PREDICTION OF MOTOR VEHICLE AIR EMISSION REDUCTIONS THROUGH INTERVENTION POLICIES

L. W. Burger[1], M. Stead[2] & A. Moldan[2]

[1] Airshed Planning Professionals (Pty) Ltd, PO Box 5269, Halfway House, South Africa

[2] South African Petroleum Industry Association, PO Box 783482, Sandton, 2146, South Africa

Abstract

There are increasing pressures in South Africa from *inter alia* the government and the motor industry, to make certain changes to current fuel specifications that enable alterations in vehicle technology, which would lead to a reduction in harmful vehicle exhaust emissions. The South African Petroleum Industry Association (SAPIA) is currently developing a long-term roadmap for future fuel specifications by means of a phased, multi-stakeholder process. This included the development and application of a vehicle emissions model that accommodates the calculation of (a) various vehicle technologies (b) fuel specifications and (c) the introduction of a vehicle Inspection and Maintenance (I & M) programme. Specifically, four cases were selected to quantify the incremental changes in air pollution impacts: a “2006 fuel” local formulation, with different vehicle parc splits (i.e. actual 2006, 2008, 2015 and hypothetical Euro 4), with and without an Inspection & Maintenance (I&M) programme in place, and an Euro 4 fuel formulation with different vehicle parc splits with and without an I&M programme.

Keywords: vehicle air emissions model, air dispersion modelling, vehicle Inspection and Maintenance programme, vehicle and fuel specifications, South Africa.

1. Introduction

Air emissions from vehicles have been identified as a potential growing air pollution problem in densely populated areas of South Africa. Although this may be due to the steady increase in the number of vehicles on the roads, a significant portion of vehicles are not equipped with emission control devices, in addition to the fact that a significant proportion of the vehicles are old and often in poor condition. In order to reduce air pollution from vehicles, interventions need to be implemented that consider formalising emissions standards, standards for vehicle fuels, inspection and maintenance programmes and traffic management.

Since these interventions do not necessarily respond in a linear fashion, it is often difficult to immediately anticipate the outcome of a strategy. It is therefore desirable to have a tool that would allow calculations of the impact of vehicle emissions for different interventions in a relatively easy manner. It further implies that this tool must accommodate the dependence of fuel specifications, vehicle types, engine sizes, emission standards, the Implementation of Inspection and Maintenance (I&M) programmes and the effect of different vehicle speeds. Subsequently, air concentration levels can be calculated using a suitable atmospheric dispersion model.

Airshed Planning Professionals (Pty) Ltd were appointed by the South African Petroleum Industry Association (SAPIA) to assist with the development and application of a Vehicle Emissions Modelling (VEM) tool that aims to accommodate the above requirements. The VEM project consists of three phases. Phase 1, and the subject of this paper, includes the development of a vehicle emissions model that must accommodate the calculation of the following three interventions:

- Various vehicle technologies;
- Fuel specifications (including the relative impact of changes to the following individual fuel parameters – petrol and diesel sulphur, petrol aromatics, petrol olefins, benzene, diesel density); and

- Inspection and maintenance of vehicles.

Phase 1 also includes the development of a new atmospheric dispersion model or off-the-shelf selection of a suitable model to calculate the dispersion of vehicle emissions along roadways.

The calculations in Phase 1 provide incremental and relative (i.e. between different scenarios) impacts only. With Phase 2, the aim is to superimpose the predictions made with the tool developed in Phase 1 on actual measurements in selected study areas. The relative contribution of the vehicle emissions to the local air pollution would indicate the necessity of implementing certain interventions and the practicality of being able to meet air quality guidelines. These results and the development of criteria for deciding the level of intervention forms the basis for Phase 3.

2. Model Formulation

In the absence of detailed local vehicle emissions factors, the emissions inventory model was based on the very comprehensive set of emission rate factors developed by the European Environment Agency (COPERT III and COPERT IV). The model is based on a Microsoft Excel Spreadsheet application.

The methodology covers regulated exhaust emissions of carbon monoxide, oxides of nitrogen, sulphur dioxide, particulate matter, volatile organic compounds (VOC) and lead, in addition to a number of other unregulated compounds. These emission factors also accommodate the dependence on vehicle types, engine types, fuel specification and vehicle speed. They also have reduction factors for the implementation of an I&M programme. Furthermore, road slope correction factors are included for heavy duty vehicles, buses and coaches.

