



Clean Air and
Urban Landscapes
Hub

National Environmental Science Programme

Report on completion of the first test case for a complete framework for road traffic emission modelling

Hugh Forehead & Nam Huynh
Clean Air and Urban Landscapes Hub

January, 2021

About the Clean Air and Urban Landscapes Hub

The Clean Air and Urban Landscapes (CAUL) Hub is funded by the Australian Government's National Environmental Science Program. The remit of the CAUL Hub is to undertake "Research to support environmental quality in our urban areas". This includes research on air quality, urban greening, liveability and biodiversity, with a focus on practical implementation of research findings, public engagement and participation by Indigenous Australians. The CAUL Hub is a consortium of four universities: The University of Melbourne, RMIT University, the University of Western Australia and the University of Wollongong.

www.nesurban.edu.au

Executive Summary

This report documents the first test case of a framework for road traffic emission and dispersion simulation. The output maps across the landscape primary pollution from motor vehicles. The framework (described in our prior report, [here](#)) was developed in response to a shortage of data for on-road transport in the National Air Pollutant Inventory. Calculating traffic emissions data is usually an expensive exercise, due to the costs of proprietary software and of the consultants engaged to use it. The traffic emissions framework will be free and available to the public. The main input to the framework is data from a traffic model, information commonly owned by local government. If required, secondary pollutants (such as ozone or secondary particulate matter (PM)) can be calculated using existing additional models.

The major components of the framework include a road traffic simulation model, a traffic emission model (MOVES, Motor Vehicle Emission Simulator), and AERMOD (American Meteorological Society (AMS)/EPA Regulatory Model) for air quality dispersion modelling. The framework includes tools for the missing links between these three major modelling components, to simplify use. Numerous dedicated software packages are available for road traffic modelling and we plan to adapt the framework for inputs from a number of these. At the time of this report, we consider Aimsun for road traffic modelling.

The data required to use AERMOD, as well as datasets required for MOVES and road traffic simulation, is an important component to the framework. For now, the framework relies on users to define parameters and provide input data into these software packages. It features tools to make the process as user-friendly as possible. However, by adapting the framework to more case studies in local governments, we hope to not only make the framework more compatible with various road traffic simulation packages but also build a database of input parameters (meteorological and topography data) for diverse locations in Australia. Such a database would become an integral part of the framework to more effectively assist practitioners (especially in local government) to build and refine road traffic emission simulations for their jurisdictions.

The test case demonstrates implementation of the framework for traffic data from Wollongong City Council's Aimsun traffic model for 100 road links in the city centre of Wollongong, NSW for AM peak hours (6.30 am – 9.30 am) for a representative weekday in 2018. The framework is designed to make widely available the capacity to model traffic emissions.

We continue the work documented in our previous report by refining spatial data, running the dispersion model and displaying the dispersion/exposure data. Inputs and model results are presented, including a map of pollution data.

Preface

The framework was developed in response to the need for more emissions data for on-road transport, expressed by participants in the Cross Jurisdictional Air Emissions Inventory and Exposure Workshop, in Sydney, 10th-12th April 2018. The Workshop included representatives from Federal and State governments, CSIRO, the NESP Clean Air and Urban Landscapes (CAUL) hub, Centre for Air pollution, energy and health Research (CAR) and other concerned individuals. The aim of the framework is to provide the means for agencies (mainly councils) to do their own traffic emissions modelling. Currently, this usually requires costly proprietary software, or more commonly, consultants who use that software. Our approach has been to take existing open-source components (traffic emissions model and dispersion model) and to connect them with our own pieces of software, written in Python, a commonly used language. The existing software is robust, extensively documented, well-maintained and well-regarded. We have been working in consultation with the NSW DPIE (formerly OEH) air quality team. They have since changed their approach to traffic emissions modelling to something like ours.

