

Air Emission GIS Interface for State Highways

THE TRANSPORT AGENCY

Summary Report

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Document history and status

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Executive summary

The purpose of the project is to assess the viability of creating a GIS tool for displaying national emission levels. The tool is to be hosted on the Geospatial Platform at the Transport Agency. This report provides a summary of the approach used to calculate and display existing emission levels on state highways in the Hawkes Bay, which has been used as a pilot project for the Transport Agency.

Methods of analysis include preparing a detailed state highway dataset and then applying vehicle emission factors in the Feature Manipulation Engine (FME) software. Results are then graphically displayed in GIS to show CO₂ and NO_x air emissions.

The pilot project was successful in showing that calculating and visually representing emissions over the state highway network is a viable proposition, notwithstanding the suggestions made for future refinement of the approach including:

- Input data improvements
- Model enhancements
- Integration steps

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to summarise the approach used to assess the viability of developing a GIS emission tool for the Hawkes Bay pilot area and advise on limitations and recommendations, in accordance with the scope of services set out in the contract between Jacobs and the Transport Agency. That scope of services, as described in this report, was developed with the Transport Agency.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Transport Agency and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Transport Agency and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Introduction

Jacobs has been engaged by the Transport Agency to assess the viability of developing a GIS tool to calculate and display existing emission levels on state highways. A summary of the scope of work based on Jacobs proposal is provided in Appendix A.

This has been achieved by concentrating on a pilot area, the Hawkes Bay, and stepping through the entire process with the aim of discovering what data exists, where there are gaps, how datasets can be brought together into an integrated model, and how they can be meaningfully represented visually.

An interim report entitled 'Air Emission Data Availability' has already looked at the state of the required datasets within The Transport Agency, and some of those findings are further discussed in Section 2 of this report. These data requirements are governed by what is necessary to calculate emissions by using the Vehicle Emission Prediction Model (VEPM).

It is understood that in the future this tool could be integrated into The Transport Agency's own systems, and would provide enough flexibility to be useful for assessing emissions of differing scenarios, such as proposed roads, different years, different speeds, different emission factors etc. However, this has not been addressed as part of this project.

2. Assumptions

From the interim Data Availability report we have noted the following with regard to the required datasets necessary to assess emissions:

Table 1 Interim data availability findings

Parameter	The Transport Agency Data Availability	Comments
Traffic volume	SH_CentreLine has ADT count and estimated ADT. This data comes from RAMM.	This is available nationwide. As an average daily value, this data is not broken into time periods. This appears to be a combination of actual traffic count information and estimated information. The data also contains lane directional information that will be necessary to assign the ADT to appropriate direction.
Fleet profile	SH_CentreLine has Heavy Vehicle %. This data comes from RAMM.	This is available nationwide. The data is not broken into time periods and has just a simple heavy / light vehicle breakdown whereas the Vehicle Emissions Prediction Model (VEPM) we will be using to calculate the emissions are based on a more detailed range of vehicle types. There will need to be assumptions made to categorise the VEPM into just these two types, and some minor extra processing required.
Average speed	ERUC_v3 has Average Speed of freight vehicles over several different time periods. This data is predominantly from 2009 and 2010. This appears to be aligned to the RAMM datasets.	This very nearly covers all highways (99%+). Missing data appears to be mainly due to age, i.e. roads built since 2009/2010 will not appear, and also some bypasses. There are average speeds for five different time periods. As this data is based on freight vehicles, the time period that provides the largest and most consistent sample size is the 10pm-5am period.
Gradient	HSD_Geometry contains a gradient (%) that is measured separately for both directions of a road.	This data has very high granularity as it is divided into 10 metre road sections. Accuracy is also very good, with it predominantly being reported as sub-metre.
Length of road section	Inherently exists by default in any GIS data.	No action necessary

From these findings it has been necessary to make some assumptions in order to complete the calculations for the pilot area.

2.1 Fleet profile

In VEPM the profile of the vehicle fleet is broken down into 14 categories, however, The Transport Agency's data is only available in two categories, heavy vehicle (HV) and light vehicle (LV).

The default fleet profile from VEPM for 2014 has been used to calculate emissions across light and heavy vehicles as shown in Table 2.

Table 2 VEPM 2014 fleet profile assignment

Light Vehicle	Car petrol	69.30%
	Car diesel	7.70%
	Car hybrid	0.60%
	Light commercial petrol	3.10%
	Light commercial diesel	12.60%
	Light commercial hybrid	0.10%
Heavy Vehicle	Bus	0.60%
	Heavy commercial 3.5-7.5 tonne	1.40%
	Heavy commercial 7.5-12 tonne	0.70%
	Heavy commercial 12-15 tonne	0.20%
	Heavy commercial 15-20 tonne	0.30%
	Heavy commercial 20-25 tonne	1.10%
	Heavy commercial 25-30 tonne	1.00%
	Heavy commercial >30 tonne	1.20%

2.2 Average Speed

Currently there is no data available that provides fleet-wide average speed data for the pilot area. The only data available in any consistent volume for the pilot area is from the Electronic Road User Charge (ERUC) data of 2009/2010, and more specifically the 10pm-5am time period. All speed data used in the calculations has been obtained from this source. This is less than ideal, as freight vehicles travelling in the early hours of the morning is not necessarily reflective of the entire fleet over the whole day.

