Selected environmental impacts of energy use by the automobile sector: Findings from a project focussed on Johannesburg and Cape Town.

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Abstract

The transport sector is the major consumer of liquid petroleum fuels, and a major source of greenhouse gas emissions. It had been estimated to contribute 11% of total national greenhouse gas emissions. It is thus a significant contributor to climate change and air pollution with the attendant negative impacts on the climate and human health. In view of this, the South African National Energy Research Institute (SANERI) supported a project, executed by the CSIR, to look at the impact of energy use in the transport sector on the environment, particularly air quality.

This paper is intended to provide information about the project, its findings and recommendations. The paper is based on limited air quality monitoring and pollutant dispersion modelling and analysis work by the Climatology Research Group at the University of the Witwatersrand, with a smaller soil and water contamination monitoring and analysis component. by Starplex Environmental Solutions. A review of relevant policies and strategies of the two cities was undertaken and two stakeholder workshops were held to discuss findings and to formulate recommendations for policymakers.

The two cities were found to have generally different levels of pollutants at the sites monitored and significant differences in their approaches to future transport planning with a view to minimising negative environmental impacts. The lessons from the examination of the different approaches, together with those from other cities can inform future national level transport policy planning. Recommendations around regulatory, legal, technological, fiscal, and awareness issues are provided from the findings of the project and subsequent stakeholder dialogue.

1. Background

The future of the energy sector depends on a critical evaluation of the environmental effects of energy generation, transmission and consumption in various economic sectors that include transport. Energy for transport is dominated by liquid fuels such as petrol and diesel, which are subject to international oil prices, geopolitics, as well as green house gas (GHG) effects. Although transport's share of GHG emissions is admittedly low in developing countries, energy consumption in the transport sector is growing faster than in other sectors [1] as there are large increases in private automobile use [2] and South Africa is no exception. In 2000, 74% of the transport energy used in South Africa was for land transport [3] and this proportion is on the increase due to increases in vehicle population particularly in the cities.

Energy supply and use in the automobile sector causes significant impacts on the environment, and accounts for a large share of global GHG emissions. The environmental problem is aggravated because the emissions occur in close proximity to areas of high human exposure potentials such as found in cities [4] [5]. Cities are identified as places where transport activities, effects and resource management decisions are most focused [6]. Energy use for transport activities causes negative impacts on air quality, water quality (both ground and surface water due to leakages where fuels are stored and to surface drainage) and soil particularly where spillages occur from vehicles or from fuel storage facilities [6].

Extreme air pollution concentrations in the atmosphere are primarily governed by meteorological fluctuations and/or change in emission patterns [5]. Air movement and mixing affect pollution levels, and are dependent upon differences in high and low pressure and the occurrence of temperature inversions. Topography plays an important role in controlling the level of air pollution either by providing a drainage pathway to transport pollution from source to areas down-gradient, or acting as a barrier to pollution movement. It is necessary, therefore, to study different regions in the country in order to understand better the impacts of energy use on the environment.

The National Environmental Management: Air Quality Act 39 of 2004 (AQA) has shifted the approach of air quality management from source-based control to receptor-based control. The basis of this approach will be control of all major sources, including industrial, vehicles and domestic sources in terms of ambient air concentrations and will be the responsibility of Local Government. The main objectives of the Act are to:

- Give effect to everyone's right 'to an environment that is not harmful to their health and well-being'
- Protect the environment by providing reasonable legislative and other measures that (i) prevent pollution and ecological degradation, (ii) promote conservation and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development

The Act makes provision for the setting and formulation of National ambient air quality standards for 'substances or mixtures of substances which present a threat to health, well-being or the environment'. More stringent standards can be established at the provincial and local levels. Vehicular emissions are a major source of air pollution, particularly in urban areas, which in turn exacerbate health and environmental problems. Most of the pollutants from vehicles are listed as priority pollutants and are covered by the standards.

In light of the effects of automobile energy use on the environment, the CSIR carried out a project that was funded by the South African Energy Research Institute (SANERI) titled "The Environmental Impact of Energy Use by the Automobile Sector: A Case of Johannesburg and Cape Town". This project aimed to:

- Provide high quality information by analysing the overall environmental effects of automobile energy use and supply on the soil, water and air in Johannesburg and Cape Town, and to record differences, if any.
- Evaluate whether infrastructure planning in the transport sector would reduce environmental impact, and to identify other technologies that can be put in place to do so.
- Evaluate the environmental, social and economic costs of reducing impacts and to make technological recommendations for policy makers.