The framework's two core models, created and maintained by the US EPA, are the Motor Vehicle Emissions Simulation (MOVES 2014b) and the American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD). They are well-regarded, extensively used and can operate at a range of scales. MOVES takes traffic movements and calculates emissions data for roads. AERMOD takes that information and calculates how the pollutants disperse across an area. Dispersion modelling is needed to estimate concentrations at different locations. The first Python module prepares data from the traffic model AIMSUN for input to MOVES. The second module provides a user-friendly interface to simplify the set-up of AERMOD. For further details on the emissions modelling, please see Forehead and Huynh (2018)

The authors would like to acknowledge the following people for their help with this research and report (in no particular order): David Fuchs, Ruby Kan, Yvonne Scorgie, Gareth Jones (NSW DPIE), Department of Agriculture Water and The Environment Air Quality Team, Jason Choi (Vic EPA), Stella Qu (Liverpool City Council), Walter Galvan (Wollongong City Council). Clare Murphy (Paton-Walsh), Peter Rayner, Robyn Schofield and Jeremy Silver (CAUL), Johan Barthelemy (University of Wollongong). We apologise to any people that we may have left off this list.

1. An emissions simulation in AERMOD

Introduction

Here we document the process of calculating and displaying the concentration of airborne pollution over the test area of the central business district of Wollongong, NSW for AM peak hours (6.30am – 9.30 am) for a representative weekday in 2018. The pollutant modelled was carbon monoxide (CO), chosen because it is a hazardous gas and an indicator of combustion in both petrol and diesel vehicles. The dispersion model used in the framework was [AERMOD](#) (American Meteorological Society (AMS)/EPA Regulatory Model), a steady-state plume model.

The study used the first 100 road segments (links) from the traffic model's spatial data file (Fig 1.1). To simplify the input file, these were straightened and the number of nodes in each line was reduced to two. This was done with free, open-source geographic information systems (GIS) software (Quantum GIS, QGIS, (QGIS_Development_Team 2020)). This process was only used for illustration, AERMOD is designed to accept more complex geometry, including line, area and volume sources.

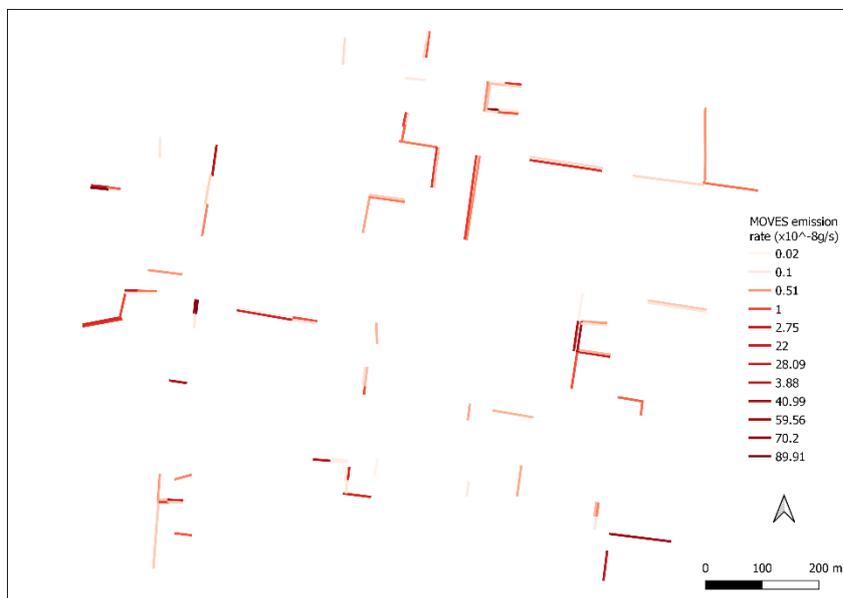


Figure 1.1. Plot of selected road links in central Wollongong, showing MOVES emission rates

Use of the Traffic Emissions Framework & results

Traffic emissions data was prepared from outputs of the council's traffic movement model. It was processed by the Emissions Modelling Framework for input to the traffic emissions model, Motor Vehicle Emissions Simulator (MOVES 2014b). MOVES generated a number of outputs, including tables of emissions factors for the road links. This was transformed by running MOVES2AERMOD tool's SQL commands with the MOVES software GUI (as part of its post-processing procedures). The tool returned a table named 'aermod-output' in the MOVES output database. A screenshot of rows in table 'wccam_out8.aermod-output' in MySQL is shown in Figure 1.2.

