ESTIMATION OF ROAD TRANSPORT EMISSIONS FOR AUSTRALIA

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ABSTRACT

COPERT is a globally used software tool used to calculate air pollutant and greenhouse gas emissions produced by road transport. Its scientific development is managed by the European Commission. The software estimates all types of emissions including hot running, start, evaporative and non-exhaust (tire wear, brake wear). Previous studies showed that a similar software used in Australia needs to reflect local fleet composition and driving characteristics in order to provide adequate and reliable predictions for the Australian situation. Therefore, a dedicated Australian version of COPERT was developed through a joint research agreement between DSITIA and an EU partner. The Australian software has been calibrated with thousands of vehicle emission tests that were conducted in Australia and includes innovative aspects that have been developed in Australia. This paper first discusses the methods and data used for the development of COPERT Australia. It then discusses the creation of an Australian input file for COPERT Australia. The model is then used to estimate road transport emissions for Australia and the results are analysed and discussed.

1. INTRODUCTION

Road transport is a significant source of air pollutants around the world. According to the 2008 US Emissions Inventory, road vehicles alone are responsible for 58% and 40% of total CO and NOx emissions, respectively (Rao et al., 2013). The corresponding numbers in Europe are 33%, and 42%, respectively (EEA, 2012). Due to the vicinity of roads to residential areas, population exposure to road transport pollution is more important compared with other sources.

In Australia and New Zealand, interest in road transport related air pollution is growing. Traffic related pollution is a health risk factor in major cities (e.g. Pereira et al., 2010). For example, in Sydney, road vehicles are responsible for 51% and 62% of total CO and NO_x emissions, respectively (NSW EPA, 2012); which is similar to other cities around the world. This is why the Australian Government has progressively introduced new vehicle emission control standards that align with the most recent Euro standards.

Assessing and monitoring the impacts of new emission standards and other measures on air quality is challenging. Road transport reflects a range of vehicle fuels and technologies and a variety of operational conditions, which all affect emission levels. Accurate estimation of emissions requires a sound knowledge of the on-road vehicle fleet characteristics (classified into vehicle types, fuel types and emission control technology), travel patterns and behaviour (e.g. speed distributions), as well as climatic conditions. Then the fleet activity needs to be combined with appropriate emission factors to calculate total emissions. This process is data hungry, demanding from a technical and modelling perspective and subject to significant uncertainties.

In addition to air quality, climate change and greenhouse gases (GHGs) emissions produced by road vehicles are at the forefront of environmental policy and science around the world. Scenario analysis into different technological solutions to reduce GHGs emissions and to improve fuel efficiency is required to develop cost-effective policies.

2. METHOD OUTLINE

COPERT is a globally used software tool used to calculate air pollutant and GHG emissions produced by road transport, and its scientific development is managed by the European Commission. Previous studies showed that a similar software used in Australia needs to reflect local fleet composition and driving characteristics in order to provide adequate vehicle emission estimates for the Australian situation. Therefore, a dedicated Australian version of COPERT was developed in cooperation with an EU partner: COPERT Australia.

2.1 General approach

COPERT Australia estimates emissions for 122 pollutants and it estimates emissions of both exhaust and non-exhaust pollutants. Exhaust pollutants are produced during engine operation and they include carbon monoxide (CO), total volatile organic compounds (TVOCs), nitrogen oxides (NO_x), particulate matter (PM) and ammonia (NH_3). Several of these pollutants are further divided into subgroups. For example, NOx are split into NO and NO_2, PM is split into different size fractions (PM_{10}, $PM_{2.5}$, $PM_{0.1}$) and carbonaceous species, and VOCs are split into several individual groups and species, including saturated, aromatic and polyaromatic hydrocarbons. GHGs are also calculated and include CO_2, methane (CH_4) and nitrous oxide (N_2O). The model can also estimate sulphur dioxide (SO_2) and several heavy metal emissions, provided that fuel properties are known.