Project research questions:

1) What is the current environmental impact of energy use by automobiles in Johannesburg and Cape Town?
2) Are the environmental impacts similar for both cities or are they location specific?
3) Are there any measures in place to reduce the environmental impact of energy use in the transport sector? Are these measures effective?
4) Would infrastructure planning assist in reducing the investigated environmental impacts?
5) What is the environmental, social and economic cost of reducing the impact of transport energy use on the environment?

2. Methodology

A desktop study was conducted to provide a comprehensive review of related literature and to identify hot spots where environmental impacts occur for setting up the monitoring stations.

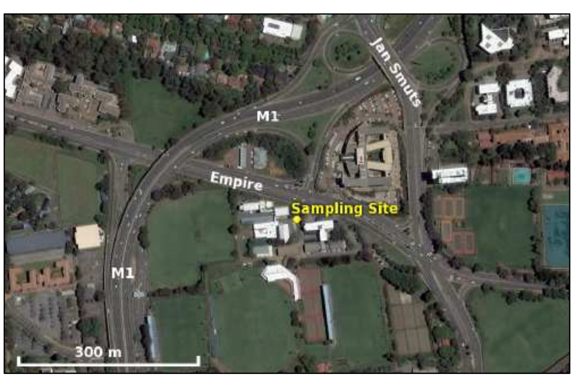

Figure 1: Location of sampling site in Johannesburg.

Air pollution monitoring was conducted after the identification of hot spots for environmental impacts in Cape Town and Johannesburg. Ambient air quality monitoring and data analysis was undertaken through a sub-consultancy by the Climatology Research Group of the University of the Witwatersrand using a mobile monitoring station.

The measurements were taken at the intersection of Jan Smuts and Empire streets in Braamfontein, Johannesburg, and beside the N2 highway near the Cape Town International Convention Centre in Cape Town.

Figure 2. Location of sampling site in Cape Town

Pollutant dispersion simulations were also run for both sites. Pollutants measured at each location included carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), and volatile organic compounds (VOCs) as well as meteorological parameters.

Soil and water contamination assessments and data analysis were conducted under a sub-consultancy by Starplex Environmental Solutions after the selection of study sites and consultation with the stakeholders in June and July 2007. The targeted hydrocarbon compounds of interest were benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN compounds) as well as MTBE and TAME.

Strategies being implemented and those planned to reduce the environmental impacts of automobiles in Johannesburg and Cape Town were evaluated with stakeholder involvement in the first stakeholder workshop. Finally, recommendations for national transport and infrastructure planning, policy and future research were made and presented to stakeholders at a final workshop which considered them and produced a final list of recommendations for consideration by policymakers.

3. Findings

The project provided a 'snapshot' view of ambient air quality at the selected monitoring sites since it was not long enough to attempt multi-year monitoring in different seasons at more numerous sites in both Cape Town and Johannesburg. It nevertheless provides useful comparative data and facilitated a process of stakeholder dialogue that resulted in the development of important policy-relevant observations and recommendations.

Ambient air quality monitoring: The research found that in general, pollutant concentrations recorded in Johannesburg and Cape Town were not comparable (with the exception of carbon monoxide - CO).

Table 1. Summary of instantaneous, hourly and daily concentrations recorded at the monitoring site in Johannesburg for June 2007.

Pollutant	Value	Averaging Period		
		Instanta-neous	1-hour	24-hour
SO_2 (ppb)	Min	0.81	0.82	3.83
	Max	80.60	53.63	26.98
	Avg	12.05	12.06	11.95
H_2S (ppb)	Min	0.03	0.01	0.01
	Max	11.68	2.75	0.92
	Avg	0.98	0.51	0.21
CO (ppm)	Min	0.01	0.01	0.08
	Max	10.58	10.50	5.54
	Avg	2.32	2.27	2.02
CO_2 (ppm)	Min	69.66	15.41	3.85
	Max	798.00	740.25	456.82
	Avg	239.65	237.48	224.62
NO (ppb)	Min	0.47	0.10	7.17
	Max	497.30	474.21	193.71
	Avg	98.19	97.96	97.24
NO_2 (ppb)	Min	0.22	0.43	0.90
	Max	111.0	83.30	59.13
	Avg	28.71	28.67	27.96
NH_3 (ppb)	Min	0.02	0.03	0.20
	Max	67.27	21.04	12.09
	Avg	9.29	8.02	7.47
O_3 (ppb)	Min	5.29	0.44	22.03
	Max	54.17	51.53	40.72
	Avg	32.57	32.39	31.97
Benzene (ppb)	Min	0.01	0.07	0.32
	Max	7.48	5.81	5.81
	Avg	1.69	1.68	1.60
Toluene (ppb)	Min	0.01	0.07	0.10
	Max	11.19	10.31	8.40
	Avg	5.87	5.78	5.02