1 • SELECT * FROM wccam_out8.aermod_output;

SO	EMISFACT	AERMODsourceId	SEASHR	c1	c2	c3	c4	c5	c6	c7	c8
SO	EMISFACT	1	SEASHR	0.000000010760...	0.00000001076035...	0.000000010760...	0.000000010760...	0.00000001076035...	0.0000000117814...	0.0000000117814...	0.00000001178140...
SO	EMISFACT	1	SEASHR	0.000000011781...	0.00000000819086...	0.000000008190...	0.000000008190...	0.00000000819086...	0.0000000081908...	0.0000000081908...	0.00000000860041...
SO	EMISFACT	1	SEASHR	0.000000008600...	0.00000000860041...	0.000000008600...	0.000000008600...	0.00000001076035...	0.0000000107603...	0.0000000107603...	0.00000001076035...
SO	EMISFACT	1	SEASHR	0.000000007811...	0.00000000781142...	0.000000007811...	0.000000007811...	0.00000000781142...	0.0000000086181...	0.0000000086181...	0.00000000861817...
SO	EMISFACT	1	SEASHR	0.000000008618...	0.00000000656400...	0.000000006564...	0.000000006564...	0.00000000656400...	0.0000000065640...	0.0000000065640...	0.00000000656400...
SO	EMISFACT	1	SEASHR	0.000000006564...	0.00000000656400...	0.000000006564...	0.000000006564...	0.00000000656400...	0.0000000065640...	0.0000000065640...	0.00000000656400...
SO	EMISFACT	1	SEASHR	0.000000006564...	0.00000000656400...	0.000000006564...	0.000000006564...	0.00000000656400...	0.0000000065640...	0.0000000065640...	0.00000000656400...
SO	EMISFACT	1	SEASHR	0.000000007266...	0.00000000726684...	0.000000007266...	0.000000007266...	0.00000000726684...	0.0000000077359...	0.0000000077359...	0.00000000773596...
SO	EMISFACT	1	SEASHR	0.000000007735...	0.00000000656400...	0.000000006564...	0.000000006564...	0.00000000656400...	0.0000000065640...	0.0000000065640...	0.00000000656400...
SO	EMISFACT	1	SEASHR	0.000000006564...	0.00000000656400...	0.000000006564...	0.000000006564...	0.00000000726684...	0.0000000072668...	0.0000000072668...	0.00000000726684...
SO	EMISFACT	2	SEASHR	0.000000003998...	0.00000000399881...	0.000000003998...	0.000000003998...	0.00000000399881...	0.0000000043782...	0.0000000043782...	0.00000000437827...
SO	EMISFACT	2	SEASHR	0.000000004378...	0.00000000304394...	0.000000003043...	0.000000003043...	0.00000000304394...	0.0000000030439...	0.0000000030439...	0.00000000319613...
SO	EMISFACT	2	SEASHR	0.000000003196...	0.00000000319613...	0.000000003196...	0.000000003196...	0.00000000399881...	0.0000000039988...	0.0000000039988...	0.00000000399881...
SO	EMISFACT	2	SEASHR	0.000000002902...	0.00000000290292...	0.000000002902...	0.000000002902...	0.00000000290292...	0.0000000032027...	0.0000000032027...	0.00000000320272...
SO	EMISFACT	2	SEASHR	0.000000003202...	0.00000000243934...	0.000000002439...	0.000000002439...	0.00000000243934...	0.0000000024393...	0.0000000024393...	0.00000000243934...
SO	EMISFACT	2	SEASHR	0.000000002439...	0.00000000243934...	0.000000002439...	0.000000002439...	0.00000000290292...	0.0000000029029...	0.0000000029029...	0.00000000290292...
SO	EMISFACT	2	SEASHR	0.000000002439...	0.00000000243934...	0.000000002439...	0.000000002439...	0.00000000243934...	0.0000000024393...	0.0000000024393...	0.00000000243934...
SO	EMISFACT	2	SEASHR	0.000000002439...	0.00000000243934...	0.000000002439...	0.000000002439...	0.00000000243934...	0.0000000024393...	0.0000000024393...	0.00000000243934...
SO	EMISFACT	2	SEASHR	0.000000002700...	0.00000000270055...	0.000000002700...	0.000000002700...	0.00000000270055...	0.0000000028748...	0.0000000028748...	0.00000000287488...
SO	EMISFACT	2	SEASHR	0.000000002874...	0.00000000243934...	0.000000002439...	0.000000002439...	0.00000000243934...	0.0000000024393...	0.0000000024393...	0.00000000243934...
SO	EMISFACT	2	SEASHR	0.000000002439...	0.00000000243934...	0.000000002439...	0.000000002700...	0.00000000270055...	0.0000000027005...	0.0000000027005...	0.00000000270055...

