	5.29	#N/A	13.33
Rotorua	5.88	#N/A	#N/A
Whangārei	11.06	#N/A	#N/A

2.7.2   Private vehicle occupancy

The Household Travel Survey (HTS) asks those who travelled in a motor vehicle how many people travelled in the vehicle with them. This data can be used to find the average occupancy of private vehicles. As seen in Table 7, the average occupancies do not notably change from region to region.

Table 7: Average number of people in motor car based on participants responses in HTS

City/Region	Ave. number of people in motor car
All of NZ	**1.21**
Auckland	1.20
Christchurch	1.22
Hamilton	1.20
Tauranga	1.19
Wellington	1.25
Dunedin	1.18
Napier Hastings	1.18
Nelson Tasman	1.20
New Plymouth	1.24
Palmerston North	1.20
Queenstown	1.22
Rotorua	1.21
Whangārei	1.21
not stated	1.15
Rest of NZ	1.22

From the data, a 'default' occupancy rate of **1.20** was decided on as a typical occupancy rate to be used in the model.

The average occupancy of taxi/ride-hail (e.g. Uber) vehicles were also considered. During service there would usually be at least two people within the vehicle (driver plus passengers), but there may be a large portion of the time where the vehicle is not in service, and the driver is the sole occupant of the vehicle. However, from an MoT review of transport costs and charges, in 2018 only 0.95% of total light vehicle VKT involved taxis or ride-hail services (Veitch Lister Consulting, 2023). Therefore, taxi/ride-hail vehicles were considered negligible to account for when calculating the occupancy of private vehicles.

For active modes such as walking, cycling, wheeled devices, and for motorcycles, is assumed that typically the average vehicle occupancy is very close to **1**, so no adjustment is allowed for.

2.7.3   Application of vehicle occupancy to mode shift

The following examples illustrate how the mode shift calculations might apply using vehicle occupancy and trip length factors:

- If **120** PKT of motor car trips (average veh occupancy of 1.2 = 100 VKT, and average trip distance 10 km = **12** person-trips, and) switch to cycling trips instead (average trip distance of 5 km, with one person per bike) then the new amount of cycling trips is only **60** VKT and 60 PKT (12×5×1).

- Conversely, if those same motor car trips were replaced by train trips (average trip distance 30 km and average train occupancy of 60), then the new amount of public transport trips would be 360 PKT (12×30) but only an extra **6** VKT (360 PKT / 60 people per train).

2.8   Effect of lower speed limits on mode shift and safety in urban areas

There is good evidence about the safety effects of speed reductions on all travel modes (in terms of reduced DSIs), and also some evidence that lower speeds can encourage greater take-up of active modes. Changes in travel speeds can be achieved through either lower posted speed limits and/or physical interventions such as traffic calming treatments.

While there are certainly notable safety benefits from the introduction of lower rural speed limits, they do not generally influence the likelihood of people changing travel modes, particularly with active transport and public transport modes being less prevalent there. Therefore, the focus on this exercise was on changes to speeds in **urban** areas.

2.8.1   MegaMaps data collection

Traffic data for each Tier 1 or 2 urban area was obtained from NZTA's MegaMaps database (NZ Transport Agency, 2026). For each road segment, this included information on road length, traffic volume, road type and road use category, posted speed limit, and mean observed free-flow speed. Some road segments were excluded from the final dataset, particularly rural state highways, motorways, and other rural roads. Data was combined to calculate the total lengths of roads with different speed limits and their respective total VKT and average free-flow speed.

Example data for Christchurch is shown in Table 8 (the data for roads with speed limits of 30 km/h or below were combined into one category). Not surprisingly, the bulk of the streets have 50 km/h speed limits, with most others in the range of 30-60 km/h.