Significantly higher sulphur dioxide (SO_2), hydrogen sulphide (H_2S), nitrogen oxide (NO), nitrogen dioxide (NO2), benzene, toluene and ammonia (NH_3) concentrations were recorded in Cape Town compared to Johannesburg while O_3 concentrations were lower. Pollutant concentrations also showed a strong correlation with the prevailing meteorological conditions, as periods of increased pollutant concentrations were associated with

Table 2. Summary of instantaneous, hourly and daily concentrations recorded at the monitoring site in Cape Town CBD for August 2007.

Pollutant	Value	Averaging Period		
		Instanta-neous	1-hour	24-hour
SO_2 (ppb)	Min	5.49	5.67	6.12
	Max	217.20	69.52	19.61
	Avg	11.61	11.68	11.51
H_2S (ppb)	Min	0.17	0.01	0.04
	Max	79.80	14.78	2.81
	Avg	4.29	2.56	1.36
CO (ppm)	Min	0.00	0.01	0.08
	Max	10.63	9.26	5.15
	Avg	1.15	1.13	1.13
CO_2 (ppm)	Min	0.34	0.03	1.72
	Max	431.20	431.20	431.20
	Avg	81.54	81.16	77.05
NO (ppb)	Min	0.40	3.96	17.48
	Max	1582.00	1228.83	480.30
	Avg	157.87	157.89	156.86
NO_2 (ppb)	Min	0.02	0.11	12.56
	Max	845	241	88.41
	Avg	45.62	45.10	44.84
NH_3 (ppb)	Min	0.04	0.01	4.89
	Max	836.20	272.37	43.51
	Avg	28.99	17.50	16.23
O_3 (ppb)	Min	0.06	0.02	24.88
	Max	69.95	48.85	30.29
	Avg	28.08	27.90	27.87
Benzene (ppb)	Min	0.01	0.08	0.38
	Max	41.19	33.35	15.74
	Avg	3.18	3.17	3.13
Toluene (ppb)	Min	0.09	0.40	1.65
	Max	86.38	76.99	47.71
	Avg	9.33	9.30	9.14

conditions promoting the stagnation of pollution in Cape Town (conducive to brown haze conditions). Air quality impacts associated with emissions from vehicles can therefore be determined to be based on location-specific conditions such as the prevailing local meteorology and underlying topography which influence the dispersion of potential of pollutants. The proximity of certain industrial activities may also influence observed pollutants, for example the dry dock and gas turbine power plants in the case of Cape Town.

Dispersion modelling: Simulations were undertaken to determine the impact of emissions from vehicles at the monitoring sites in Johannesburg and Cape Town. Use was made of both locally derived emission factors (where available) and built-in British emission factors to determine oxides of nitrogen (NOx), SO2, particulate matter of less than 10 microns in diameter (PM10), CO and benzene concentrations.

Table 3. Predicted maximum hourly concentrations at the monitoring in Johannesburg, using local and British emission factors.

Pollutant	Units	Predicted Maximum Hourly Concentrations		City of Johannesburg Hourly Air Quality Guideline
		Local	British	
NO_x	ppb	751.76	739.620	104
SO_2	ppb	24.36	-	130
PM_{10}	µg/m^3	17.17	36.72	-
CO	ppb	6 133.80	2 652.40	25 800
Benzene	ppb	4.24	-	-

Table 4. Predicted maximum hourly concentrations at the monitoring site in the Cape Town using local and British emission factors.

Pollutant	Units	Predicted Maximum Hourly Concentrations		City of Cape Town Hourly Air Quality Guideline
		Local	British	
NO_x	ppb	1 537.3	1 438.9	150
SO_2	ppb	38.712	-	47
PM_{10}	µg/m^3	23.187	63.72	-
CO	ppb	13 623	5 981.9	-
Benzene	ppb	9.47	-	-

In general, a good agreement is observed between predicted NOx concentrations using local and British emission factors in both Johannesburg and Cape Town. Hourly NOx concentrations exceeded the respective guideline in both Johannesburg and Cape Town while daily NOx concentrations were below the guideline in Johannesburg.

Predicted SO2 and PM10 concentrations were low in Johannesburg and Cape Town, when compared against their respective guidelines (where available). Ambient hourly CO concentrations were below the guideline in Johannesburg, with a maximum hourly concentration of 6 133 parts per billion (ppb) and 2 652 ppb using the local and British emission factors, respectively. In Cape Town, maximum hourly concentrations were 13 623 ppb and 5 982 ppb, respectively. Maximum hourly benzene concentrations were 4.24 ppb and 9.47 ppb in Johannesburg and Cape Town, respectively.