Figure 1.2. Screenshot from MySQL Workbench of rows in the 'wccam_out8.aermod-output'

The table has a total of 1,200 rows, which correspond to 12 rows (i.e. 12 months) for each of the 100 AERMOD sources (which in turn are associated with the 100 road links selected for input into MOVES2AERMOD, as described above).

A copy of the complete MOVES output database 'wccam_out8' with table 'aermod-output' is available [here](#).

The table is structured so that the rows can be directly copied and pasted into an AERMOD control input file to specify variable emission rate factors for the selected sources. The tool for preparing input data for AERMOD in the Traffic Emissions Framework was used to generate the main input file (aermod.inp) for the dispersion model. The input traffic data dictates the date range and temporal resolution for the simulation, but the user selects the averaging interval (minimum 1 hr) for outputs.

There were also prepared two files of meteorological data that included information from the default values recommended by AERMOD.

- surface (.sfc) file for wind speed/direction, cloud cover, sky cover, surface roughness, Bowen ratio and albedo;
- profile file (.pfl) for vertical temperature profile.

The complete AERMOD input file 'aermod.inp,' is also [here](#), it contains the commands required for the run as well as emission factors from MOVES and references to external data.

The US EPA plotting routine for the dispersion data, [AERPLOT](#) was installed for plotting data on a map. The AERMOD run generated a range of tables of CO concentration data for 4 seasons (example: Table 1) and files for plotting (aermod.out, aerplot.inp). A command in the aermod.inp file called AERPLOT, which processed and displayed the dispersion data on a Google Earth map (Fig 4). The map has contour lines of pollutant concentration across the study area. It also shows concentric rings of spot locations, called 'receptors', with colour-coded concentration data. If required, receptors can be located anywhere in the study area, by specifying coordinates in the aermod.inp file. This can be useful for calculating levels of pollution at locations of interest, such as schools or aged care facilities.

Table 1. 50 receptor locations with greatest one hour maximum average concentrations for simulated AM peak, part of the file output by the AERMOD dispersion model