Exhaust pollutants are classified according to their production mechanism into hot running and cold-start emissions. Hot running emissions (E_{HOT}) are produced after the engine and the emission control system are thermally stabilized – hence the term 'hot'. Cold-start emissions are excess emissions that occur in the first few minutes of driving when the engine and emission control system warms up. Due to inefficient combustion and ineffective emission control during warm-up, cold engine starts generate additional emissions to hot emissions. For a given vehicle activity level, expressed as total vehicle kilometers travelled (VKT) for the period concerned, hot emissions are calculated as follows:

$$E_{HOT} = VKT \times e_{HOT} \quad (1)$$

The emission factor (e_{HOT}) in eq. (1) represents the mean emission level of the on-road fleet, and it is expressed in grams per kilometre. Cold-start emissions are calculated by the expression shown in equation (2).

$$E_{COLD} = \beta \times VKT \times e_{HOT} \times (e_{COLD} / e_{HOT} - 1) \quad (2)$$

β is the fraction of the total vehicle activity before the engine has reached hot running conditions, and it is a function of vehicle technology, ambient temperature and mean trip length of a particular vehicle type. The term in parentheses corresponds to the excess-emission level compared to the hot emissions.

Non-exhaust emissions calculated by the software include hydrocarbon emissions resulting from fuel evaporation of spark-ignition vehicles. Evaporation losses can occur through the fuel canister, which is used to capture fuel vapours from the fuel tank, through non-metallic fuel lines or plastic fuel tank walls, or through losses in fuel line connectors and fittings. In COPERT Australia, evaporation losses are considered to occur from the daily variation in temperature (diurnal), in stationary condition after hot operation (soak) and during vehicle operation on the road (running losses). Specific computation methods are used to estimate the contribution of each type of evaporative emissions and then total evaporation emissions are calculated with equation (3). Evaporation emissions increase for highly volatile fuels, such as low ethanol blends. Hence, they are important in Australia where E10 biofuel blends are used in a number of States.

$$E_{EVAP} = E_{DIURNAL} + E_{SOAK} + E_{RUNNING} \quad (3)$$

A final source of emissions is wear of vehicle components, primarily brakes and tyres. The wear contributes to the total PM generation by the vehicle. Studies have shown that for a typical petrol passenger car, the amount of wear contributing to airborne PM is larger than the contribution from vehicle exhaust (Van der Gon et al., 2013). Hence non-exhaust emissions should not be ignored in air emission inventories.

The software also provides functions to calculate the fuel consumption of individual vehicle types. The total calculated fuel consumption per fuel can then be compared with fuel sales data in the region of interest as a validation step.

2.2 Vehicle classification

COPERT Australia uses emission factors for 226 individual vehicle classes. The vehicle classification is shown in Table 1. Note that ADR emission standard is used as a proxy for 'emission control technology level'. ADRs refer to "Australian Design Rules", which are the emission standards adopted in Australia and the software considers 22 ADR categories, including future ones.

Table 1: COPERT Australia Vehicle Classification.

Main Category	Sub Category	Fuel Type	Emission control standard
Passenger Car	Small (<2.0 l); Medium (2.0-3.0 l); Large (≥ 3.0 l)	Petrol; Diesel; LPG; E10	Uncontrolled; ADR27;ADR37/00-01; ADR79/00-05
SUV	Compact (≤ 4.0 l); Large (> 4.0 l)	Petrol; Diesel; E10	Similar to PC; +ADR36 (SUV-L); +ADR30; (SUV-Diesel)
Light Commercial Vehicle	GVM ≤ 3.5 t	Petrol; Diesel	Uncontrolled; ADR36 (P); ADR30 (D); ADR37/00-01; ADR79/00-05
Heavy Duty Truck	Medium; Heavy; Articulated	Petrol; Diesel; LPG	Uncontrolled; ADR30; ADR70; ADR80/00; ADR80/02-05
Bus	Light Bus (≤ 8.5 t); Heavy Bus(>8.5 t)	Diesel	
Moped	2-stroke; 4 stroke	Petrol	Conventional; Euro 1-3
Motorcycle	2-Stroke; 4-S <250 cm^3; 4-S 250-750 cm^3; 4-S ≥750 cm^3		

Australian data have been used for the large majority of emission factors available. Any gaps have been filled with emission information from the European version of COPERT, considering the equivalencies between the Euro and ADR vehicle emission standards.

COPERT Australia uses a different vehicle classification than the (European) COPERT 4 software to adequately reflect the Australian fleet characteristics and the structure of the Australian empirical database. For instance, COPERT 4 does not include large passenger cars with an engine capacity larger than 3 litres and SUVs, which are both important vehicle classes in Australia.

