Theme: Communicating Science and Effective Monitoring and Measuring

Abstract: Another way to look at vehicle emissions

In 2014 the NZ Transport Agency (the Agency) commissioned a vehicle emission mapping tool that automates calculation of both harmful air pollutants and greenhouse gas emissions. The tool has been developed in stages and can now be applied to all public roads throughout New Zealand.

The tool is housed in a geographical information system (GIS) framework so that data can readily present as maps that are useful for engaging with both technical and non-technical audiences.

The tool extracts data from the Agency's information technology systems, which builds detailed data set of input variables for the emission calculations.

A matrix of vehicle emission factors, extracted from the New Zealand Vehicle Emission Prediction Model (VEPM 5.3), is used with the input variables to calculate the mass of pollutant per length of roadway.

To date the tool has been used to create a national vehicle emission dataset for 2016 and it has been designed to allow future datasets to be calculated quickly and easily as new input data becomes available.

Maps can be produced that allow users to explore how vehicle emissions vary at a range of spatial scales from national to local. The tool has flexibility to be used for analyses including:

- Developing inventories of harmful air pollutant and greenhouse gas emissions
- What if emission scenario testing (e.g. changes in fleet and speed)
- Assessing the impact of changing emission factors
- Reporting trends in emissions over time
- Understanding the network impact of transport projects
- Supporting investigations into the health effects of exposure to vehicle emissions

Validation of the tool has involved comparing output data with local authority air pollutant emissions inventories. The results demonstrate that the tool can be used as a reliable and consistent means of generating vehicle emission datasets at various geographical scales throughout New Zealand.

Introduction

Good data presentation can bring to life scientific concepts to communicate with audiences of varied backgrounds and specialisations. The Agency needs to engage on transport-related air pollution with specialists including planners, transport planners, road designers, traffic engineers, urban designers, and environmental managers; as well as project sponsors, policy developers and the general public; with the aim of communicating the problem and developing solutions.

Transport related air pollution can have both environmental and public health effects. Harmful effects on human health range from breathing problems to premature death of susceptible people, particularly those who already suffer from lung and heart disease. It was found that 22% of all social costs associated with anthropogenic air pollution are attributed to motor vehicles and more than 256 people in New Zealand are estimated to die prematurely every year due to emissions from motor vehicles (Kuschel et al. 2012).

The Agency commissioned Jacobs New Zealand to develop a tool that calculates national vehicle emissions and present the data as maps that are easily extracted to support communications. The maps created allow for presentation of emission data relative to population and therefore provides a surrogate for exposure to assist with communicating risk.

In addition, the emission calculation tool provides a consistent and repeatable approach, which has been validated, that means data sets across regions and between years are comparable, making the tool effective for measuring trends over time. The tool has potential to be used diagnostically to evaluate why changes have occurred, which may be more difficult if relying on ambient air monitoring station data alone.

Methodology

The tool was developed in a series of phases. First the concept was tested as a pilot on a limited study area (Jacobs 2014) and then extended to cover the national state highway network (Jacobs 2015). Data availability at the local authority level was then tested as a second pilot study (Jacobs 2016); and then extended to cover the entire NZ public road network (Jacobs 2017).

Data sets for all of the required emission calculation inputs were identified, which are: traffic count, fleet profile, average speed and gradient. These inputs are aligned spatially as they relate to each road section. Road sections are set at 50 metre lengths unless modified by the user. A digital elevation model was used, aligned with road centreline data, to automatically calculate the road gradient. All roads were assumed two-way as a simplification because road directionality was unavailable. Figure 1 is a visual representation of the model configuration.