*** THE MAXIMUM 50 1-HR AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***											
INCLUDING SOURCE(S): LINK1 , LINK2 , LINK3 , LINK4 , LINK5 ,											
LINK6 , LINK7 , LINK8 , LINK9 , LINK10 , LINK11 , LINK12 , LINK13 ,											
LINK14 , LINK15 , LINK16 , LINK17 , LINK18 , LINK19 , LINK20 , LINK21 ,											
LINK22 , LINK23 , LINK24 , LINK25 , LINK26 , LINK27 , LINK28 , . . . ,											
** CONC OF OTHER IN MICROGRAMS/M**3 **											
RANK	CONC	(YYMMDDHH)	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	(YYMMDDHH)	AT	RECEPTOR (XR,YR)	OF TYPE
1.	0.02458	(88030208)	AT	(306230.98, 6188767.39)	GP	26.	0.00876	(88030304)	AT	(306389.02, 6188714.12)	GP
2.	0.02191	(88030222)	AT	(306292.61, 6188829.02)	GP	27.	0.00873	(88030207)	AT	(306389.02, 6188714.12)	GP
3.	0.02190	(88030224)	AT	(306292.61, 6188829.02)	GP	28.	0.00870	(88030318)	AT	(306264.00, 6188446.00)	GP
4.	0.02133	(88030223)	AT	(306292.61, 6188829.02)	GP	29.	0.00852	(88030223)	AT	(307047.01, 6188696.00)	GP
5.	0.01973	(88030320)	AT	(306439.00, 6188749.11)	GP	30.	0.00848	(88030224)	AT	(307047.01, 6188696.00)	GP
6.	0.01715	(88030324)	AT	(306230.98, 6188767.39)	GP	31.	0.00847	(88030320)	AT	(307083.85, 6188617.01)	GP
7.	0.01604	(88030401)	AT	(306230.98, 6188767.39)	GP	32.	0.00837	(88030222)	AT	(306364.00, 6188879.01)	GP
8.	0.01575	(88030407)	AT	(306230.98, 6188767.39)	GP	33.	0.00833	(88030222)	AT	(307047.01, 6188696.00)	GP
9.	0.01429	(88030218)	AT	(306230.98, 6188767.39)	GP	34.	0.00816	(88030305)	AT	(307047.01, 6188696.00)	GP
10.	0.01360	(88030305)	AT	(306389.02, 6188714.12)	GP	35.	0.00812	(88030220)	AT	(307047.01, 6188696.00)	GP
11.	0.01278	(88030319)	AT	(306292.61, 6188829.02)	GP	36.	0.00810	(88030320)	AT	(307480.03, 6188946.00)	GP
12.	0.01195	(88030104)	AT	(306292.61, 6188829.02)	GP	37.	0.00808	(88030224)	AT	(307047.01, 6188696.00)	GP
13.	0.01145	(88030221)	AT	(306292.61, 6188829.02)	GP	38.	0.00800	(88030207)	AT	(307047.01, 6188696.00)	GP
14.	0.01126	(88030318)	AT	(306292.61, 6188829.02)	GP	39.	0.00797	(88030103)	AT	(307047.01, 6188696.00)	GP
15.	0.01104	(88030317)	AT	(306292.61, 6188829.02)	GP	40.	0.00796	(88030405)	AT	(306230.98, 6188767.39)	GP
16.	0.01087	(88030222)	AT	(306230.98, 6188767.39)	GP	41.	0.00794	(88030319)	AT	(306230.98, 6188767.39)	GP
17.	0.01084	(88030320)	AT	(306942.89, 6188565.71)	GP	42.	0.00793	(88030207)	AT	(306942.89, 6188565.71)	GP
18.	0.01074	(88030321)	AT	(306230.98, 6188767.39)	GP	43.	0.00771	(88030220)	AT	(306942.89, 6188565.71)	GP
19.	0.01018	(88030224)	AT	(306230.98, 6188767.39)	GP	44.	0.00770	(88030323)	AT	(306439.00, 6188749.11)	GP
20.	0.01005	(88030320)	AT	(307047.01, 6188696.00)	GP	45.	0.00766	(88030106)	AT	(306292.61, 6188829.02)	GP
21.	0.01003	(88030402)	AT	(306230.98, 6188767.39)	GP	46.	0.00749	(88030320)	AT	(307106.40, 6188359.18)	GP
22.	0.00999	(88030208)	AT	(306180.99, 6188696.00)	GP	47.	0.00740	(88030220)	AT	(306389.02, 6188714.12)	GP
23.	0.00982	(88030223)	AT	(306230.98, 6188767.39)	GP	48.	0.00738	(88030403)	AT	(306230.98, 6188767.39)	GP
24.	0.00913	(88030324)	AT	(306439.00, 6188749.11)	GP	49.	0.00724	(88030223)	AT	(306364.00, 6188879.01)	GP
25.	0.00882	(88030406)	AT	(306230.98, 6188767.39)	GP	50.	0.00722	(88030104)	AT	(307047.01, 6188696.00)	GP



Figure 4. Plots of CO concentration across study area, generated by traffic on 100 road links (in red). Lines show gradients (legend at top), points are spot concentrations (lower legend).