Due to its wide international acceptance for the simulation of air concentrations near roadways, the USA CALINE-4 atmospheric dispersion model was deemed suitable for this project.

3. Assumptions and Limitations

The very comprehensive set of emission rate factors were developed by the European Environment Agency, as summarised in their background documentation of COPERT III (Computer Programme to Calculate Emissions from Road Transport) (EEA 1999) and later updated in COPERT IV (Ntziachristos *et al*, 2007). The most important assumption made in this investigation and model development is that the emission factors developed for the European vehicle fleet apply equally to the South African vehicle fleet.

The assumption was also made that the fuel correction functions provided in COPERT III & COPERT IV could be used to calculate the effect on emissions when using fuels with different characteristics from the base fuel formulations.

In order to calculate the impact of the various interventions, the assumption was made that the vehicle engine and truck size categories on all South African roads approximate the country's average split. This assumption had to be made due to the absence of detailed vehicle definitions.

Similarly, average vehicle speeds had to be assumed in the absence of actual onsite data. Some air pollutants depend strongly on vehicle speed and it is therefore important to obtain reasonably accurate speeds when calculating absolute concentration impacts. Since this investigation's focus was more on relative emission reductions/increases, using an incorrect vehicle speed may well not be that significant.

For the purposes of this investigation, and in the absence of a detailed pre- Euro vehicle parc split for South Africa, all Euro 1 and pre-Euro vehicles were assumed to be equally distributed, i.e. 50%:50%.

A hybrid of the COPERT methodology was adopted based on the following recommendations taken from Stone (2007) with respect to the effect of an I&M:

- The COPERT methodology for modelling the effect of emissions deterioration and

I&M programs should be used until such time as an empirical study proves it is not applicable.

- The COPERT methodology for the deterioration of emissions from Euro 3 and Euro 4 gasoline vehicles should not be applied to modelling the South African vehicle parc because emissions control system onboard diagnostics (OBD) is generally disabled in South Africa. As a more realistic alternative, the Euro 1 and 2 deterioration methodology should rather be applied to the Euro 3 and 4 base factors.
- COPERT will, due to its design, return a higher I&M range of effects for a South African vehicle parc than for a typical European vehicle parc. Further increasing this range of effect, given a paucity of data around high emitters, therefore seems ill-advised.
- It appears a hybrid approach between COPERT 3 and 4 is justified for the South African case.

4. Results

The control of emissions from vehicles has been the target of relevant European legislation since the 70s. In order to fulfil those requirements, vehicle manufacturers have been improving the technology of their engines and introducing emission control systems. As a result, today's vehicles are more than an order of magnitude cleaner than vehicles two decades ago with regard to conventional pollutants (carbon monoxide, oxides of nitrogen and volatile organic compounds). European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in European Union (EU) member states. The emission standards are defined in a series of EU directives, staging the progressive introduction of increasingly stringent standards, expressed as Euro 1, Euro 2, Euro 3, etc. In order to comply with these standards, the engine technology requires a certain type of fuel. Separate fuel standards are needed to enable the meeting of the emission standards e.g. for petrol vehicles, the Standard EN 228: 1993 is needed to meet Euro 3 emission standards and EN 228: 2004 is needed to meet Euro 4 emission standards. Only emissions of nitrogen oxides (NOx), total hydrocarbon (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO) and particulate matter (PM) are currently (Euro 4) regulated. The following standards apply to petrol passenger vehicles:

Pre-Euro

- Carburetted vehicles

Euro 1

- Fuel injection and two-way catalyst
- The use of unleaded fuel is mandatory.

Euro 2

- Emission standards impose a 30 % and 55 % reduction in CO and HC+NOX respectively.
- Three-way catalyst and small carbon canister

Euro 3

- Impose a 30 % CO reduction, 40 % NOX and 40 % VOC reduction over the Euro II emission standards
- All technologies make use of closed-loop three way catalytic converters for the reduction of pollutant emissions.

Euro 4

- Further requirements is the introduction of on-board diagnostic systems (OBD) and emission conformity in tests at low ambient temperature (-7°C).
- Extended life catalyst

Four key case studies were used to illustrate the use of the emission inventory and dispersion models. These are discussed below.

