NIWA Taihoro Nukurangi

Memo

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To	Jeff Bluett, PDP
CC	
Date	29 June 2020
Subject	NIWA Traffic Impact Model v3.1
File path *(right click to update)*	*C:\Gerda's Jobs' Files\HAPINZ 3.0\4_Clarifications\NO2 material\NIWA_memo on TIM 3.1_Jun20.docx*

This model has been developed by NIWA with the support of the NZTA. It predicts long-term average NO_2 for most urban areas in the country.

Purpose of the Traffic Impact Model

The model aims to predict long-term concentrations of traffic-related air pollutants at any outdoor location in urban New Zealand and therefore is useful for exposure and health risk assessments. It is designed to be as accurate as possible for as many locatoins as possible. It is empirically optimised to minimise global error. This means the model is generally not conservative and its use or project assessment should be considered with this in mind.

Capabilities and limitations of version 3.1 of the Traffic Impact Model

Version 3.1 is the latest version at the time of writing. It has the following scope:

- Coverage of all urban areas in New Zealand at 10 m resolution.
- Predicts long-term[1] average NO_2 arising from emissions from road transport only. In most locations road transport is the only significant source. In proximity to airports and seaports the model predicts the contribution of road transport on public roads only, not emissions from aircraft, ships or port-specific ground transport, and may therefore under-predict observed concentrations.
- Predicts concentrations where dispersion conditions are typical for that city. Most importantly this means it under-predicts for dense street canyons. In downtown areas the model effectively predicts what NO_2 would be in the absence of tall buildings.
- Predicts concentrations at ground-level (strictly at 2.5 – 3 m above ground) only.

Foundation of the model

TIM is a two-part semi-empirical model. The first part expresses the concept that where long-term concentrations of an air pollutant are dominated by road traffic emissions, then concentrations can (in most locations) be effectively predicted by the distance-weighted traffic density (which we call “traffic

[1] Long-term means ‘typical’ annual mean concentration over the period 2010 – 2020.

impact factor") at that location alone. The second part empirically relates concentrations of a specific pollutant (NO_2 in the case of v3.1) to the traffic impact factor.

Both parts of the model use empirical parameters to describe average dispersion and emission characteristics across a model zone. A zone is typically a town or city. Where observational NO_2 is available the parameters are calibrated using that data. Where it is not, default values are used derived by combining all data for the whole country.

Part one of the model is:

$$roadside\ increment = AADT(e^{-Ax}) \text{ for each road within 2 km} \quad [1]$$

$$traffic\ impact\ factor\ (TIF) = \sum roadside\ increment \quad [2]$$

Where *AADT* = annual average daily traffic, and *x* is the shortest distance from the road to the receptor.

The parameterisation of the traffic impact factor (the value of *A*), which enables the weighting of traffic using a normalised near-road concentrations gradient, is established using observational roadside transect data collected during several research campaigns in Auckland and Wellington. Although research shows that *A* varies between locations, this version of the model applies nationally-averaged value which is applied everywhere, leading to some small errors in some locations.

The model assumes that emissions are proportional to *AADT* in the long-term. This assumption may introduce a small error for some roads.

Part two of the model is:

$$NO_2[\mu g\ m^{-3}] = B(TIF)^C \quad [3]$$

The parameters *B* and *C* are established using local observational data where available. Elsewhere nationally-averaged values are used.

The model has been locally calibrated for:

- Wellington
- Porirua
- Lower Hutt
- Upper Hutt
- Auckland
- Hamilton
- Hastings
- Napier

- Dunedin
- Gisborne
- Kāpiti Coast

Data Requirements

- Traffic data as AADT for each road link making up the road network. This is currently supplied as output from CoreLogic's traffic model (https://www.nzta.govt.nz/about-us/open-data/national-road-centreline-data-request). Currently, 2016 is used as the base year.
- Concentration data from NZTA's NO_2 monitoring network. Each site's data is averaged over the years 2010 – 2016 inclusive.
- Concentration data from other NO_2 monitoring campaigns. Data from campaigns lasting less than 12 months are seasonally-adjusted to estimated annual means.

Building the Model

The TIF is calculated for each NZTA monitoring site. The traffic layer is clipped manually to ensure total coverage of traffic data for each site. The accumulated TIF is then calculated for each site, based upon the roadlinks within a 2 km buffer area around each site.

An "urban area" is defined by combining geographical areas defined in Urban-Areas 2019 from StatsNZ and the LCDB4 "urban area" definition. A buffer of 200 m meter is created to encompass the total urban area based on this intersection. Each urban region is named manually. A 1 km polygon grid is created overlaying New Zealand and a subset is clipped based on the Urban Area definition. The traffic is then subsetted for each urban area.

The model is then run for each 10m tile in the urban area to calculate accumulated TIF, based upon a TIF value for every road within a 2 km buffer around each tile.

Limitations of the model

- Model uncertainty is lower where data from more sites is available, and vice versa.
- In densely built-up downtown areas, the model assumption of average dispersion is violated. Observed concentrations can be up to 10 $\mu g\ m^{-3}$ higher than the modelled estimates (in the absence of other effects) which equates to the unmodelled 'street canyon' effect.
- At busy signalised intersections, the model assumption of average emissions is violated, due to excess acceleration. Observed concentrations can be up to 10 $\mu g\ m^{-3}$ higher than the modelled estimates (in the absence of other effects) which equates to the unmodelled 'intersection' effect.
- As the model predicts impacts due to road traffic only, it will under-predict concentrations in locations significantly impacted by other sources. This effect has been noted close to airports and seaports and may impact some industrial areas.
- Any other discrepancy between model prediction and observation may indicate other violations of the 'average dispersion, average emissions' assumption. This may arise due to

- Steep road gradients (extra emissions)
- Differences in grade (receptors are above or below the road(s))
- Higher than average concentration of heavy-duty diesel vehicles

Due to local deviations from average values of parameters *A*, *B* and *C*, the model is slightly conservative (over-predicts) in urban areas with

- relative open settings,
- relatively smooth traffic.

Similarly, the model slightly under-predicts:

- In densely built-up settings
- Where there is stop-start traffic

Application to estimating urban background

The model has been used to estimate long-term urban background NO_2 concentrations across the country. Estimates aggregated to census area unit level were provided to NZTA early in 2020.

This was achieved using ArcGIS. The NO_2 concentrations from TIM are stored as rasters. We created a roadside buffer around every road in New Zealand within which the roadside increment (estimated using equation 1) was < 1 μg m^{-3}. The buffer was used to delete roadside NO_2 data from the concentration raster. Census Are Units were then overlaid as polygons and the remaining NO_2 data aggregated within each polygon. The mean raster value within each CAU was extracted and taken to represent the urban background concentration representative of the whole CAU.

Figure: (left) Original 10 m resolution NO_2 raster, (mid) roadside buffers added, (right) mean NO_2 for each CAU after buffers removed.

This method yields results for 1239 census area units. 97 % of values are evenly distributed between 0 and 15 μg m^{-3}. The top 3 % lie between 15 and 29 μg m^{-3} and represent inner urban centres.

The values are a little lower than concentrations observed at most sites in the NZTA Monitoring Network classed as ‘Urban Background’. This is because the Network contains a weak bias towards sites that are more centralised and more not necessarily outside the roadside corridor as defined in this work, i.e. represent the upper percentiles of concentrations across whole urban areas. This is demonstrated in detail in our report “Review of the National Monitoring Network” (NIWA report 2020004AK).