2 The Liverpool case study

This section reports on the road traffic simulation data available from the Liverpool City Council and discusses the potential application of the AIMSUN-MOVES interface developed in Section 1. While not directly usable by our AIMSUN-MOVES interface, the traffic simulation data from the Liverpool case study underlines the heterogeneity of road traffic data available to local governments and the needs of a framework which can accommodate such variability of road traffic data to simulate road traffic emission and dispersion.

Section 2.1 reports on the road traffic simulation data available from the Liverpool City Council. Section 2.2 discusses processing procedures and supporting datasets required to make the Liverpool data ready for use by the AIMSUN-MOVES interface. These procedures can be regarded as a future extension and an inherent part of the interface.

2.1 Road traffic simulation data available for the Liverpool City Council

The study area in the AIMSUN road traffic simulation model available from the Liverpool City Council (LCC) is shown in Figure 2.1

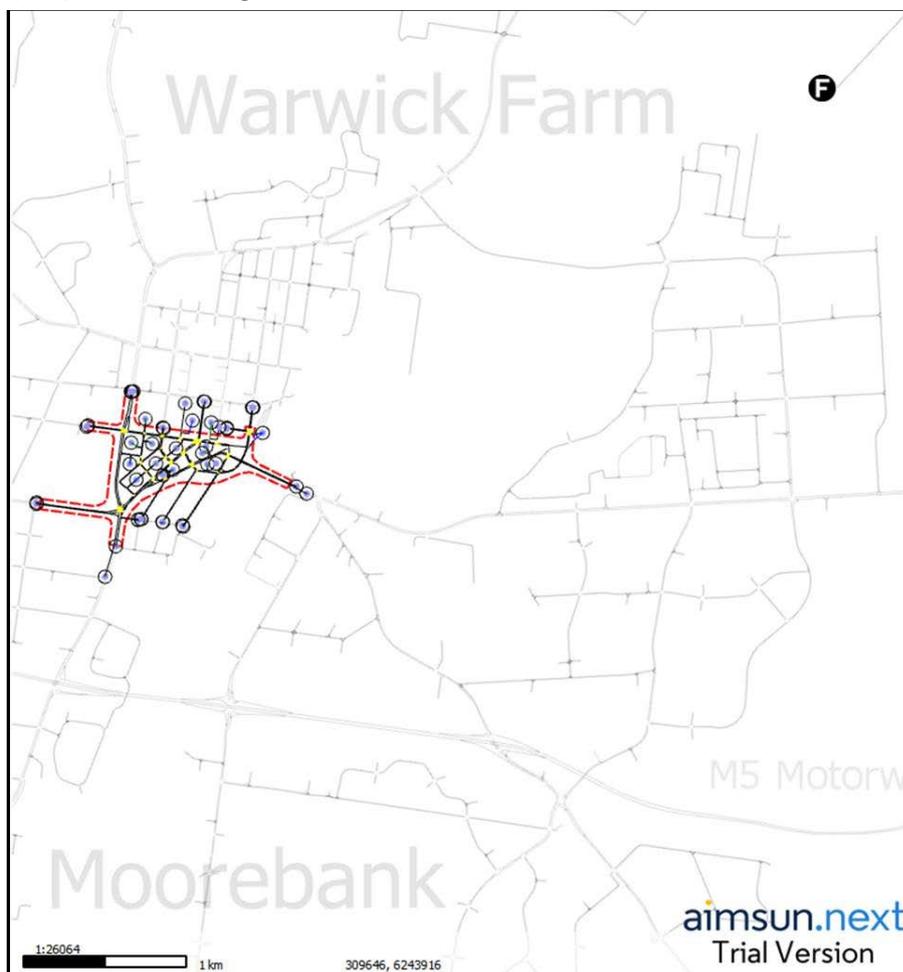


Figure 2.1. Map showing location of Liverpool NSW study area, as shown in Aimsun traffic software.

The LCC model employed demand data for 1 hour of AM peak traffic (8.00-9.00) and for 1 hour of PM peak traffic (5.00-6.00), specifically the Origin-Destination matrices (using the TZ06 configuration in the Sydney Strategic Transport Model, STM) for 3 transport modes, car, truck and heavy truck.