Table 8: Example of speed data from MegaMaps for the Christchurch urban area

Speed Limit	Total Km	%	Total VKT	Ave Free Spd
≤30	194.63	8.8%	431,617	20.3
40	181.24	8.2%	257,182	23.1
50	1562.58	70.8%	5,424,535	26.0
60	210.33	9.5%	1,675,376	51.7
70	18.82	0.9%	232,672	57.9
80	37.53	1.7%	184,417	62.5
90	0.00	0.0%	-	-
100	1.48	0.1%	11,948	87.5
	2206.62		**8,217,747**	

2.8.2   Relative risk and speed limits

The Elvik exponential model (Elvik 2013, Elvik *et al*. 2019) was used to find the change in DSIs expected on a road when there is a change in speed.

$$\{Estimated\ DSIs\ After\} = \{Estimated\ DSIs\ Before\} \times \{Relative\ risk\ change\}$$

where:

$$Relative\ risk\ change = e^{(Speed\ After - Speed\ Before) \times exponent}$$

For serious and fatal injuries, the exponent used is **0.06**.

Previous research by Elvik *et al*. (2004) showed that, for each 10 km/h of speed limit decrease, an associated ~2.5 km/h decrease is observed in mean operating speeds. Similar findings have been observed in various studies in New Zealand; however, it is possible that greater speed changes could be observed. Based on this, a default **3 km/h** estimate of speed change per 10 km/h limit has been assumed.

The speed risk model first calculates the initial relative risk of all roads at each speed limit by using the average free speed of the roads compared with a base speed of **20 km/h** (which is assumed to have a base risk of 1.00). For example, the 50 km/h streets in the Christchurch example above have an average free-flow speed of 26.0 km/h; therefore, their relative risk (compared with 20km/h) would be $e^{(26-20) \times 0.06}$ = 1.43.

By multiplying the relative risk of each speed limit with the total VKT at these speed limits, a 'weighted risk' can be obtained. Summing up the weighted risk across all roads at each speed limit will give the **existing total weighted risk** if no speed changes are implemented.

Users can then enter the length of roads they would like to change from an existing speed limit to a new speed limit for these roads and also whether they want any traffic calming installed. A view of the user interface (found in the Settings tab) is shown in Figure 6. There are checks available to make sure the user does not change more length of road than is available at each speed limit.

Figure 6: Interface to allow users to enter speed limit changes

Speed Management		for Christchurch streets/roads		
Enter details below for new sections of road with speed management				
Current Spd Lim	Roads (km) at Spd Lim	Change (km)	New Spd Lim	Traf. Calming?
100	1.5	0.0	80	NO
80	37.5	0.0	60	NO
70	18.8	0.0	60	NO
60	180.3	30.0	50	YES
50	892.6	200.0	40	YES
40	281.2	100.0	30	YES
50	892.6	500.0	30	YES
		0.0		
		0.0		
		0.0		
		0.0		
		0.0		

To calculate the change in relative risk, there are five steps:

1) Firstly, a new **changed free speed** $v_{f,reduced}$ of the roads with new speed limits is calculated:
   - A speed reduction of **3 km/h** per 10 km/h posted speed limit reduction is applied to the roads.
   - If traffic calming is provided, then an additional **3 km/h** speed reduction is applied per 10 km/h speed limit change.
   - A minimum base limit of 20 km/h is applied to these speeds.

2) Next, a weighted average using VKT is used to calculate the **new average free speed** for each speed limit.

$$v_{f,speed\ lim} = \frac{v_{f,curr} \times VKT_{curr} - (VKT_{reduced} \times v_{f,curr}) + (VKT_{new} \times v_{f,reduced})}{VKT_{curr} - VKT_{reduced} + VKT_{new}}$$

where:
   - $v_{f,speed\ lim}$ is the new average free speed for a speed limit
   - $v_{f,curr}$ and VKT_{curr} are the average free speed and VKT of roads at the speed limit *before* any speed changes are made
   - $VKT_{reduced}$ is the VKT of the road lengths that are *reduced* from the speed limit of concern to a lower speed limit
   - VKT_{new} is the VKT of the road lengths that are now *added* to the speed limit of concern from a higher speed limit
   - $v_{f,reduced}$ is the recalculated free speed of the road lengths that have been changed to a new speed limit, after having the speed reductions applied in step (1).