2.3 Emission factors

The hot running and cold start emission factors in COPERT Australia have been developed on the basis of 100 m driving segments (Smit and Ntziachristos, 2012; 2013a), using driving profiles representing real-world vehicle operation in Australia. The test data have been made available from various Australian test programmes that were conducted over time. These emissions data have been collated in a verified emissions database with about 2,500 modal (i.e. second-by-second) emission tests and about 12,500 individual bag (i.e. specific parts of driving cycles) measurements, which have been analysed to derive the emission factors used in COPERT Australia.

In COPERT Australia, hot running emission factors are expressed as a function of the mean (travelling) speed. Figure 4 (page 8) shows and example of these relationships. The emission factors are a function of traffic performance ('average travel speed'), as well as several other factors such as fuel quality, ambient temperature, ageing, etc. The input required for average speed models matches the output from macroscopic transport models.

The range of driving conditions that can result in the same average speed but quite different driving behaviour, and hence emissions, increases as the average speed drops. Hence, the representativeness of emission factors that only take into account average speed and not dynamic driving behaviour may be reduced at lower (urban) speeds.

More detailed Australian models like the PΔP model (Smit, Casas and Torday, 2013) have recently been developed to address this issue. PΔP predicts vehicle emissions on a second-by-second basis using (the change in) engine power as the predictor variable. PΔP is designed to simulate the impacts of changing traffic and operational conditions, but requires second-by-second speed information, which may be available from microscopic simulation models and GPS databases.

However, average speed is a variable that is relatively easy to obtain either from traffic models or from monitoring of traffic performance (e.g. travel time studies). This is particularly the case for large study areas which vary from from urban or regional areas to a national scale. For several applications average speed is therefore a good compromise between accuracy of emission factors and accuracy of the input data (Smit et al., 2010).

Given the large variation in local traffic conditions it is challenging to determine exactly in which situations average speed emission factors should no longer be used and more detailed modelling is required. However, international research indicates that COPERT can satisfactorily be used and/or validated at street level (e.g. Gualtieri, 2010), city level (e.g. Borge et al., 2012), and country level (e.g. Cai and Xie, 2007).

3. ESTIMATION OF MOTOR VEHICLE EMISSIONS FOR ROAD TRANSPORT IN AUSTRALIA

This section will discuss the creation of a COPERT input file for Australia for base year 2010 in section 3.1 and will then demonstrate a few different ways how the software output can be analysed and used.

3.1 Creating an input file

Although running of the COPERT Australia software to estimate total emissions of 100+ air pollutants and greenhouse gases from Australian road transport only takes a few minutes, constructing an accurate input data file requires some effort. The following types of input data are required to run the software:

- Monthly meteorological data (ambient temperature, humidity)
- Fuel parameters (e.g. Reid Vapour Pressure, sulphur content, lead content)
- Proportion of total travel in urban, rural and highway conditions
- Average speed in urban, rural and highway conditions
- On-road vehicle population
- Mean annual mileage by vehicle class
- Accumulated mileage by vehicle class
- Annual fuel consumption by fuel type
- Vehicle parameters (e.g. fuel tank size, carbon canister size).

Australia is a vast continent with local climate varying from tropical to temperate. For this study, two “contrasting” large cities were chosen to simulate a range of climate and fuel volatility impacts: Brisbane with a subtropical climate and Melbourne with a temperate climate. Representative meteorological data can be sourced from relevant state agencies or the Bureau of Meteorology. Detailed meteorological data were extracted from DSITIA’s own air quality monitoring network in South-East Queensland to create a representative input file with ambient temperatures for each hour of the year. Information on petrol fuel volatility was collected from the Brisbane BP and Caltex oil refineries. The Victorian EPA (EPAV) was contacted and the same data were kindly provided for Melbourne (Delaney, 2012).

Macroscopic transport models provide an excellent source of information regarding average network speed and the share of the three driving modes “urban”, “rural” and “highway”. Data from the South East Queensland Strategic Transport Model (SEQSTM) were analysed to create link speed distributions (expressed as percentage of total network travel) for light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs), as is shown in Figure 1. It has been assumed that the SEQ road network (46,000 road links) will provide a reasonable estimate for Australia as a whole, but analysis of data from different States will further improve the accuracy of an input file for Australia.

The speed ranges for the three driving modes are arbitrarily set to 0-64 km/h for “urban”, 65-94 km/h for “rural” and larger than 95 km/h for “highway”. Following these definitions it is clear that HDVs show significantly more travel in rural and highway conditions as compared with LDVs. The mean urban speed of 45-47 km/h is close to the reported average value of 42 km/h for Australia by Austroads (2013).