Unfortunately there is no alternative average speed data available. To partly mitigate this, or at least to highlight what influence speed may have, calculations using the average speed + 10km/h have also been made.

It should also be noted that emissions for this pilot are calculated at a daily level, whereas average speed is not normally considered at this daily level. This is further discussed in Section 5.

2.3 Other VEPM Assumptions

Other assumptions used in the VEPM calculations are shown in Table 3.

Table 3 Input parameters used in VEPM calculations

Year	Minimum Speed	Maximum Speed	Step size	Average trip length
2014	10 km/h	100 km/h	1 km/h	16 km

3. Methodology

The main premise behind the methodology for calculating emissions on the state highways is to build as detailed a picture as possible for the roads, and then from the information gathered for each road section apply the suitable emission factors as supplied from the VEPM table.

To build a detailed picture of the roads, it is first necessary to merge the different datasets together, so that the information is all in the same place. There are three input datasets used for the pilot:

- SH_Centreline (from RAMM)
- ERUC_v3
- HSD_Geometry (from GPS)

Ideally all necessary information to perform the emission calculations would be available in the same place, i.e. there would be one dataset that contained the traffic volume, fleet profile, speed and gradient data. With the exception of the gradient data, which by its nature will remain an independent dataset, this is an improvement which the Transport Agency would benefit from.

All of the following steps have been performed inside the Feature Manipulation Engine (FME) software produced by Safe Software. Models can be created in FME that allow the user to fully automate the processes involved with calculating the emissions. As well as the model being very flexible and fully repeatable, it is a graphical tool and clearly illustrates the workflow that is taking place. See Figures 1 and 2 for example screenshots of the FME model used for this pilot project.