Soil and water monitoring: The work was a smaller component of the project. It was hampered by the reluctance of most service stations to participate in the project. Those that agreed did so on condition their identities were not revealed. This made any attempt at adopting a sampling approach futile, and the results cannot be regarded as representative. Nevertheless issues that would have to be looked at in future research were raised. Key recommendations were measures to bring some service stations up to the new SANS standards:

- Need for monitoring wells to be installed around tank farms.
- Need for improved storm water management including the installation of separator tanks/pits to prevent the mixing of storm water from potentially contaminated areas with clean storm water.

City strategies: Both the City of Johannesburg and the City of Cape Town have developed various strategies to address emissions from vehicles in both these areas. Both cities have recognised the contribution of vehicle emissions to deteriorating urban air quality and have taken steps to monitor and implement measures to reduce vehicle emissions. Most of the strategies are not yet implemented, but Cape Town seemed to be ahead of most cities in its efforts at building a sustainable transport system. The City of Tshwane participated at the final stakeholder workshop and shared their vision and plans around transport and environment, and was keen to learn from the other cities that have gone further in implementing their strategies.

Examples of costs of selected strategies: City of Cape Town

Travel Demand Management (TDM)

The focus of this strategy is to promote a diversity of sustainable travel modes and practices that will influence the choices made by commuters in order to reduce the overall number of trips, minimise travel time and optimise travel cost. The City of Cape Town has identified the following TDM measures for implementation:

Park and ride

The focus of this project is to encourage commuters to park their vehicles at the rail stations and to use the train for the remainder of their journey. A total of 27 stations were identified and this list was narrowed down to 12. The major cost elements include consultancies, design, construction, management and maintenance costs. The budget is approximately R47m. Design work is complete and construction is to commence in June 2009.

Large Employer Programme

Aims to develop partnerships between the City of Cape Town and four other large employers in Cape Town in order to assist large employers to focus on the travel needs of their employees in an effort to reduce congestion. Various interventions such as car pooling; adoption of flexi hours; and telecommuting will be considered. Incentives are to be provided in order to motivate and encourage employees to make use of these. This project may go to tender in mid 2009 subject to availability of funds.

Integrated Rapid Transit

The City of Cape Town has unveiled a multi billion rand public transport plan to alleviate traffic congestion, reduce transport times and stimulate new developments. Currently the City is planning to construct bus lanes and cycle lanes on Koeberg Road and the R27 as far as Blaauwberg Road and beyond. It is estimated that 5 000 public transport passengers per hour in the peak direction would immediately benefit from these improvements during peak periods, and it is hoped that the demand for public transport rather than for private car travel will increase in future. Some 90 km of bicycle paths have been built throughout the city, while funding has recently been approved for 14 new projects that improve pedestrian access to public transport.

The new Bus Rapid Transport (BRT) system offers benefits similar to a light rail system but at one twentieth of the cost. It will consist of dedicated bus and taxi lanes on a number of routes across the city. The system also provides for the reorganisation of the bus and taxi industry according to a smart card system for all modes of public transport. The first phase of the new BRT system which will initially cover the Cape Town Central Business District and link to the Cape Town International Airport, will cost R2.8 billion.

Air quality management

The city's Specialised Environmental Services air quality management work encompasses air pollution control and diesel vehicle testing. By March 2009 there were three vehicle testing teams conducting roadside tests. The costs associated with one such team were given as approximately R460 000 for capital equipment including instrumentation, consumables and safety wear, and R5 800 per annum recurrent costs.

Transport Planning Vehicle Emissions Working Group

The City of Cape Town has established a Transport Planning Vehicle Emissions Working Group to address key objectives of the Air Quality Management Plan, one of which is to control vehicle emissions. The City is currently in the process of developing a strategy to 'green' its vehicle fleet.

4. Stakeholder Workshop observations and recommendations

The two stakeholder workshops produced a range of observations and recommendations which are classified into regulatory and legal, information and awareness, technological, and fiscal/tax issues. While the stakeholder suggestions put forward at the first workshop that roadside soil sampling would have been more relevant for comparison with the ambient air monitoring work have merit, the project proposal did not envisage soil sampling next to the road. It specifically called for monitoring at service stations and outlined the methodologies for the sampling. The sampling of soil next to the road would be interesting but was outside the scope of the project and could be the subject of a different study. The small sample size due to the reluctance of service station operators to participate means the soil and water contamination findings are not representative of the situation in the subject cities. The findings are at best indicative of likely problem areas.