Additional data sources (ABS, 2011; BITRE, 2013) were used to estimate mean speed and share of total VKT by driving condition and main vehicle type for Australia. The results are shown in Table 2.

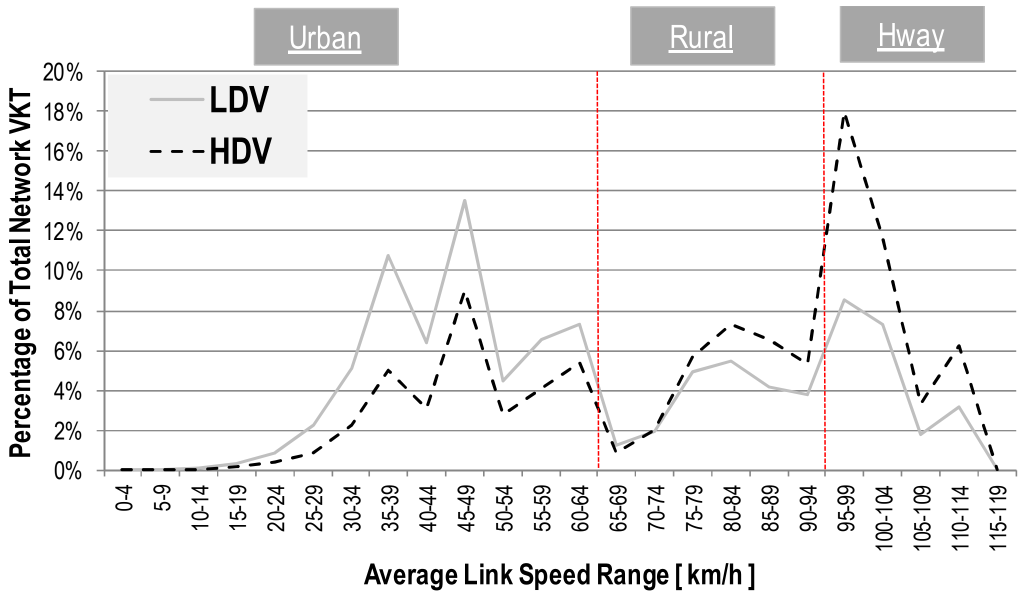

Figure 1: Link Speed Distributions for LDVs and HDVs for the SEQ Road Network.

Table 2: Estimated Speed and Driving Mode Distributions for Australia.

Main Vehicle Type	Mean Speed [km/h]			VKT Share		
	Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	45	80	100	60%	20%	20%
Light commercial vehicles	45	80	100	60%	20%	20%
Medium and heavy commercial vehicles	45	80	90	30%	30%	40%
Articulated trucks	45	80	90	30%	20%	50%
Buses	45	80	90	30%	30%	40%
Motorcycles	45	80	100	60%	20%	20%

A substantial amount of data regarding fleet composition, fuel use and vehicle use are available for Australia from different sources. However, developing a model from these data is a challenge for two reasons: the available data reflect different vehicle class definitions than those used in the software; and the available data are often too aggregated to be useful for the high level of detail required for vehicle emissions modelling. Information regarding vehicle population, mean annual mileage and accumulated mileage were taken from TER (2014):

- Available vehicle registration data (ABS Motor Vehicle Census) and vehicle sales data (e.g. ABS, 2012a) were combined to create a vehicle population input table that lists the number of on-road vehicles for each of the 226 vehicle classes in Australia for the base year of interest (2010).
- Mean annual mileage and accumulated mileage for each vehicle class were estimated using age-mileage functions that have been calibrated with data on total fuel use by type of fuel.

Finally, specific parameters for Australian vehicles such as fuel tank size and carbon canister size were collected or estimated in a dedicated study (Mellios et al., 2013).

3.2 Results: analysis of output

COPERT Australia creates a wealth of emissions information that can be analysed in various ways and with different levels of detail to address different research or policy questions. The software can create output in the form of either Excel spread-sheets or report format with different options regarding the required breakdown of emissions. An example of a report is shown in Figure 2.