Once all input information was collated, the appropriate vehicle emission factors from VEPM were applied to calculate the pollutant mass emission rates. VEPM look-up tables were developed for each regional authority area to account for variability in average temperature across NZ, which is known to affect cold start emissions[1]. Separate VEPM look up-tables were developed for light and heavy vehicles. A fleet profile ratio is then applied to calculate the relative pollutant contributions from light and heavy vehicles. The tool uses the default ratio of light and heavy vehicles from VEPM, but future development could allow for user defined inputs, for example, to test this variable for policy development.
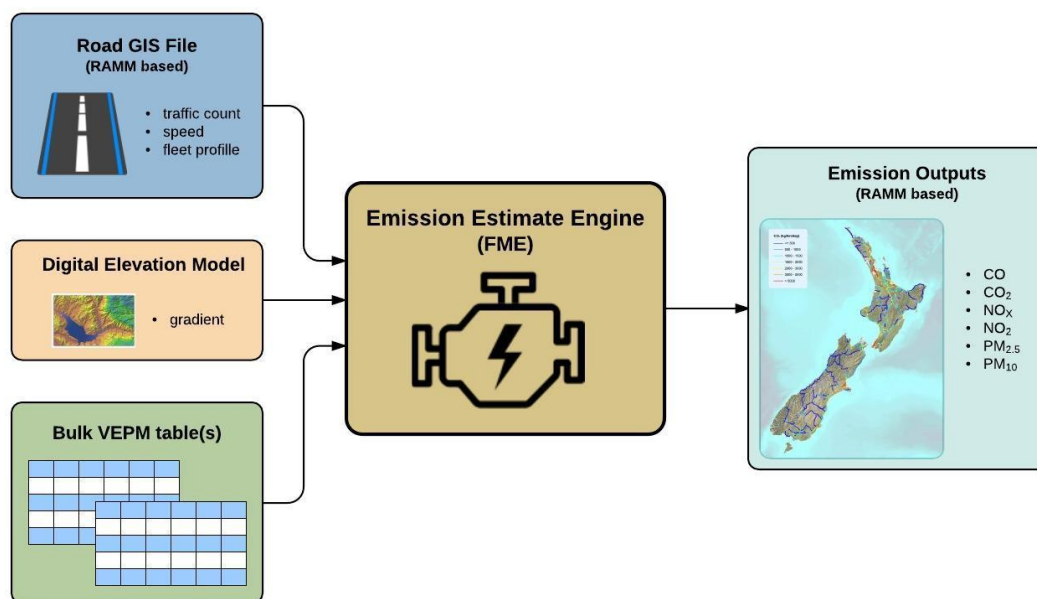

Figure 1. Visual representation of the vehicle emission calculation tool.

The results are organised into various outputs for analysis and visual representation as maps and allows calculation of emissions for each local authority in a consistent and repeatable way.

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[1] Cold start emissions are tailpipe emissions that a vehicle produces before the engine has warmed up; as this is an inefficient process, vehicles emit significantly higher quantities of contaminants to air (Ministry for the Environment (MfE), 2008). Cold start emissions are particularly important in the vicinity of large, long-term car parks.

Model Outputs

Table 1 shows the aggregated emissions output calculated for all NZ roads in 2016. PM_{10}[2]is calculated by adding particulate from both the exhaust emissions ($PM_{2.5}$[3]) and from tyre and brake wear (PM_{BT}).

Table 1. Total NZ On-Road Vehicle Emissions for 2016

Pollutant	Kilo tonnes per year
CO	164.35
NO_X	36.38
NO_2	5.13
PM_{10}	2.21
$PM_{2.5}$	1.79
CO_2	10,440.05

The tool displays results graphically as maps of mass emissions as a variable over the road network as kg/km/day, as illustrated for CO_2 covering the Auckland/Hamilton/Tauranga regions in Figure 2.
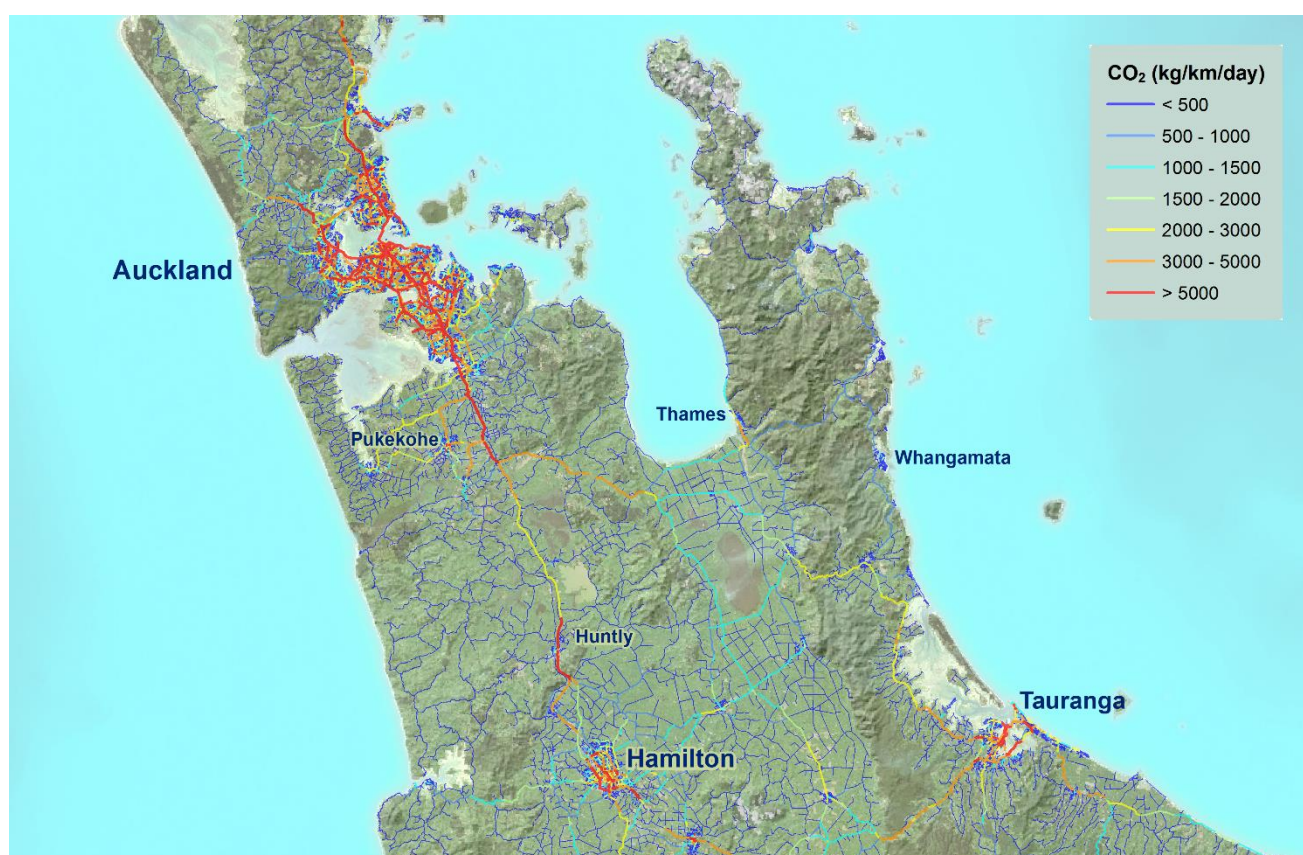