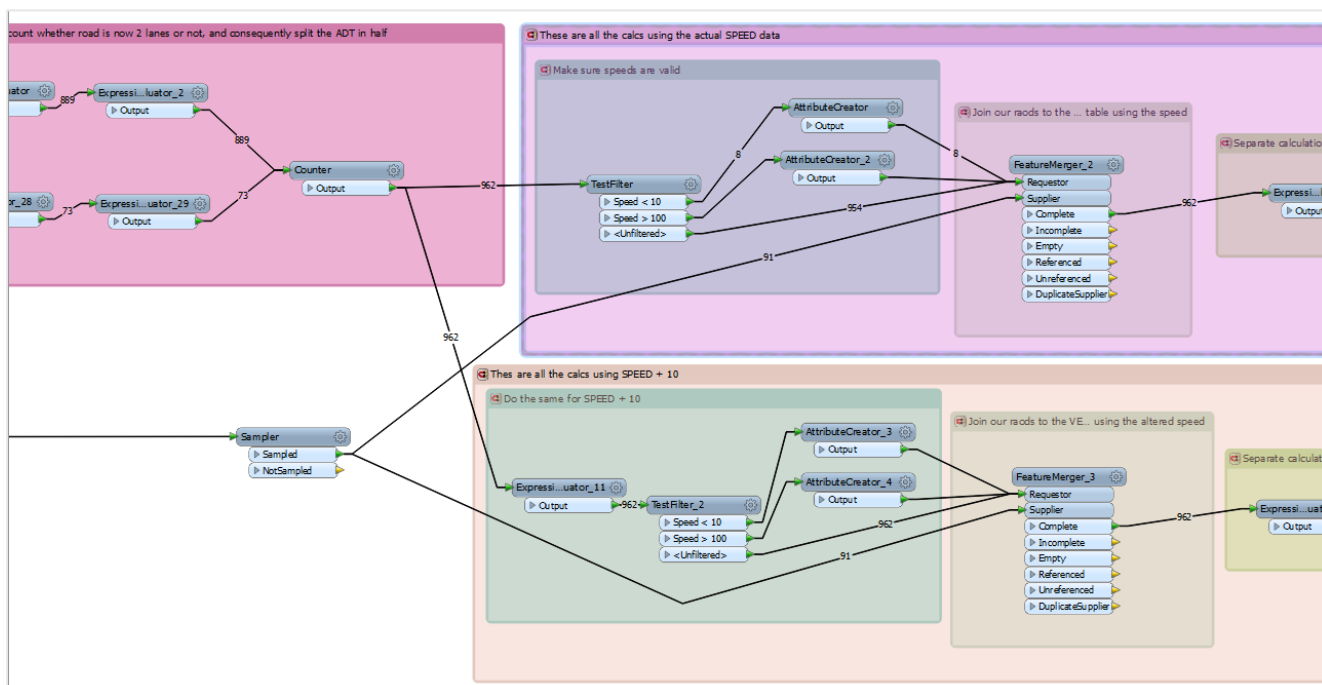


Figure 1 Example FME model screenshot

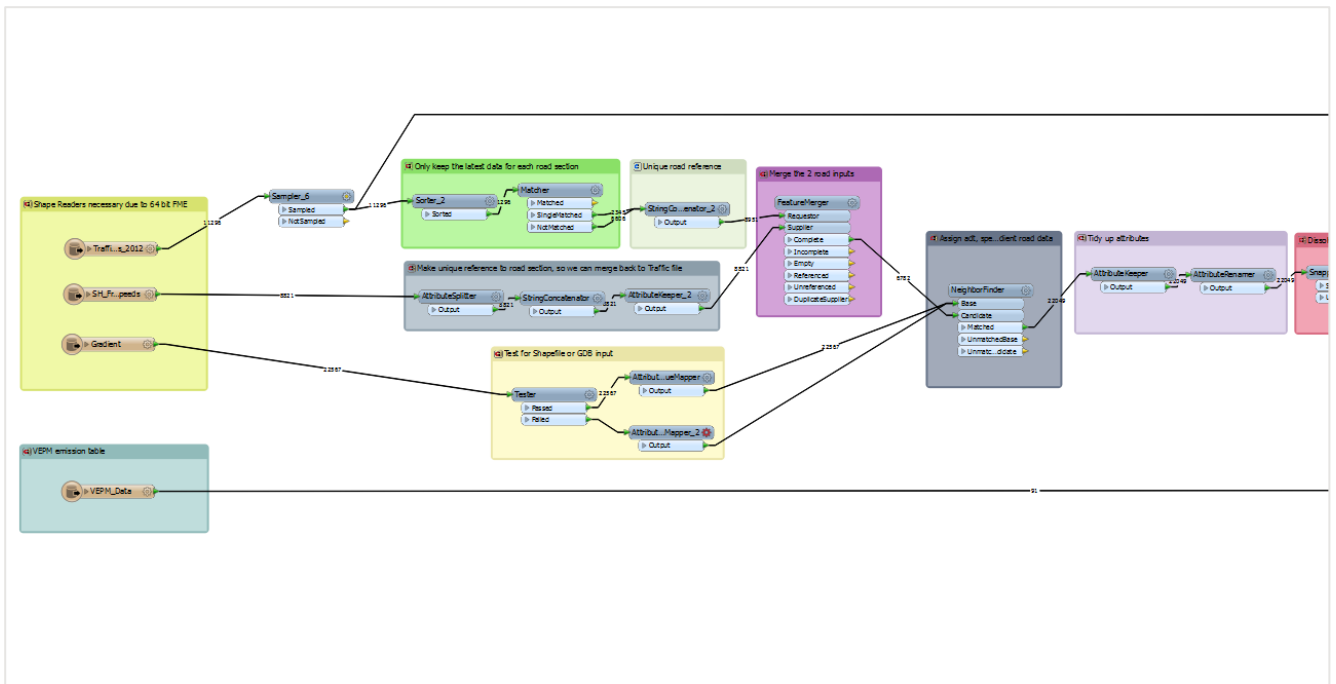


Figure 2 Example FME model screenshot

3.1 Process Steps

3.1.1 Merging datasets

The SH_Centrelines and ERUC_v3 datasets match very well spatially, and are presumably derived from the same RAMM source, however they do not share a unique attribute identifier. This makes it a little more difficult to merge them, but was achieved by using a combination of the road_name, start_name and end_name fields as the identifier. The resulting dataset now has traffic volume, fleet profile and average speed.

The HSD_Geometry dataset is sourced from GPS and is specifically created to capture gradients in both directions of the road. It therefore uses two lines to identify a section of road where the RAMM based data mostly only uses one line. The GPS based data also appears to be more recent, with a couple of instances of new road alignments that the RAMM data does not show. The GPS data is split into 10 metre sections to capture the dynamic nature of gradient as accurately as possible. Because this dataset has the finest level of spatial granularity, it was decided to perform the calculations at this level.

The GPS based data then acquires the traffic volume, fleet profile and average speed data from the nearest RAMM based centrelines. Where the RAMM based centrelines represents both directions of travel, the traffic volume is halved when it is applied to the GPS data.

3.1.2 Calculations

Each piece of road section has an average speed, and this can be used to look up its appropriate emission value from the VEPM emission table. This look up uses a combination of the speed, the fleet profile (LV or HV), and the gradient category (-6°, -4°, -2°, 0°, 2°, 4°, 6°) to determine the correct CO₂ and NO_x emission factors to apply to each road section.

The emissions are calculated independently for LV and HV. The Fleet Profile ratio is applied to the traffic volume to obtain LV and HV traffic volumes. These volumes are then multiplied by the appropriate emission factor to get LV emissions and HV emissions (g/km/day) for each road section. These are then added together to obtain the combined emission rate (g/km/day) for each road section.