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Emission Results - Driving Mode oriented

COPERT Australia v1.0

CO

POLLUTANT	YEAR	SECTOR	URBAN [t]	RURAL [t]	HIGHWAY [t]	TOTAL [t]
CO	**2010**		**604,913.96**	**88,664.68**	**114,246.31**	**807,824.95**
		Passenger Cars	**340,607.47**	**35,869.75**	**48,727.12**	**425,204.35**
		PC-S-petrol	95,458.94	8,378.73	12,524.84	116,362.52
		PC-M-petrol	60,184.86	7,115.67	9,275.69	76,576.22
		PC-L-petrol	125,060.28	8,374.55	9,137.03	142,571.85
		PC-S-diesel	87.16	10.05	7.16	104.37
		PC-ML-diesel	92.85	10.77	7.94	111.55
		PC-S-E10	19,992.05	3,318.19	4,650.66	27,960.90
		PC-M-E10	6,058.57	1,281.77	1,934.79	9,275.13
		PC-L-E10	9,527.15	2,302.19	3,479.09	15,308.42
		PC-LPG	24,145.61	5,077.84	7,709.93	36,933.38
		SUV	**79,454.92**	**12,358.96**	**12,653.07**	**104,466.95**
		SUV-C-petrol	16,510.51	1,497.99	1,791.79	19,800.29
		SUV-L-petrol	54,837.62	9,485.28	9,121.00	73,443.91
		SUV-diesel	1,963.92	351.18	474.07	2,789.17
		SUV-C-E10	1,314.22	210.98	296.42	1,821.61
		SUV-L-E10	4,828.65	813.53	969.79	6,611.96
		Light Commercial Vehicles	**143,344.06**	**23,183.34**	**29,578.33**	**196,105.73**
		LCV-petrol	139,299.40	21,782.02	27,326.05	188,407.47
		LCV-diesel	4,044.66	1,401.32	2,252.28	7,698.26
		Heavy Duty Trucks	**9,737.97**	**6,110.75**	**10,480.03**	**26,328.76**
		MCV-petrol	353.33	271.20	354.35	978.88
		MCV-diesel	3,809.07	2,523.48	3,073.58	9,406.13
		HCV-diesel	1,307.35	726.13	969.87	3,003.35
		AT-diesel	3,832.51	2,255.53	5,645.28	11,733.32
		Autogas Trucks	435.70	334.42	436.95	1,207.08
		Buses	**561.14**	**468.46**	**681.49**	**1,711.09**
		BUS-L-diesel	369.00	320.66	488.40	1,178.06
		BUS-H-diesel	192.14	147.80	193.09	533.03
		Mopeds	**0.00**	**0.00**	**0.00**	**0.00**
		2-stroke <50 cm^3	0.00	0.00	0.00	0.00
		4-stroke <50 cm^3	0.00	0.00	0.00	0.00
		Motorcycles	**31,208.40**	**10,673.41**	**12,126.27**	**54,008.09**
		2-stroke >50 cm^3	0.00	0.00	0.00	0.00
		4-stroke <250 cm^3	0.00	0.00	0.00	0.00
		4-stroke 250 - 750 cm^3	31,208.40	10,673.41	12,126.27	54,008.09
		4-stroke >750 cm^3	0.00	0.00	0.00	0.00

Figure 2: Example of COPERT Australia output report (2010).

Figure 3 shows the results for carbon monoxide (CO) for base year 2010 with a breakdown by driving mode and vehicle category. Note that the vehicle categories are presented in a more aggregated form than used in the actual emissions simulation and excludes ADR level.

Table 3 presents total estimated motor vehicle emissions for Australia in 2010 for a selected number of pollutants. Note that the table shows averaged total emissions for the Brisbane and Melbourne climate/fuel simulations to provide a preliminary estimate for Australia. A more detailed analysis for each state individually will provide more accurate results.

Table 3: Total Motor Vehicle Emissions for Australia (2010).

Tonne	Urban	Rural	Highway	Total
CO (tonne)	814,134	88,665	114,246	1,017,045
NO_x (tonne)	175,433	66,431	112,686	354,549
TVOC (tonne)	84,591	9,054	9,402	103,047
$PM_{2.5}$ (tonne)	5,969	1,806	2,525	10,301
NH_3 (tonne)	3,578	2,276	1,922	7,776
N_2O (tonne)	1,951	386	295	2,632
Pb (kg)	5	1	1	7

Table 3 shows that urban driving conditions typically account for about 80% of total emissions, whereas the estimated share in total VKT is 57%. This is the case for CO, TVOC, N_2O and lead (Pb), but not for NO_x, $PM_{2.5}$ and NH_3 where urban conditions account for about 50-60% of total emissions. These differences reflect the variation in the shape of the average speed – emission factor relationships between vehicle classes and pollutants, and hence the different impacts of congestion and high speed conditions on emissions (e.g. Smit and Ntziachristos, 2012). This is demonstrated in Figure 3 for large petrol passenger cars (ADR79/00) where the relative impacts of low speed urban driving and highway conditions are more pronounced for CO than those for NO_x.