4.1 Case 1.

Case 1 was to keep the fuel specifications constant (i.e. current specification for 2006), and to use different vehicle parc splits (i.e. 2006 [base year], 2008 and 2015), with no Inspection & Maintenance programme in place.

The simulations showed that for the today's (2006) fuel character[1] and using the vehicle parc for 2008, 2015 and Euro 4, the reduction in carbon monoxide emissions from the base case (2006 vehicle parc split) would be -17.2% (2008 vehicle parc split), -49.3% (2015 vehicle parc split) and -81.7% (Euro 4 vehicle parc only), respectively.

[1] Oxygenates: 3.7 %; Sulphur Content:500 ppm; Aromatics Content: 50 %; Olefins Content: 20 %; Benzene: 3%; Mid Range Volatility: 52 %; Tail End Volatility: 87 %; RVP 65 kPa;

The reduction in oxides of nitrogen emissions from the base case (2006 vehicle parc split) would be -16.5% (2008 vehicle parc split), -46.6% (2015 vehicle parc split) and -89.2% (Euro 4 vehicle parc only), respectively.

The reduction in benzene emissions from the 2006 vehicle parc split would be -19.4% (2008 vehicle parc split), -56.3% (2015 vehicle parc split) and -91.9% (Euro 4 vehicle parc only), respectively.

The reduction in particulate matter emissions from the base case would be -13.9% (2008 vehicle parc split), -10.0% (2015 vehicle parc split) and -71.1% (Euro 4 vehicle parc only), respectively. Although PM emissions would generally reduce with decreasing fractions of Euro1 and PRE-ECE vehicles, the 2015 vehicle parc scenario displayed an increase over the 2008 scenario. This is due to the projected increase in the use of diesel vehicles for 2015, viz. 4.5% (2.7% passenger, 1.6% delivery vehicles and 0.2% busses) over the 2008 vehicle parc.

4.2 Case 2.

In this case Euro 4 enabling fuel specifications was used for different vehicle parc splits, (i.e. 2006 [base year], 2008 and 2015), with no Inspection & Maintenance programme in place.

With no I & M programme, the carbon monoxide emission reductions with the vehicle parc for 2006, 2008, 2015 and Euro 4 from the base case (2006 vehicle parc split) would be -13.1% (2006 vehicle parc split), -28.0% (2008 vehicle parc split), -55.9% (2015 vehicle parc split) and -55.9% (Euro 4 vehicle parc only), respectively.

A similar conclusion can also be reached for oxides of nitrogen, particulate matter and benzene. The oxides of nitrogen emission reductions with the vehicle parc for 2006, 2008, 2015 and Euro 4 from the base case would be -8.5% (2006 vehicle parc split), -23.4% (2008 vehicle parc split), -50.1% (2015 vehicle parc split) and -89.3% (Euro 4 vehicle parc only), respectively.

For particulate matter the emission reductions from the base case would be -8.1% (2006 vehicle parc split), -21.1% (2008 vehicle parc split), -17.4% (2015 vehicle parc split) and -74.0% (Euro 4 vehicle parc only), respectively. For benzene the emission reductions would be -12.1% (2006 vehicle parc split), -29.2% (2008 vehicle parc split), -61.9% (2015 vehicle parc split) and -92.9% (Euro 4 vehicle parc only), respectively.

4.3 Case 3.

Case 3 is the same as Case 1, but with the introduction of an Inspection & Maintenance programme.

If today's fuel formulation is used with vehicle parc data for 2006, 2008, 2015 and Euro 4, and an enhanced Inspection and Maintenance programme is to be introduced, the reduction in carbon monoxide emissions from the base case (2006 vehicle parc split, no I & M) would be -15.1% (2006 vehicle parc split), -29.7% (2008 vehicle parc split), -57.0% (2015 vehicle parc split) and -84.5% (Euro 4 vehicle parc only), respectively. An enhanced I & M programme would therefore result in a decrease of 15.1%, 12.5%, 7.7% and 2.8%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

Although great reductions of oxides of nitrogen emissions are realised with changes in the vehicle parc split, an enhanced I & M programme is less significant with regard to carbon monoxide. The reductions from the base case (2006 vehicle parc split, no I & M) with an enhanced I & M programme would be -8.0% (2006 vehicle parc split), -23.1% (2008 vehicle parc split), 50.2% (2015 vehicle parc split) and -89.4% (Euro 4 vehicle parc only), respectively. The result of an enhanced I & M programme would therefore reduce emissions by -8.0%, -6.6%, -3.6% and -0.2%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