A further calculation is performed, using the length of the road section, to give a total emission (g/day) for each road section.

As mentioned previously, with the uncertainty over the suitability of the average speed data currently available, separate calculations were run in parallel with the above to produce emission rates for average speed + 10 km/h.

3.1.3 Aggregating the results

The steps performed up to this point have calculated emissions for the road sections as defined by the GPS based dataset. This is very good for performing the calculations, but not always ideal when wanting to visualise them.

Because the emissions are calculated independently for the direction of the road, the emission values are split between both sides of the road. Unless the viewer is zoomed in very close, it is unlikely that they will be able to distinguish the two separate directional lines of the road. On casual viewing this may result in the viewer making an assumption that a road's emission is only half of its total.

To remedy this situation, a further step is taken to aggregate the 'directional' results back into the original RAMM based road centrelines, where the roads are mostly represented by a single line. This is achieved by a series of steps that include intersecting the GPS data with buffered RAMM data, then summarising the GPS data within each RAMM buffer, and performing the final calculations.

4. Results

4.1 Output Presentation

Full results for the air emission calculation outputs are provided in Appendix B for CO₂ and Appendix C for NO_x.

Two outputs are produced from the above methodology, a directional emission dataset shown in Figure 3 that shows the emissions in both directions separately, and a total emission dataset shown in Figure 4 that shows the combined emissions from traffic in both directions.

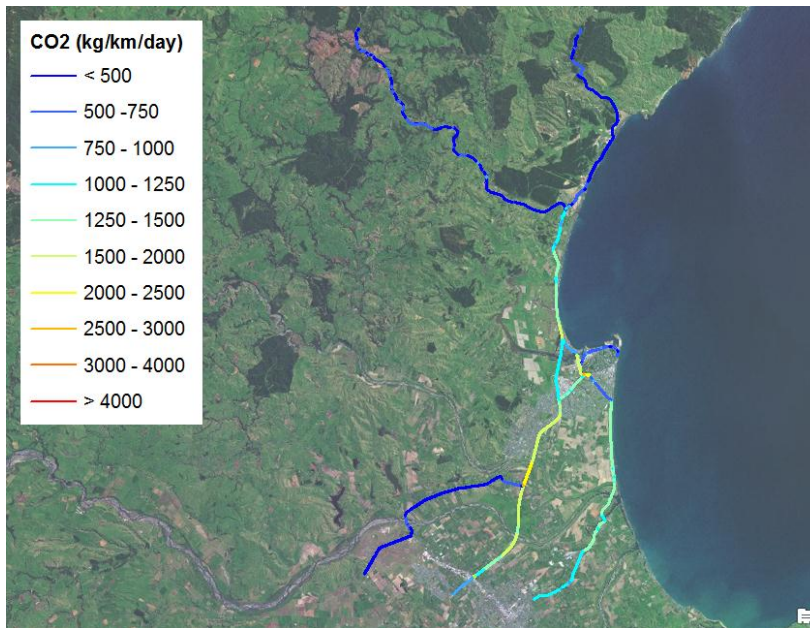


Figure 3 Directional emission data output - study area

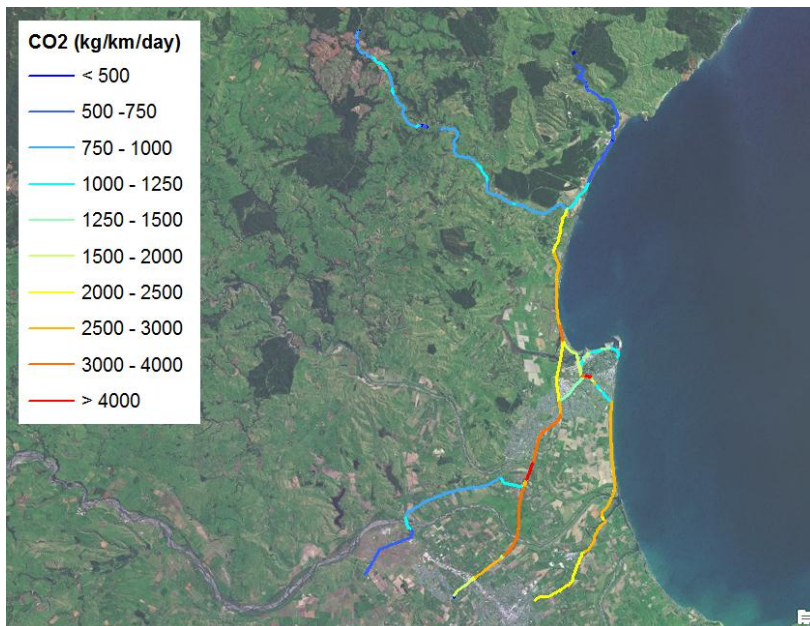


Figure 4 Total emission data output – study area

Note that when viewing the directional emission output in Figure 3, the separate lines showing directionality of the roads are not visible. At this scale they appear as one line, and at approximately half the emission level when compared to the total emission output. Great care should therefore be used when viewing the directional emission data. As shown in Figure 5, when the viewer is zoomed in much closer, and especially in urban areas, there may be some value in visualising the directional emission data. It should also be noted that where the RAMM dataset portrays dual carriageways as separate lines, as in Figures 5 and 6, then they will remain as separate lines in both directional and total emission outputs.