If the new average free speed is below the base (20 km/h) speed, then it was set to the base speed.

3) The **new relative risk** for each length of changed road is calculated by using Elvik's *relative risk change* equation (described above), with the *new average free speed* for each speed limit used as the 'speed after', and the base (20 km/h) speed used as the 'speed before'.

4) The new relative risks are multiplied by the VKT of the roads at each speed limit of concern and summed together to calculate a **new total weighted risk**.

5) Finally, the new total weighted risk is divided by the existing total weighted risk to obtain a **scaling factor**, which is applied to reduce the existing DSIs for all road transport modes.

For example, if the existing total weighted risk for a city's street network is 10,000,000 and the new total weighted risk after lower speed limits are introduced becomes 9,250,000 then the reduced risk factor is **0.925** or a **7.5% reduction** in DSIs. This can then be applied to the relative safety of each mode, e.g. if there were previously 100 pedestrian DSIs, that would now become 92.5 DSIs, etc.

2.8.3   Mode shift effects of lower speeds

There has been some research suggesting that reductions in posted speed limits typically results in a greater take-up of active and public transport modes (e.g. Tiwari *et al* 2025, Magkafas *et al* 2025). In terms of cycling, a separate analysis was undertaken relating the changes in weighted risk from speed limit changes (described in section 2.8.2) and improved Cycling QoS (described in section 2.3.1) to potential changes in cycle mode share across the various main NZ urban centres.

On the basis that *increased CQoS* and *decreased Weighted Risk* are both likely to increase cycling take-up, a combined ratio of these two factors (i.e. CQoS/Risk ratio) was plotted against the observed mode-share percentages. Figure 7 shows the resulting relationship.

Figure 7: CQoS/Risk ratio vs Cycling mode share
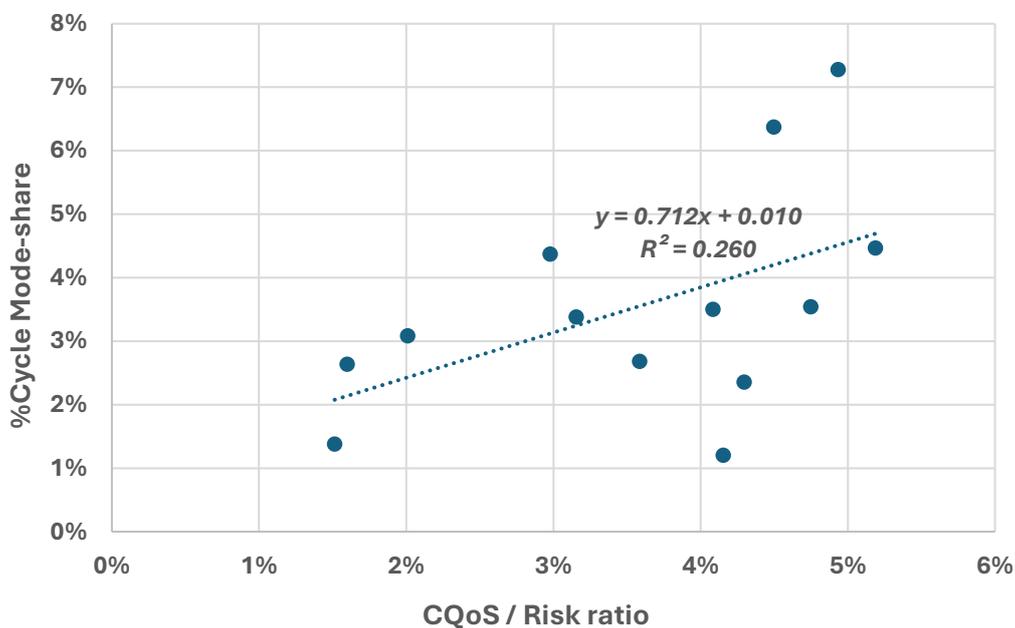
While the relationship is slightly weak, the trend provides some indication of increases in cycling when the road speed risk and the cycle-friendliness rating both improve. The results suggest that, for every 1% (absolute) increase in QoS/Risk ratio, there is likely to be a corresponding (absolute) increase in cycling mode-share of ~**0.71%**.