The Department of Environmental Affairs and Tourism (DEAT) participated in the final stakeholder workshop and made a presentation that illustrated the issue of urban air quality as resting on vehicle technology, appropriate fuel standards and an inspection / maintenance and traffic management system. The presentation also indicated that steps were underway to declare vehicles controlled emitters. Several shortcomings were highlighted including the slow movement in regulations around engine technology, and the limited enforcement capacity for enforcement of maintenance standards. A new vehicle emission regime was contemplated in terms of section 23 of the Air Quality Act to regulate emissions of vehicles when they are declared as controlled emitters. The resulting standards will only apply to newly manufactured vehicles. Municipalities will be encouraged to develop by-laws to deal with emissions of vehicles already on the road.

Regulatory and Legal issues

DEAT, working with other relevant governments departments and stakeholder should set national fuel and vehicle specifications. There was also need to ensure availability of technology to meet the set standards.

It was important not to lose sight of the contribution of smaller vehicles like two stroke engine motorcycles to toxic, non carbon emissions since lubricating oil is normally added to fuel in such engines. The focus tends to dwell too much on larger vehicles like SUVs and their higher carbon emissions.

The vehicle emission standards associated with the upcoming controlled emitter status of vehicles will apply only to new vehicles. This leaves out old vehicles and there seemed to be no coordinated approach to deal with these.

There are issues around car sharing that need to simplified, for example the provisions of the Road Traffic Act for occupants of shared cars, and tax implications around various car sharing arrangements.

Regarding the possibility of very low cost vehicles coming to South Africa from India for example, it would be undesirable to encourage greater use of cars as this would worsen congestion and emissions. The emphasis should be on improved public transport options.

Localised use of flex fuel vehicles would be a smart way to introduce flex fuel vehicles without the need to set up extensive national infrastructure.

The disposal of old vehicles was a complex issue and a 'toolkit' of diverse options is needed to deal with it.

Monitoring vehicles in low income settlements where many of the oldest vehicles end up after they are officially scrapped. Such vehicles were normally in very poor condition.

Kenya has a large 4-8 year old fleet of imported used Japanese vehicles. Acquiring such vehicles would remove the worst offenders from South Africa's roads. In addition, it may be worth finding out how Kenya has been able to maintain such relatively advanced vehicles.
Enforcement of vehicle odometer logging which is provided for (but hardly recorded) at the time of licensing would provide valuable data on kilometres driven.

Information and awareness
Stakeholders were impressed with Tshwane's work with synchronisation of traffic lights. There was a suggestion that Tshwane could share with other cities the technology used, which could be magnetic strips, timing or TV counters.
Stakeholders looked forward to a transport centre for public information and awareness that SANERI was setting up in Midrand.

Technological issues
The steep terrain in some areas of South Africa would make them unsuitable for bicycles. In China there is a growing trend towards electric bicycles that could also be pedalled, but the cost of such bicycles was also very low in China.
Some Tshwane traffic signals are solar-powered. This avoids a situation where power cuts automatically lead to traffic chaos. New technology brings with it new requirements for repair and maintenance, and the need to upgrade facilities, for example to be able to deal with computerised vehicles.
SANERI's smart grid initiative, mentioned during the final stakeholder workshop was welcomed. This focussed on electrification of public transport and was aimed at rail and (e.g. light rail, trams) and hybrid systems.

Fiscal and tax issues
Tax incentives may be useful in certain cases, e.g. for promotion of hybrid vehicles, scrapping old vehicles, and bringing down public transport costs.
Cash incentives could be provided for the repair or scrapping of old vehicles. The infrastructure to competently repair and maintain vehicles was needed.

5. Conclusion

The project brought together a diverse group of stakeholders and, in addition to the technical exchanges facilitated productive interaction in a neutral environment. The interaction brought out the need for greater sharing of strategies and experiences between municipalities, and the importance of engaging with national-level policymakers to ensure that barriers, in particular legal and regulatory barriers such as those identified by the project and are beyond the control of local authorities, are addressed.

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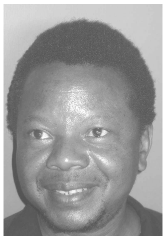

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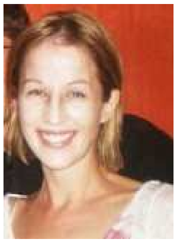

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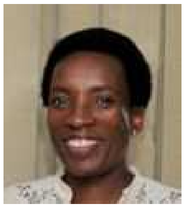

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