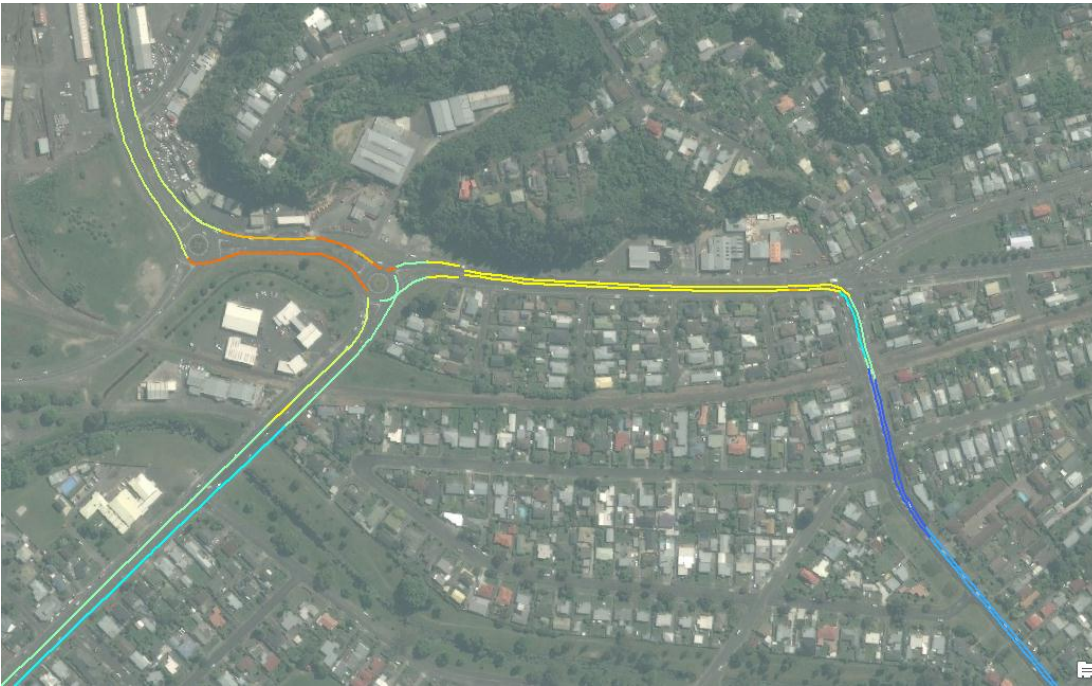


Figure 5 Directional emission data output – urban view

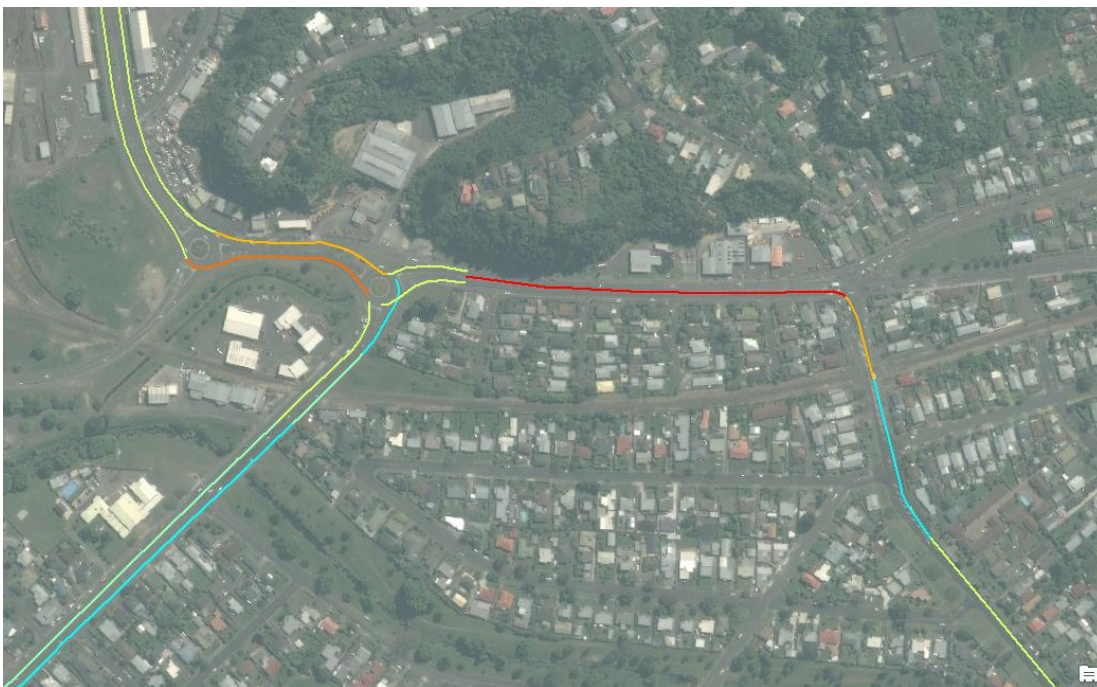


Figure 6 Total emission data output – urban view

4.2 Important Notes

4.2.1 Missing Output Data

Figure 7 shows three areas in the study area where emission data was not able to be calculated.