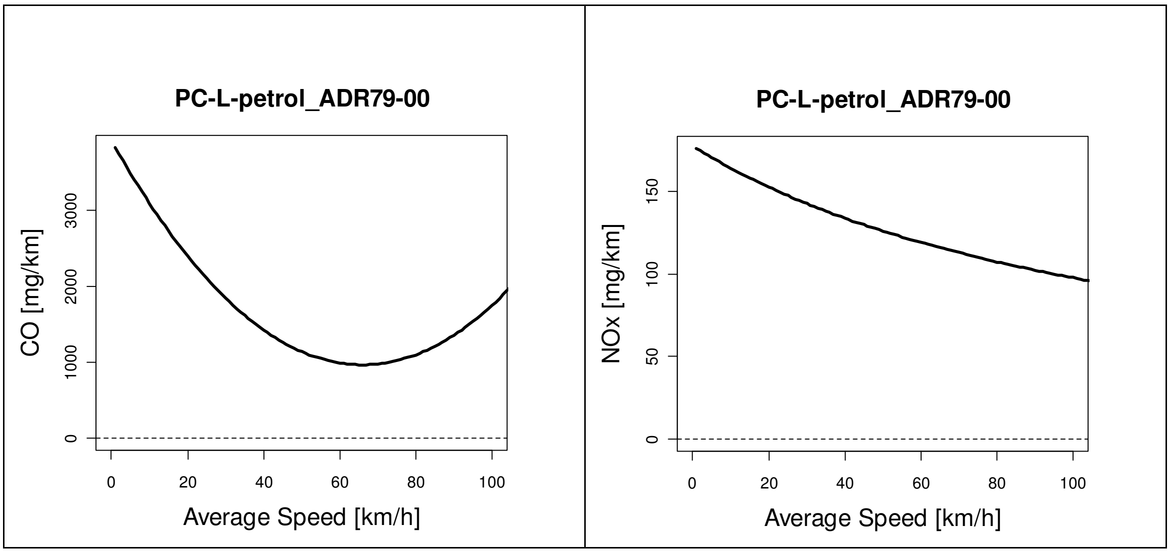

Figure 3: Example of average speed – emission factor relationships for CO and NOx.

To put the numbers in Table 3 into perspective, total motor vehicle emissions are compared with total emissions from major industrial facilities in Australia. Industry emissions data were obtained from the National Pollutant Inventory (NPI, 2014). Figure 4 shows the results.