A similar attempt has been made to estimate likely increases in walking and PT (bus/train) use as well when there are just changes in the speed-adjusted Weighted Risk score (and normalised by total road length). Figure 8 shows the relationship between Speed Weighted Risk score per km and the observed Walking Mode share across the various main NZ urban centres.

Figure 8: Speed Weighted Risk score / km vs Pedestrian mode share
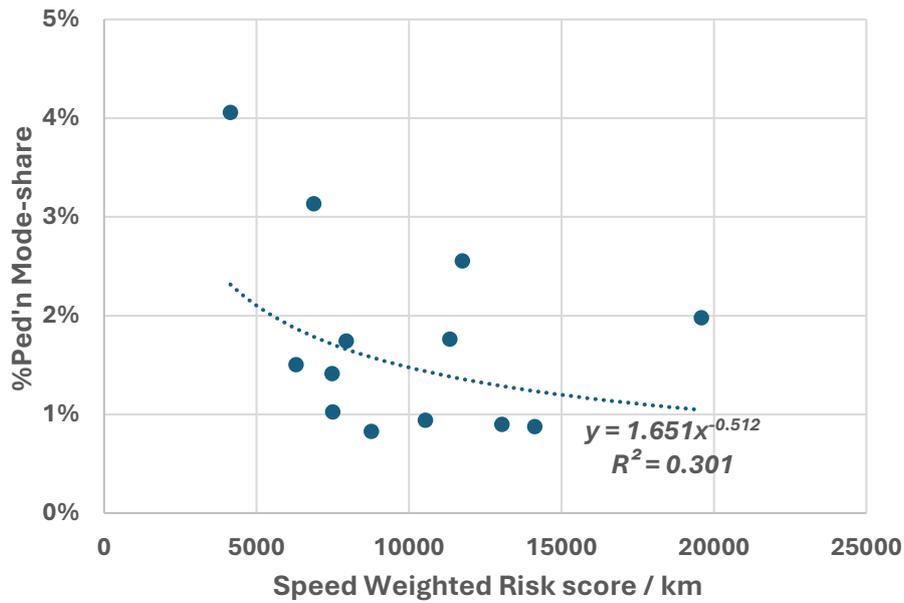
Again, the relationship is somewhat weak, but the trend provides some indication of exponential increases in walking when the distance-adjusted road speed risk reduces. The results suggest that, for every 1% (absolute) decrease in Weighted Risk/km, there is likely to be a corresponding proportionate increase in walking mode-share of ~**0.51%**.

We were unable to find a similarly clear relationship between public transport (bus/train) use and the weighted risk score for each urban area. However, other literature reviewed suggests that the increases for public transport (bus/train) modes may be larger than those associated with walking and cycling. For example, switching most urban streets in European cities to 30 km/h limits (which reduces Weighted Risk in major NZ urban areas by ~12-15%) was found to increase public transport by ~60-75% (proportionately). Therefore, we have assumed that, for every 1% (absolute) decrease in Weighted Risk/km, there is likely to be a corresponding proportionate increase of ~**5%** for public transport (bus/train) modes.

2.9   Error margins for model results

For the first iteration of this model, a single value was selected for each of the factors affecting overall modal shift and safety impacts. However, a model with a range of possible high and low values (i.e., error margins) is a useful improvement, to highlight the likely range and uncertainty in some of the estimates. Therefore, an effort has been made to introduce an error margin into the updated model.