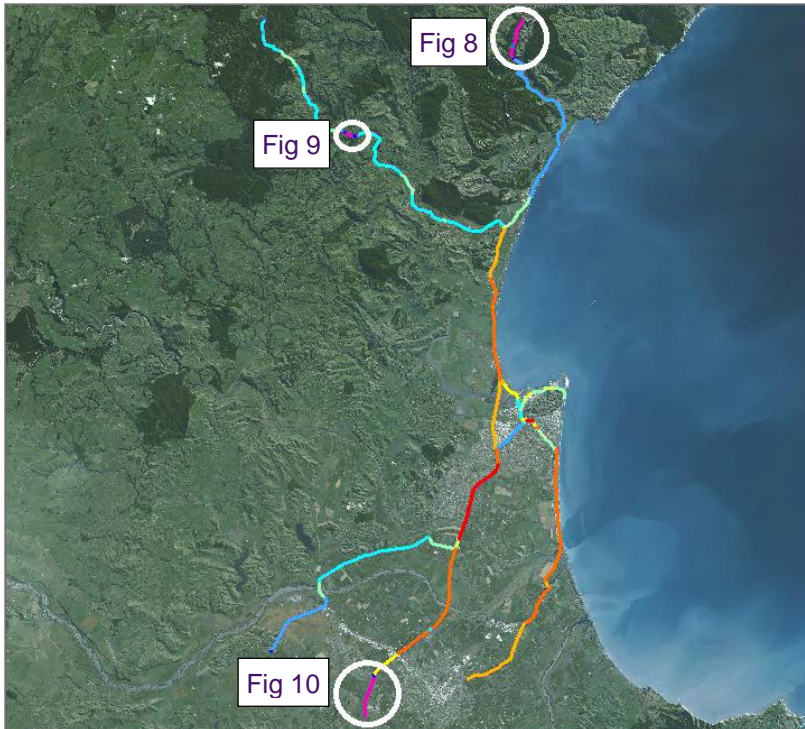


Figure 7 Missing data overview

In all three cases this was because there was a spatial mismatch between the input datasets. In Figure 8 the mismatch appears to be related to data quality, where the definition of the GPS data may be more accurate than that of the RAMM data, or visa-versa.



Figure 8 Missing data

Figure 9 illustrates the scenario where the GPS data has a more recent definition of the road.

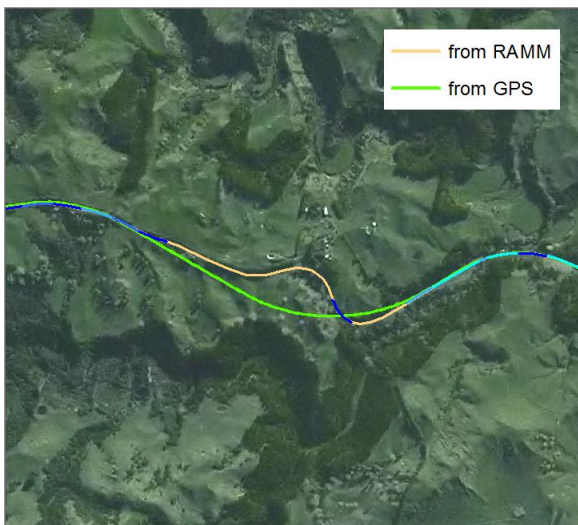


Figure 9 Missing data

Figure 10 illustrates a by-product of the different purposes of the input datasets. In this case the freight based speed data is recorded through a by-pass, whereas the GPS based gradient data has no recordings for this by-pass.

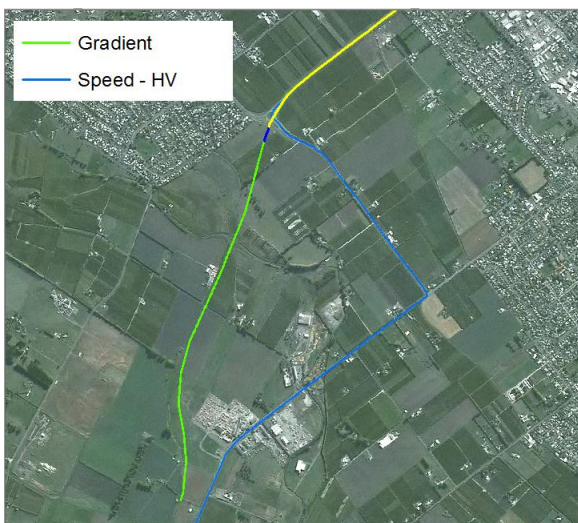


Figure 10 Missing data

Overall these represent small gaps in the emission data, and help clarify where input data improvements can be made to increase the range and quality of the resulting emission data.