The reductions in benzene emissions from 2006 vehicle parc split (no I & M) with an enhanced I & M programme would be -8.7% (2006 vehicle parc split), -26.5% (2008 vehicle parc split), -60.3% (2015 vehicle parc split) and -92.9% (Euro 4 vehicle parc only), respectively. The enhanced I & M programme would therefore result in a decrease of -8.7%, -7.1%, -4.0% and -1.0%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

The reductions in particulates from the base case (2006 vehicle parc split, no I & M) with an enhanced I & M programme would be -3.2% (2006 vehicle parc split), -16.0% (2008 vehicle parc split), -11.2% (2015 vehicle parc split) and -71.1% (Euro 4 vehicle parc only), respectively. The enhanced I & M programme would therefore have an additional decrease of 3.2%, -2.1%, -1.2% and -0.0%, for vehicle parc splits for 2008, 2015 and Euro 4. With no change in the vehicle parc distribution, the reduction in emission after an enhanced I & M programme would be -2.8%. All particulate matter emission factors reported in COPERT III and IV refer to PM2.5, as the coarse fraction (PM10) is negligible in vehicle exhaust.

4.4 Case 4.

Case 4 is the same as Case 2, but with the introduction of an Inspection & Maintenance programme.

With an Euro 4 enabling fuel formulation is used with vehicle parc data for 2006, 2008, 2015 and Euro 4 and an enhanced Inspection and Maintenance programme, the reduction in carbon monoxide emissions from the base case (2006 vehicle parc split, no I & M) would be -26.1% (2006 vehicle parc split), -38.9% (2008 vehicle parc split), 62.5% (2015 vehicle parc split) and -86.5% (Euro 4 vehicle parc only), respectively. An enhanced I & M programme would therefore result in a decrease of 13.0%, 10.9%, 6.6% and 2.4%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

The reductions in oxides of nitrogen with an enhanced I & M programme are less significant in comparison to the reductions for carbon monoxide. The reductions from the base case (2006 vehicle parc split, no I & M) with an enhanced I & M programme would be -15.7% (2006 vehicle parc split), -29.3% (2008 vehicle parc split), 53.4% (2015 vehicle parc split) and -89.5% (Euro 4 vehicle parc only), respectively. The result of an enhanced I & M programme would therefore reduce emissions by -7.2%, -5.9%, -3.3% and -0.2%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

It is also interesting to note that these reductions are similar to the reductions obtained with the introduction of an enhanced I & M whilst still using the 2006 fuel formulation.

The reductions in benzene emissions with an enhanced I & M programme would be -19.8% (2006 vehicle parc split), -35.5% (2008 vehicle parc split), -65.4% (2015 vehicle parc split) and -94.3% (Euro 4 vehicle parc only) from the base case, respectively. The enhanced I & M programme would therefore result in a decrease of -7.7%, -6.3%, -3.5% and -0.8%, for vehicle parc splits for 2006, 2008, 2015 and Euro 4.

The reductions in particulates with an enhanced I & M programme would be -10.9% (2006 vehicle parc split), -22.9% (2008 vehicle parc split), -18.4% (2015 vehicle parc split) and -74.0% (Euro 4 vehicle parc only) from the base case, respectively. The enhanced I & M programme would therefore have an additional decrease of -2.8%, -1.8%, -1.0% and -0.0%, for vehicle parc splits for 2008, 2015 and Euro 4.

4.5 Atmospheric Dispersion Calculations: Busy Freeway

The Buccleuch interchange, located on the freeway between Johannesburg and Pretoria, also known as the Ben Schoeman Highway, was selected for the case study. The freeway is South Africa's busiest road, with maximum vehicle numbers reaching about 15 000 vehicles per hour at some sections along the highway. The US Environmental Protection Agency's CALINE 4 dispersion model was used to predict ground level air pollution concentrations. The results of the base case scenario (i.e. 2006 fuel formulation and 2006 parc split) is shown in Figure 1 for NOx.