Figure 2. Example map output of CO_2 emissions

Users have the option of running the tool for the entire country, or on a local authority area. Raw emission data or data aggregated using the One Network Road Classification[4] are output options. It is also possible to display and analyse the emission differences between light and heavy vehicles, as illustrated in Figures 3 and 4.

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[2] Particulate matter that is smaller than ten micrometres in diameter (PM_{10}); sources of particulate matter in terms of road transport include exhaust emissions, the re-suspension of road surface dust, tyre wear, and brake and road surface wear.

[3] Particulate matter that is smaller than 2.5 micrometres in diameter ($PM_{2.5}$); this is a component of $PM_{10.}$

[4] The One Network Road Classification is a system which divides New Zealand's road into categories, based on how busy they are, whether they connect to important destinations, or are the only route available (NZ Transport Agency, 2017).
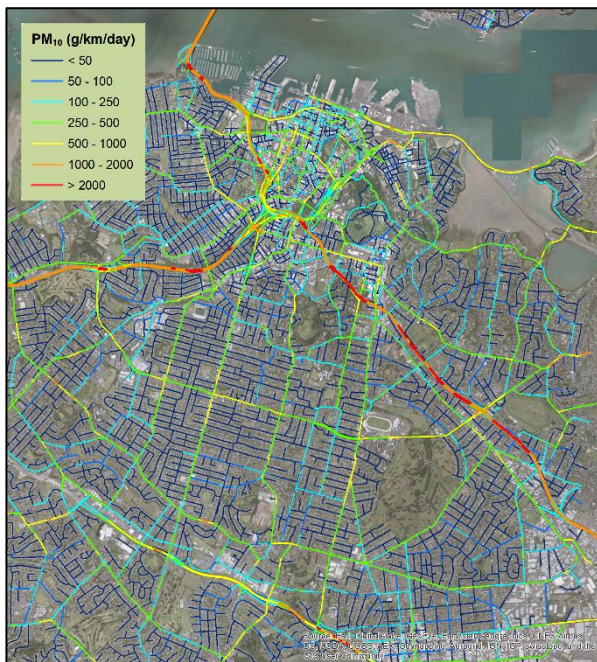
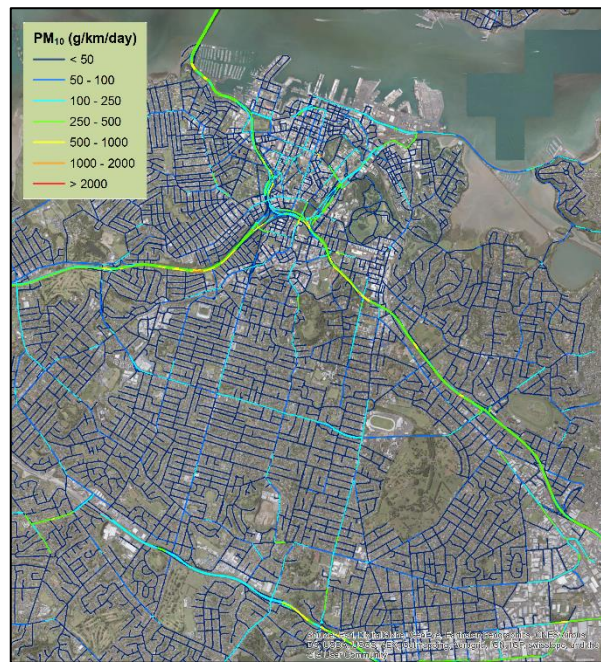| Figure 3 Light Vehicle PM$_{10}$ emissions in Auckland | Figure 4 Heavy Vehicle PM$_{10}$ emissions in Auckland |