The following data inputs (Table 9) have been selected for specifying both a low and high value for the model calculations, relative to their current estimated (base) values derived above:

Table 9: Selected data variables and their relative high-low values

Data variable	Base values	Low value	High value
Crash-prediction model coefficients	See Table 1	-0.05	+0.05
% of Walk/Cycle PT trip-chains used for wheeled devices	20%	15%	25%
DSI safety effects of different cycle facility types	See Table 3	+0.05	-0.05
Increase in walking trips per 5% improved Pedestr'n LOS	5%	4%	6%
Increase in cycling trips per 0.01 improved CQOS	0.7%	0.6%	0.8%
DSI risk reduction per 5% improved Pedestrian LOS	-5%	-4%	-6%
DSI risk reduction for ped'n access improvements to PT	-20%	-15%	-25%
Average trip distance / duration for each mode	See Table 4	-10%	+10%
Average public transport occupancy	See Table 6	-10%	+10%

Data variable	Base values	Low value	High value
Average private motor vehicle occupancy	1.20	1.15	1.25
Reduction in mean speed per 10 km/h speed limit drop	3 km/h	2.5 km/h	3.5 km/h
Reduction in mean speed with traffic calming	3 km/h	2.5 km/h	3.5 km/h
Increase in cycling trips per 1% increase in CQoS/Risk	0.71% (abs)	0.6%	0.8%
Increase in walking trips per 1% drop in Weighted Risk	0.51% (prop)	0.4%	0.6%
Increase in bus/train trips per 1% drop in Weighted Risk	5% (prop)	4%	6%

In most cases, the particular values were determined by manual inspection of the original data values and in some cases, the observed variation in values.

The resulting model front-end presents the calculated estimates for DSIs, trips, person-kms, veh-kms, and veh-hrs as a range of high and low values.

3   Data limitations of the model

This updated model has the potential to provide considerable flexibility to assess many different mode-shift scenarios, based on existing New Zealand evidence and indicative trends from associated research.

It is important to note that the model should *not* be used solely to justify or target any particular modal mix. Mode shares affect many different societal factors, including travel time, travel reliability, greenhouse gas emissions, accessibility, public health, and community severance. All of these effects – together with safety effects – need to be considered in a comprehensive cost-benefit analysis before policymakers implement measures to target a particular modal profile.

A brief summary of the current model's data limitations follows.

- The model is likely to significantly underestimate total reductions in per-capita crash casualties, particularly over the long run if, for example, active-mode improvements induce more shifts to public transport and provide a catalyst for more compact, transit-oriented development.

- Weighting factors for each geographic and demographic breakdown are derived from the **2018** Census, while both usage and crash statistics cover years before and after 2018. Geographic boundaries set during the 2018 Census have also been used; however, boundaries have changed over time, particularly since the 2023 Census.

- Hospital casualty data is geographically categorised by the area in which the patient *resides* – it is assumed that the crash occurred within the same urban environment.

- Datasets have different methods of categorising vehicle types – the model uses the most detailed breakdown of mode possible; however, some modes are still grouped together (e.g., bike and e-bike, private and public-hire e-scooters, trucks of all types).

- CQOS is based on open-source data (OpenStreetMap), which has varying quality and has been calculated through a process that makes assumptions about facility quality that may not reflect real-world conditions. The CQOS method is focused on midblock facility type, but did not consider intersections, which are generally where the biggest risks to cycling safety can occur. It was assumed that, if midblock facilities are provided, intersection provision will be at least to the same safety standard. Ultimately, it would be useful to further investigate the relationship between the measured CQOS scores in different cities and their equivalent cycle crash rates, to determine a more robust safety relationship.

While none of these factors are likely to greatly affect the overall ranking of the relative personal-risk profile or the collective-risk profile across modes, they do mean that any specific instance of mode shift could have markedly different effects on DSI than is observed on average. By providing model outputs with a range of possible high and low values (i.e., error margins), we are hopefully highlighting the likely range and uncertainty in some of the estimates.

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