4.2.2 Average Speed Sensitivity

Due to the average speed data coming from a less than representative data source, it was decided to calculate emissions at 10 km/h greater than the average speed to investigate the effect of speed on the resulting emission values.

Figure 11 illustrates the difference that results from using the average speed plus 10 km/h to calculate emissions, when compared with using the average speed.



Figure 11 Emission difference when using the average speed + 10 km/h for CO₂

For CO₂ areas of slower speeds, particularly evident in Napier, result in an emission reduction from the increased speed, whereas areas of higher speeds result in an emission increase with the increased speed.

5. Future Considerations

5.1 Data Improvements

5.1.1 Improved speed data

A current limitation of the emission calculation process is the suitability of the speed data that is available. The calculations would clearly benefit by obtaining a more representative dataset. It is understood that The Transport Agency is currently involved in investigations looking at collection of real time data from various sources, and this is likely to greatly influence the amount and quality of speed data. We understand there is still considerable uncertainty over this work, and it is unlikely that there will be better speed data available in the near future.

5.1.2 Use of modelled data

The use of modelled traffic data, as opposed to actual measured data, is completely viable under the structure of the FME model used for this project. The process itself doesn't differentiate whether the data is modelled or measured. It is also clear that the creation of any emission calculations for different scenarios would require the use of modelled data. Of key importance here is being able to define a data structure to store the modelled data so that it can be used as seamlessly as possible in the emission calculations.

5.1.3 Suitability of daily calculations

In traffic modelling there is no concept of a daily average speed. Data is broken into more detailed time periods that better reflect the fluctuations throughout the day. In theory a better method of calculating daily emissions would be to calculate each time period separately, then add them together. This also allows individual comparisons to be made between different time periods, or to just calculate emissions for a specific time period such as AM peak. This of course assumes that this level of data is available. With any modelled data this expectation is valid; however for nationwide coverage this is very unlikely. The level of accuracy or generality that is acceptable as an output of this process is a future consideration.

5.1.4 Input (and output) data stored in one place

For known national datasets it would be advisable to aggregate the different emission calculation components into a single dataset. This may take the form of simply adding fields to an existing RAMM dataset, but the key is to be able to collect as much information about the road as simply as possible. It is acknowledged, however, that the GPS data will likely never be integrated with the RAMM data, as it is specifically broken into 10m lengths with separate lines for different directions. Decisions also have to be made on data storage including: how differing versions of VEPM emission factors are stored, where outputs are stored and named, and how different scenarios are handled and stored.

5.2 Model Improvements

Currently the FME model has been created with hard-coded input datasets for the purposes of the pilot study. It also follows a mostly linear process based on the known inputs. For this model to be useful in a more general sense to the Transport Agency the model would need to be more flexible and robust. It would have to allow for different input datasets to be used, such as those carrying information for a new roading project, or a revised VEPM calculation table and it should also allow for calculations being performed in more detailed time periods, rather than just as a daily average.

5.3 Integration

Once an overall strategy has been decided as to what level of improvements to process and data should be made, the updated FME model and database structure would be ready to be integrated into the Transport Agency's systems.

Appendix A. Proposal Scope

This is a summary of the “Scope of Work” outlined in the proposal ‘NZTA GIS Air Emissions proposal V3.docx’ dated 18 December 2013.

Stage 1 Data Gathering and Review

In Stage 1 Jacobs will establish what data is currently held by the NZ Transport Agency with a view to its suitability for being used to generate air quality emission data. We will demonstrate whether it will be possible to convert this data into useful and usable emissions information at a number of scales, this is in order to test the possible resolution of the tool. We will establish the time series of data that is held to demonstrate how changes in emissions over time may be able to be demonstrated e.g. annual, 5 yearly or campaign data. The steps are as follows:

- i) Establish data availability from the NZ Transport Agency required for VEPM inputs within the project area, which include:
 - a. Traffic volumes (including temporal resolution)
 - b. Fleet profile (including temporal resolution)
 - c. Speeds
 - d. Gradients
 - e. Lengths of road sections for representing emissions per unit length
- ii) Review the data format, transferability and completeness within the project area. It is likely that the availability of the required data will vary across the network. It is possible that data gaps could be “in filled” from adjacent data with a series of rules.

Stage 2 Data Review and Presentation

Jacobs will liaise with the NZ Transport Agency’s key personnel to develop a preferred concept for how the Agency would like the data presented. This will involve discussions with Agency staff to work through the concepts and how to address any data limitations and gaps.