VEPM spreadsheets are currently incorporated for 2016; to assess future years additional VEPM spreadsheets will be needed.

Applications

In addition to developing emission inventories and reporting trends and impacts, the Agency and local authorities can use visual outputs to engage with the public and communicate with decision makers on policy. Examples could be maps to show where emissions are highest, so that a low emission zone (LEZ) or similar could be developed. The effects of various restrictions within a LEZ could be investigated. Likewise, low emission routes for walking and cycling could be promoted through mapping.

Validation

Air emission inventories from four Territorial Authorities were selected to validate the tool. The area covered by each emission inventory and the tool were aligned using Census Area Units. Validation was undertaken for predictions of vehicle emissions in 2015, whereas the emission inventories ranged from 2005 to 2014. Better alignment between manual methods and this tool were achieved when the study years were closer, due to emission factors generally decreasing over time. Appendix A provides tabulated data showing good agreement of the tool with the Blenheim and Nelson inventories, the two most recent inventories reviewed.

Conclusions

As a result of this work, all on-road vehicle emissions in NZ can readily be calculated and presented. Output files can be analysed at a national, regional and local level to assist the Agency and local authorities understand how the road network contributes to air pollution and provides information to measure trends and develop policy. The work enables communication and engagement strategies to be developed with the public and decision makers. The tool provides a consistent approach to data input sources providing a repeatable process for emissions reporting and prediction.

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Bibliographies

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Rob is a Technical Manager at the New Zealand Transport Agency. He is a Certified Environmental Practitioner with over 25 years of experience working in the UK and NZ in the field of environmental management, in particular noise and air quality. Rob enjoys working collaboratively across the transport and environmental sectors to enable the delivery of public good outcomes.

He is the current secretary of the World Road Association (PIARC) environment committee and deputy-chair of the Transport Special Interest Group of the Clean Air Society of Australia and NZ.

Rob has worked at the Transport Agency and its predecessors since 2006. He manages a team of technical specialists covering a broad range of disciplines including; noise and air quality, urban design and landscaping, cultural heritage, community and stakeholder engagement, resource efficiency, ecology, storm water as well as road safety engineers and multi-modal transport professionals.

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Greg Haldane is a Principal Environmental Specialist with the New Zealand Transport Agency. His focus area at the Transport Agency is the impacts of transport on human health, including air quality, noise, vibration, air quality and hazardous substances. Greg is a civil and environmental engineer with over 25 years of experience in environmental assessment and management. His current involvement with transport-related air quality effects includes vehicle emissions research, monitoring, preparation of guidelines, and technical review of air quality assessments and management plans.

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Deborah is the Technical Leader for the Jacobs New Zealand Air Quality Practice. Deborah is a CASANZ Certified Air Quality Practitioner with 25 years' experience in the air quality field, principally through undertaking assessments of environmental effects across a range of infrastructure and industrial projects, but is also experienced in air emission inventories and policy development. Deborah is an experienced RMA practitioner and has current certification as a Hearing Commissioner under the Making Good Decisions programme.

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Keith is a senior GIS developer for Jacobs, and his spatial analysis, data integration and application development skills have been used widely as a basis for scientific modelling studies. He has also developed numerous web-sites for effectively managing data in large infrastructure and environmental monitoring projects.

Appendix A

Table A1 Blenheim Air Emission Inventory 2012 comparison with Transport Agency prototype tool for 2015

	Area (Ha)	PM_{10} (kg/day)	CO (kg/day)	CO_2 (t/day)	NO_X (kg/day)
Blenheim Air Emission Inventory 2012 (Marlborough District Council, 2012)	1,930	12	1,123	52	152
NZTA prototype 2015	1,930	9	858	53	147

Table A2 Nelson Air Emission Inventory 2014 comparison Transport Agency prototype tool for 2015

	Area (Ha)	PM_{10} (kg/day)	CO (kg/day)	CO_2 (t/day)	NO_X (kg/day)
Nelson Air Emission Inventory 2014 (Nelson City Council, 2014)	9,316	29	3,381	160	469
NZ prototype 2015	9,412	30	2,760	188	478