The highest concentration of 2020 µg/m³ is predicted to occur near the currently- located air quality monitoring station operated by the City of Johannesburg Municipality. Using the air quality sampling data at this monitoring station, it is noted that the predicted maximum hourly observation is slightly higher, but within the same order, i.e. observations between 700 µg/m³ and 1600 µg/m³. The predicted CO and SO_2 concentrations, of 11 489 µg/m³ and 108 µg/m³ are also similar to the observations, i.e. 6000 to 10000 µg/m³ for CO, and 40 to 133 µg/m³, for SO_2.

The slight over-prediction is expected to be as a result of the assumption that the current parc of Euro 1 and older vehicles consists of an equal split between Pre-ECE and Euro 1 vehicles. Repeating these simulations with all Pre-ECE and Euro 1 specified as Euro 1, the predicted concentrations reduce to 770 µg/m³, for NOx, 1911 µg/m³, for CO and 97 µg/m³, for SO_2.

4.6 Summary of Results

The study showed that there is a clear reduction in air emissions with the natural progression of the vehicle parc split from 2006 to 2015, whilst still using the current fuel formulation. This reduction is illustrated by example for NOx in Figure 2. The most significant reduction would be obtained when all cars comply with Euro 4. Also shown in the figure is the estimated reduction obtained with the introduction of an I&M programme. The greatest reduction would be with the initial, 2006 vehicle parc, resulting in a NOx reduction of about -8.0%. This reduction decreases as the vehicle parc progresses to Euro 4.

The study also showed that there would be reduction in air emissions with the introduction of Euro 4 enabling fuel specification. This is illustrated in Figure 3, which represents the reduction in NOx emissions for different vehicle parcs (2006, 2008, 2015 and Euro 4). For comparison, the figure also includes the reduction with today's fuel (i.e. Figure 2). Introducing Euro 4 enabling fuel with the 2006 parc would result in a -8.5% reduction, which is similar to using today's fuel with an I&M programme, i.e. -8.0% (see Figure 2).

Figure 1. Receptor locations for Buccleuch Intersection simulations. The values represent maximum NOx concentrations (μg/m³) for the base case (i.e. 2006 fuel and 2006 parc split). The vector represents the wind direction resulting in the highest concentrations at the receptor.