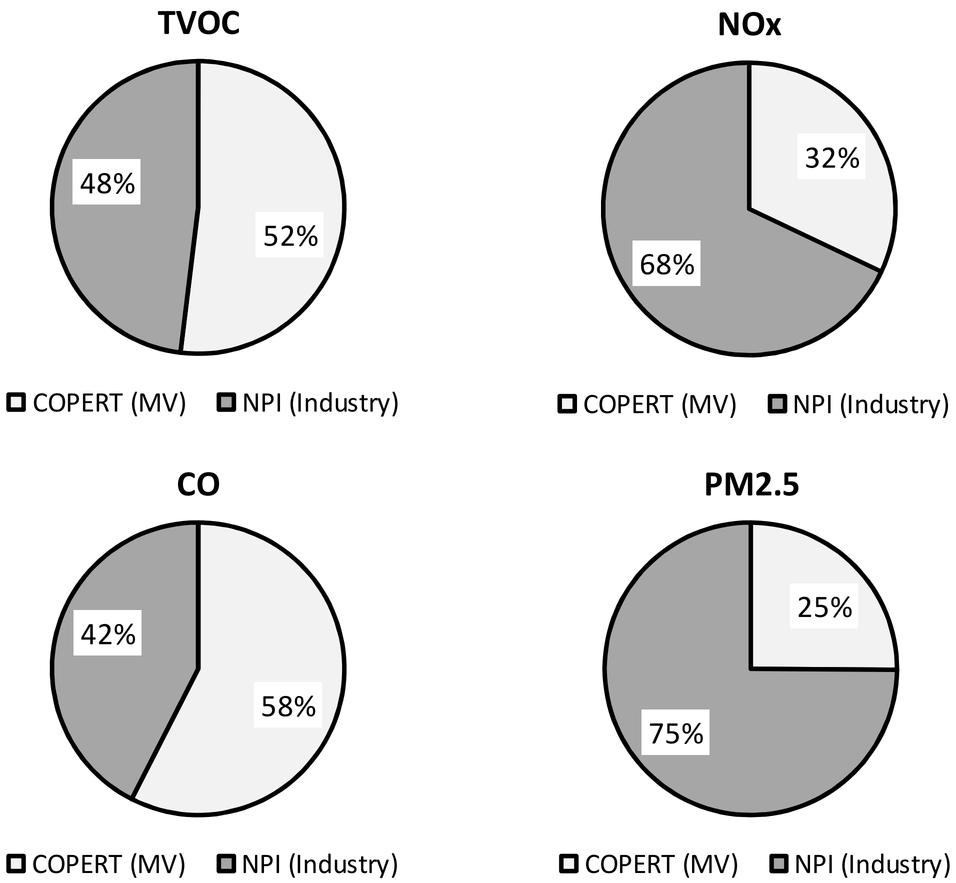

Figure 4: Comparison of industrial and motor vehicle emissions for Australia (2010).

Figure 4 shows that motor vehicle emissions are significant in comparison with industrial emission levels. In the case of CO and TVOC emissions motor vehicles have a similar or even larger level of emissions. It is noted that the actual contribution of motor vehicle emissions to population exposure (and thus health effects) is typically much larger than for industrial sources (e.g. Caiazzo et al., 2013). This is because motor vehicle emissions are released close to ground level and in close proximity to where people live and work. In contrast, industrial emissions are typically emitted through vents and stacks, which means that industrial emissions are often significantly diluted before they reach the population.

Analysis of the breakdown of total emissions by ‘type of emission’ (hot, cold, evaporative) is another relevant exercise. This information is important as the type of emission has a strong spatial and temporal component to it and therefore has implications for population exposure to air pollutants. Hot running (exhaust) emissions occur when vehicles are moving and the engine and the emission control system (e.g. catalytic converter) have reached their typical operating temperatures. Cold start (exhaust) emissions also occur when vehicles are moving, but when engines and catalysts are not (fully) warmed up and operate in a non-optimal manner. These additional emissions typically occur within the first few minutes of driving (Smit and Ntziachristos, 2013a). Cold start emissions occur when vehicles are started such as in and around residential areas, parking lots and shopping centres. Evaporative emissions are non-exhaust hydrocarbon losses through the vehicle's fuel system, and occur when vehicles are parked.

An analysis of the magnitude of different types of emissions can provide input and direction to policy development. Figure 6 shows the results for three air pollutants and CO_2. The results clearly show that 'residential/parking' emissions are particularly important for CO and TVOCs. This implies that policy measures that aim to reduce the number of trips (vehicle starts) will particularly affect total emissions of these pollutants. In contrast, cold start emissions for NO_x and CO_2 are significantly less important with a proportion of 5-10% of total emissions. Reduction of total travel (VKT) will have the largest effect on total emissions for these pollutants.