Stage 3 Data collation and calculations for the project area

Jacobs will collate the data collected in Step 1 for the project area, and format the data appropriately to perform the calculations. The data will be collated as a spatial database file representing the road sections and will be linked by an ID to a database table that contains each section’s emission parameters ((i) a to e above).

Jacobs will then confer with NZTA key personnel to establish a resolution that is appropriate to the available data and identify areas for future refinement. Jacobs will undertake the calculations initially for NO_x and CO₂ in order to establish the concept, while minimising cost during the trial phase. The tool will be built in such a way that contaminants could be readily expanded should NZTA wish to further develop and expand the tool.

Depending on the amount of data there is we could either:

- a. use the approximation techniques developed as part of the Further North project (if there are thousands of data points); or
- b. link directly to a VEPM batch run (if the number of data points is manageable in a VEPM batch).

Stage 4 Reporting and presentation

Jacobs will process the data and produce GIS layers for the emission calculations. We will store the resulting emission data in a database table that is linked to the spatial road sections.

Jacobs will provide a short report summarising the approach for the project area, any limitations identified and recommendations (where appropriate).

Appendix B. Air Emissions CO₂



TITLE State Highway Air Emissions Calculated Daily CO ₂	SCALE @ A4 1: 200,000
	SKM PROJECT No AE04567



Appendix C. Air Emissions NO_x



TITLE State Highway Air Emissions Calculated Daily NO _x	SCALE @ A4 1: 200,000
	SKM PROJECT No AE04567



Appendix D. Output Attribute Metadata

The following two tables explain the meaning of the attributes contained in the output datasets as presented in Appendices B & C.

D.1 Directional Emission

All calculations in this study have been initially performed using the directional emission dataset. Directional means that a road is always represented separately for both directions. It is necessary to perform the calculations separately on both directions of the road to ensure account is taken for the different gradients when travelling in opposite directions.

The last six attributes of the table below represent inputs that have been used in the emission calculations, and do not represent an emission output in themselves.

Directional Emission		
Field Name	Field Type	Description
CO2_g_km_day	Double	CO ₂ emission rate in grams/kilometre/day
NOx_g_km_day	Double	NO _x emission rate in grams/kilometre/day
CO2_total_g_day	Double	Total CO ₂ emission for a road section in grams/day
NOx_total_g_day	Double	Total NO _x emission for a road section in grams/day
CO2_LV_g_km_day	Double	CO ₂ emission rate of Light Vehicles in grams/kilometre/day
CO2_HV_g_km_day	Double	CO ₂ emission rate of Heavy Vehicles in grams/kilometre/day
NOx_LV_g_km_day	Double	NO _x emission rate of Light Vehicles in grams/kilometre/day
NOx_HV_g_km_day	Double	NO _x emission rate of Heavy Vehicles in grams/kilometre/day
CO2_g_km_day_plus10	Double	CO ₂ emission rate in grams/kilometre/day when 10km/hr has been added to the speed variable
NOx_g_km_day_plus10	Double	No _x emission rate in grams/kilometre/day when 10km/hr has been added to the speed variable
CO2_total_g_day_plus10	Double	Total CO ₂ emission for a road section in grams/day after 10km/hr has been added to the speed variable
NOx_total_g_day_plus10	Double	Total NO _x emission for a road section in grams/day after 10km/hr has been added to the speed variable
Gradient_degrees	Text 20	Categorised gradient of road in range of degrees
Speed_km_h	Double	Average speed in km/hr
ADT	Double	Average Daily Traffic count
LV_ADT	Double	Light Vehicle Average Daily Traffic count (calculated from ADT & HV_Percent)
HV_ADT	Double	Heavy Vehicle Average Daily Traffic count(calculated from ADT & HV_Percent)
HV_Percent	Double	Percentage of Heavy Vehicles in Average Daily Traffic count

D.2 Total Emission

The total emission dataset is derived from the directional emission dataset. Both directions of a road are combined into one road section where represented as such in the RAMMS dataset, and the emission values added together. If the RAMMS dataset represents dual carriageways as separate road sections then this total emission dataset will do likewise.

Total Emission		
Field Name	Field Type	Description
CO2_g_km_day	Double	CO ₂ emission rate in grams/kilometre/day
NOx_g_km_day	Double	NO _x emission rate in grams/kilometre/day
CO2_total_g_day	Double	Total CO ₂ emission for a road section in grams/day
NOx_total_g_day	Double	Total NO _x emission for a road section in grams/day
CO2_g_km_day_plus10	Double	CO ₂ emission rate in grams/kilometre/day when 10km/hr has been added to the speed variable
NOx_g_km_day_plus10	Double	NO _x emission rate in grams/kilometre/day when 10km/hr has been added to the speed variable
CO2_total_g_day_plus10	Double	Total CO ₂ emission for a road section in grams/day after 10km/hr has been added to the speed variable
NOx_total_g_day_plus10	Double	Total NO _x emission for a road section in grams/day after 10km/hr has been added to the speed variable

Appendix E.