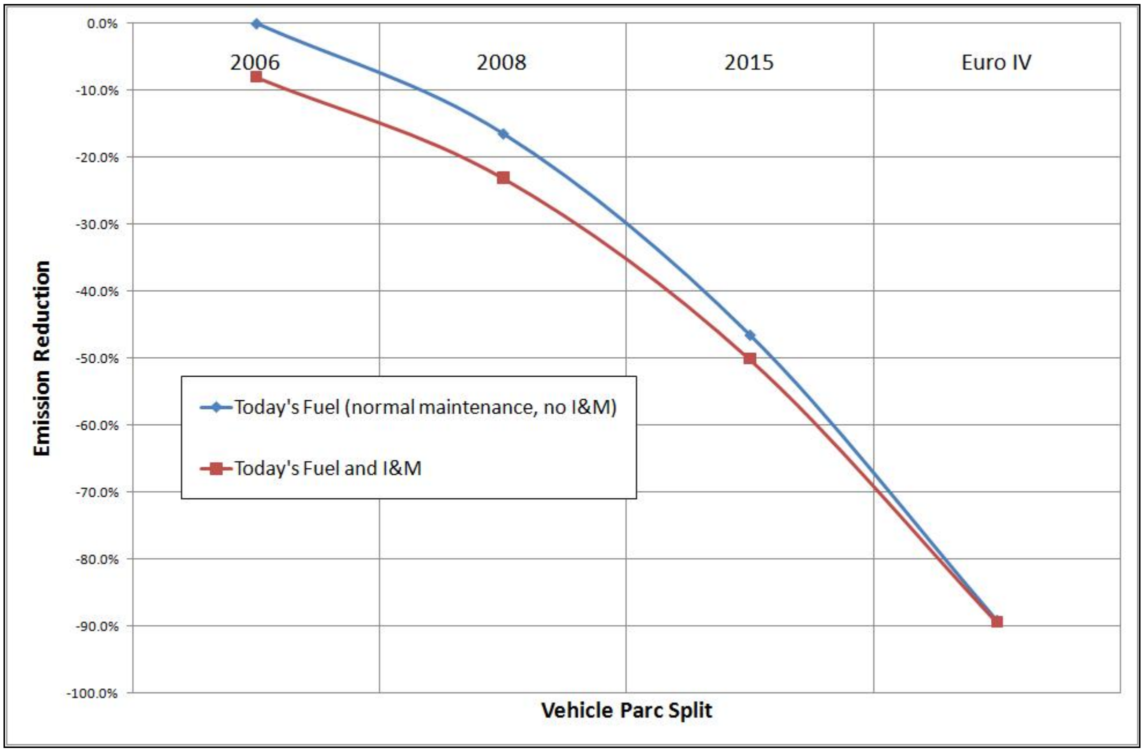

Figure 2. NOx emissions reduction utilising today's fuel specification in the projected vehicle parc splits for 2006, 2008 and 2015, and assuming, as a best case, all vehicles conforming to Euro 4 technology.

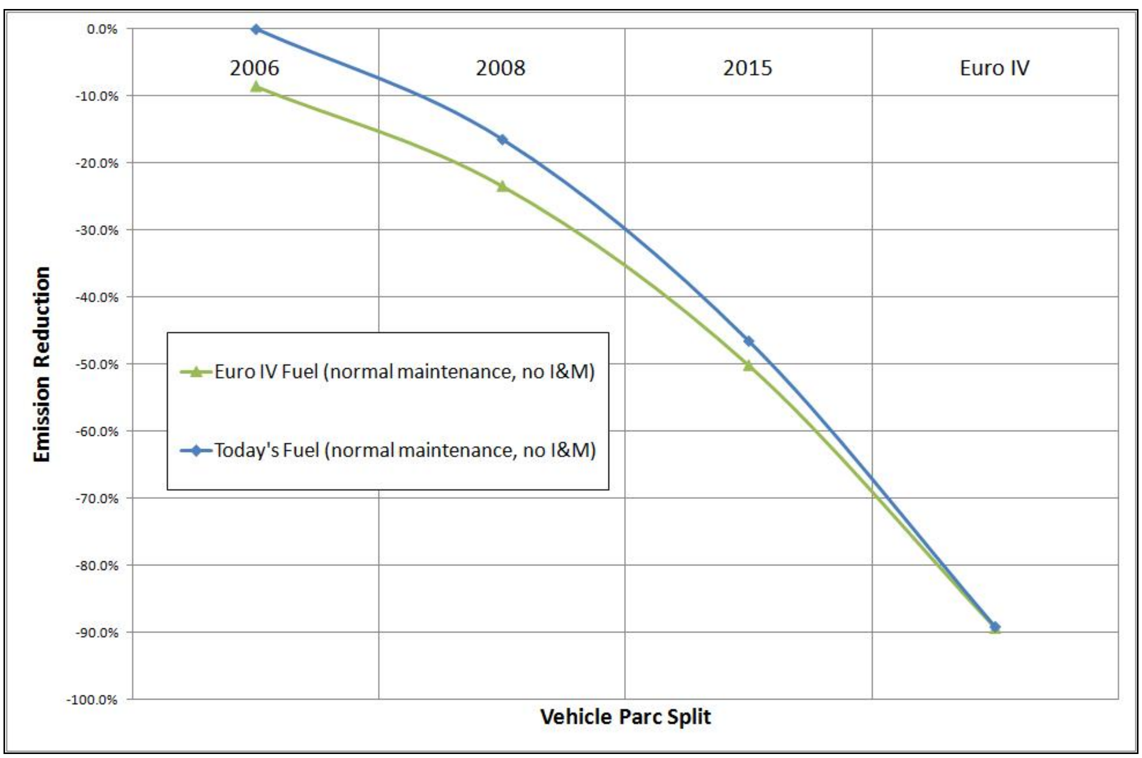

Figure 3. NOx emission reduction with the replacement of today's fuel with Euro 4 enabling fuel specification for different vehicle parc splits. The emission reduction assuming today's fuel is also shown for comparison.