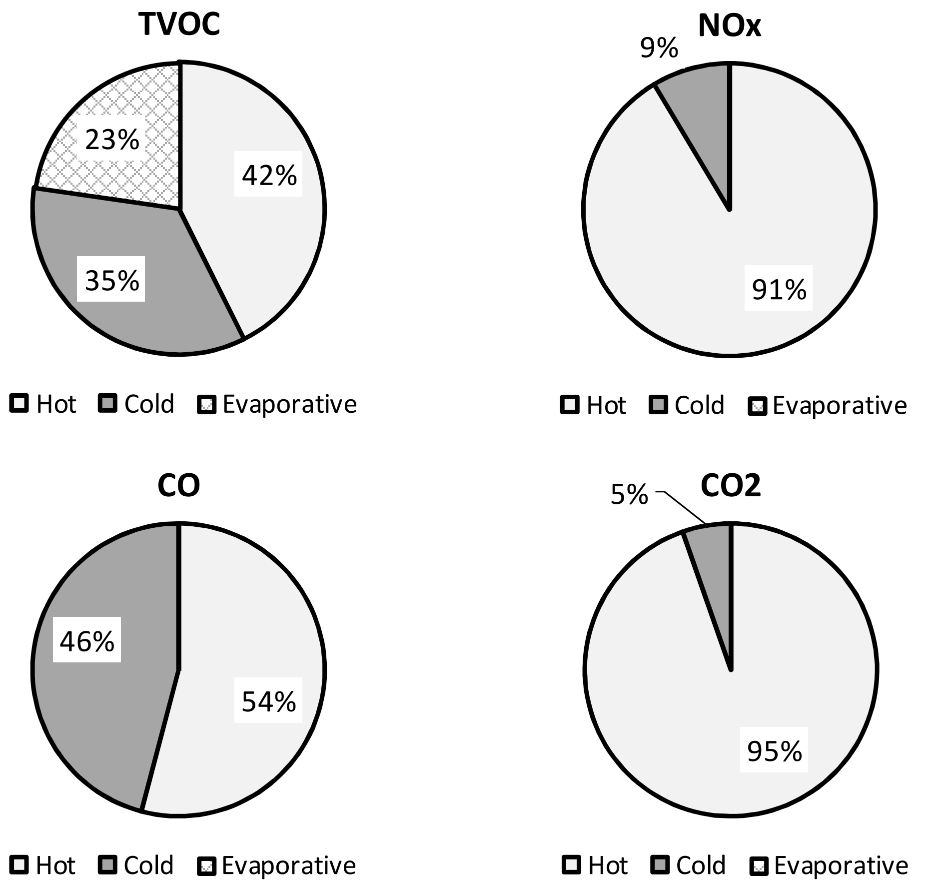

Figure 5: Distribution of total emissions by pollutant and type of emission (2010).

Finally, COPERT Australia can be used to develop speed-dependent emission factors that can be combined with transport models to conduct emissions and fuel consumption simulations at a high spatial and temporal resolution. COPERT is then used to compute composite emission factors that match the classification in the selected transport models. For instance, speed-dependent composite emission factors, expressed as grams per VKT, can be calculated for two vehicle categories such as LDVs and HDVs, which can then be readily combined with link specific information in urban road networks including traffic volume, link length and average link speed.

An example of such an application is shown in Figure 6. These emission maps were developed using link data from the South East Queensland Strategic Transport Model (DTMR, 2012) to estimate speed-dependent hot running emissions (and non-exhaust PM emissions) and trip matrices to compute cold start emissions.

Figure 6: Emission map for Brisbane CBD (source: Smit and Ntziachristos, 2013b).

Improved spatial and temporal attribution of vehicle emissions is of increased importance because of a new international (and Australian) focus on the reduction of population exposure to air pollution and (health) risk. So traffic emissions information with a high resolution in time and space can be fed into air quality models, which simulate dispersion and chemical conversion processes to predict air pollution concentration levels, exposure and health risks in urban areas. This type of analysis can be used to identify air pollution ‘hot-spots’, or even GHG emission hot spots, in urban areas. A population density overlay can then be added to assess if hot spots coincide with areas where people live. This information can then be used for policy development and focussed assessment of specific traffic management measures.

4. CONCLUSIONS

This paper discussed the development and calibration of an overseas software package to create a dedicated Australian software tool to predict emissions and fuel consumption for road transport. The software has been adopted from the well-tested, comprehensive and user-friendly COPERT software that is used internationally, and has been calibrated with data from a large Australian emissions database.

It includes a number of new and innovative aspects that were developed specifically for the Australian spin-off software. Examples are explicit consideration of spatial modelling resolution for hot running average speed functions and inclusion of trip matrices in the computation of cold start emission factors. The main differences between (European) COPERT 4 and COPERT Australia relate to the vehicle classification and the methods that were used to develop average speed (hot running) emission algorithms and cold start emission factors.

The paper discussed the development of an input file for Australia after different aspects of the simulation results were examined. COPERT requires a range of input varying from meteorological and fuel data to information regarding the on-road fleet and vehicle use. The detailed vehicle classification (226 classes) imposes a particular challenge on the development of the input file, but once the process is completed, running the software and analysis of the results is fast and straightforward.

This paper has presented some preliminary estimates of total Australian emissions for a number of pollutants. Further work is required to improve the input file. This includes analysis of transport model output and measured traffic data from different states and consideration of different climate regions and variation in fuel quality across Australia. It is anticipated that the software will be applied to other States and cities in Australia. New information and emissions data for the Australian fleet (where available) and new scientific information from European programs will be incorporated into the model through regular updates.

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