The total number of cars, trucks and heavy trucks in these OD matrices were approximately 800,000, 22,600, and 5,100 respectively.

The simulation results were available only in the form of 15-minute block traffic volume for each vehicle type along each possible traffic direction at each intersection (site) in the study area.

2.2 Recommendations for additional processes

As described in Section 1.2.4 of the previous report, the Aimsun output of detailed trajectory of the paths of each simulated vehicle are required to prepare the table "OperatingModeDistribution", which is an input table into the MOVES traffic emission simulation. Therefore, the Liverpool road traffic simulation data in its current form, though sufficient for traffic planning purposes at the local council level, is not readily suitable for traffic emission modelling purposes.

Often the reported 15-minute blocks of traffic volume at intersections are outputs of a postprocessing procedure of an original Aimsun simulation, which has the trajectory of all simulated vehicles in the study area. The technical team developing the original Aimsun simulation model of the study area (which is commonly an external consultant employed by the local council) should be able to extract such detail of the simulated paths from the model without too much effort (as was the case of the Wollongong CBD case study).

In cases where the technical team developing the Aimsun model was unable to provide the simulated trajectories, the 15-minute traffic volume in each possible direction at intersections need to be disaggregated into the equivalent number of individual vehicles travelling along each of those directions. A potential procedure for such disaggregation is described below

1. Generate a population of synthetic vehicles. The statistics of registered vehicles each quarter from Q2/2000 on the RMS website, such as the data of year of manufacture by vehicle age, can be a good source of information for generating such synthetic vehicle population. Each resulting synthetic vehicle is assigned a unique ID along with their attributes, e.g: vehicle type, age, and fuel type.
2. Assuming that the rate of vehicle flow along each direction at each intersection is constant within each 15-minute block, calculate the traffic volume by vehicle type for each second for each direction at each intersection.
3. For each direction at each intersection in the study area, randomly select the number of vehicles by type from the synthetic vehicle population as specified by the volume per second for each vehicle type. Because there was no data available on the age distribution and fuel type distribution of vehicles along a direction at each intersection, the age and fuel type of the selected vehicles are random.
4. Repeat step 3 for all directions and for all intersections and at every second in the simulated period.
5. Build the path of each synthetic vehicle by synchronising their travel along two consecutive intersections. More specifically, starting with each synthetic vehicle at an intersection at the boundary of the study area and at the beginning of the simulation, search for the vehicle ID at adjacent intersections within a reasonable time (which can be calculated by using speed limit and length of the corresponding road links).
6. If the vehicle ID is found at least one adjacent intersection, randomly select one intersection and repeat step 5.
7. If no vehicle ID is found at any adjacent intersection, randomly select one intersection which has the corresponding vehicle type and swap an existing vehicle with the vehicle selected in step 5. This step can be skipped if the selected vehicle already travelled a predefined minimum number of intersections.
8. Repeat step 5 to step 7 for all selected vehicles.
9. While the output of the procedure in step 5 to step 8 would be rather deterministic, repeating this procedure multiple times with different and random starting vehicle and at different

starting intersection would result in multiple scenarios of possible paths of the simulated vehicles, i.e. the procedure becomes a Monte Carlo simulation itself, and so would be the traffic emission modelling and simulation on these possible scenarios.

The estimated trajectory of simulated vehicles resulting from the above procedure are the inputs required for preparing table "LinkSourceTypeHour" and table "OperatingModeDistribution" (Section 1.2.4 of previous report). The preparation of all other tables required for a MOVES simulation follow the same procedure outlined in Section 1.2 of the previous report.

Once a MOVES simulation (again, there are multiple scenarios of vehicle paths for such a MOVES simulation) is complete, the preparation for the following AERMOD simulation is similar to that for the Wollongong case study (except for any local differences, e.g. meteorology data).

References

Forehead, H. and N. Huynh (2018). "Review of modelling air pollution from traffic at street-level - The state of the science." *Environmental Pollution* **241**: 775-786.

QGIS_Development_Team (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project.