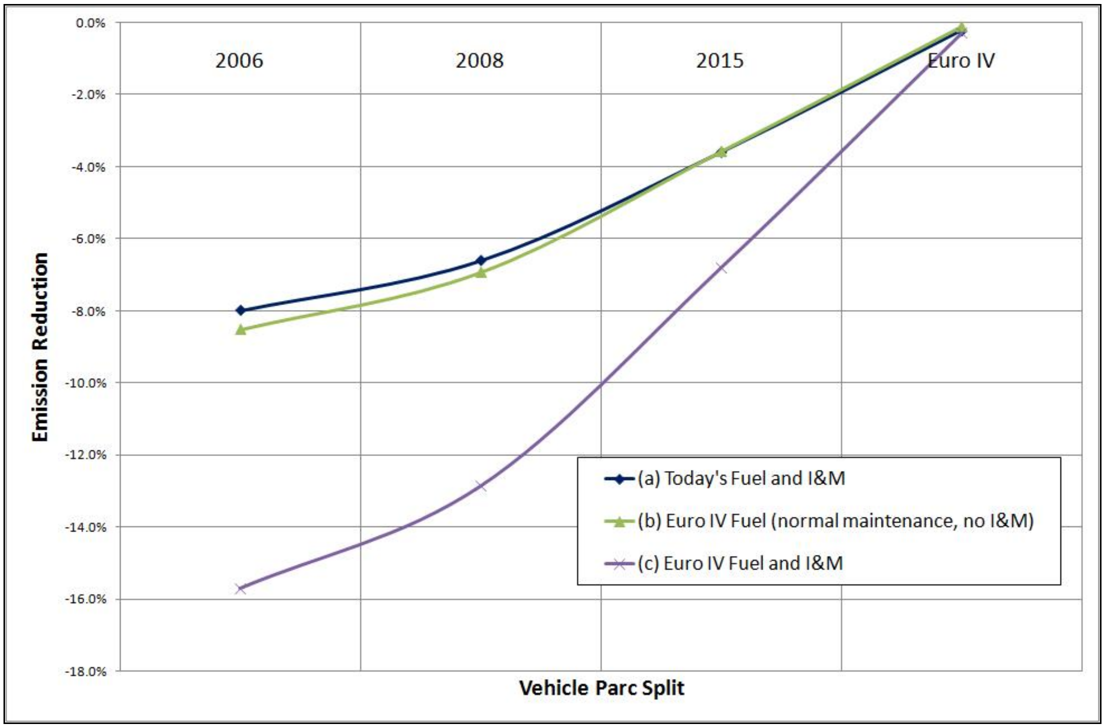

Figure 4: The incremental NOx emission reduction for different vehicle parc with (a) keeping today's fuel, but introducing an I&M programme; (b) the replacement of today's fuel with Euro 4 enabling fuel specification; and (c) replacing with Euro 4 enabling fuel and an I&M programme.

The incremental NOx emissions reductions (i.e. the reduction over and above the reduction which would be obtained due to the natural change in vehicle parc splits whilst still using today's fuel) for the different interventions are given in Figure 4. The largest reduction (-15.7%) would be for a 2006 vehicle parc with the introduction of Euro 4 enabling fuel and an I&M programme. These incremental emission reductions decrease as the vehicle parc changes towards Euro 4.

The emissions for CO, VOC and particulate matter follow similar trends as shown above for NOx. However, SO_2 will only show significant reductions with the introduction of low sulphur fuels, as is the case with the Euro 4 enabling fuels. The simulations assumed 500 ppm sulphur in today's fuel, compared with the 50 ppm sulphur in Euro 4 enabling fuel.

5. Conclusions

An emissions inventory tool was developed, which can be used to calculate and predict a variety of air pollutant emissions and subsequent air concentrations from road going vehicles. The tool was successfully employed to test a number of interventions including vehicle technologies, fuel specifications and Inspection and Maintenance programmes.

The success of the interventions varies between pollutants of interest and the vehicle parc split. Shown below are the reductions with a 2006 parc split for the different pollutants:

Pollutant	Changing Fuel to Euro 4 Enabling Fuel	Inspection & Maintenance Programme
CO	-13%	-15%
NOx	-9%	-8%
VOC	-10%	-8%
PM	-8%	-3%
SO_2	-89%	0%
benzene	-12%	-9%

I&M proved to reduce CO emissions slightly more than changing the fuel spec to Euro 4 enabling, i.e. -15% reduction versus -13%. However, NOx, VOCs and particulate matter would reduce slightly more with Euro 4 enabling specification fuel than the introduction of an I&M programme.

A reduction of SO_2 emissions can only be realised with reduced sulphur content in the fuel.

Changing the vehicle parc split from 2006 to 2008 (i.e. increasing Euro 2, Euro 3 and Euro 4 fractions), would result in a significant reduction in emissions in all but SO_2 emissions, as shown below:

Pollutant	Changing to 2008 parc using Today's Fuel	Changing Fuel to Euro 4
CO	-17%	-28%
NOx	-16%	-23%
VOC	-18%	-26%
PM	-14%	-21%
SO_2	0%	-89%
benzene	-19%	-29%

As shown, a further reduction can be achieved by changing the fuel specifications to Euro 4 enabling or the introduction of an I & M programme. The incremental reductions (i.e. above the effect of changing vehicle parc) obtainable with these two interventions appear to be of a similar magnitude, as shown below:

Pollutant	Changing to 2008 parc using Today's Fuel	Today's Fuel and I & M
CO	-11%	-12%
NOx	-7%	-7%
VOC	-8%	-7%
PM	-7%	-2%
SO_2	-89%	0%
benzene	-10%	-7%

Although not shown above, Euro 4 enabling fuels together with an I & M programme offers the greatest reduction, i.e. CO 39%; NOx 29%; VOC 32%, PM 23%, SO_2 89%; and benzene 36%.

A similar trend is observed when changing the vehicle parc from a 2006 split to a 2015 split:

Pollutant	Changing to 2008 parc using Today's Fuel	Changing Fuel to Euro 4
CO	49%	63%
NOx	47%	53%
VOC	51%	58%
PM	10%	18%
SO_2	4%	93%
benzene	56%	65%

The incremental improvement of introducing Euro 4 enabling fuels is less pronounced than the 2008 example above. This is shown below:

Pollutant	Changing to 2008 parc using Today's Fuel	Today's Fuel and I & M
CO	7%	8%
NOx	4%	4%
VOC	4%	4%
PM	8%	1%
SO_2	89%	0%
benzene	6%	4%

6. Recommendations

The projected natural progression of the vehicle parc changing from pre-Euro and Euro 1 to increasing fractions of Euro 2, 3 and 4 vehicles were clearly shown to result in the most significant reduction in vehicle emissions. This finding applies to all pollutants in the study except sulphur dioxide. Sulphur dioxide emissions are directly related to the sulphur content of the fuel, and therefore reducing sulphur in the fuel would have a direct reduction in emissions. These calculations assumed the fuel correction functions provided in COPERT III & COPERT IV could be used to calculate the effect on emissions when using fuels with different characteristics from the base fuel formulations. Based on these results, it is therefore recommended to:

- Focus on national interventions that would encourage a move towards the introduction of vehicles that conform to Euro 3 and Euro 4 specifications;
- Investigate the effect on air emissions of using local fuel in vehicles complying with Euro standards;
- reduce the sulphur content of fuels to Euro 4 requirements if there is evidence that vehicle emissions contribute significantly to the total urban air sulphur dioxide inventory; and
- for additional air pollution improvements (order of 10%), introduce Euro 4 enabling fuels.

An enhanced I&M programme indicated the potential for significant emission reductions. Given the potentially high fraction of high emitters in the South African fleet, when compared to the

European fleet, the potential reduction could be higher than changing from today's fuel to Euro 4 specifications. It is therefore recommended that a better estimate be obtained of the fraction of high emitters and hence a more realistic estimate of the emission reductions possible due to an I&M programme.

It is recommended that the emission inventory and dispersion modelling tools be applied to include a city/urban block simulation. Such an application covers a different drive cycle and a different vehicle parc split.

Since the emissions inventory tool has been debugged and tested, it is recommended that the project continue with the completion of Phase 2 and Phase 3.

7. References

EEA (1999). COPERT III. Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors, European Environment Agency, European Topic Centre on Air Emission, July 1999.

Ntziachristos L, Kourdis C, Samaras Z and Zierock K-H (2007). Emission Inventory Handbook: Road Transport Revision 6.0, SNAP Codes 070100 to 070500.

Stone A (2009). The Potential Effects Of High Emitters On The Emissions Of The South African Vehicle Parc And On The Range Of Effect Of An Inspection And Maintenance Program, Report to SAPIA, Revision 3.