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Mitigation Action Plans & Scenarios

ENERGY MODELLING FOR THE TRANSPORT SECTOR
A summary of the SATIM methodology

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By the Systems Analysis & Planning Group, Energy Research Centre, University of Cape Town

Introduction

The energy consumption of the transport sector in South Africa is large, totalling around 28% of total final consumption (TFC) in the national energy balances. The bulk of this energy demand (97%) is in the form of liquid fuels, accounting for 84% of the national liquid fuel demand (DoE, 2009) (IEA, 2011). The evolution of transport demand, both in terms of its magnitude and the technologies and energy carriers meeting demand, is very uncertain.

Structural assumptions and modelling decisions

The transport sector input data of the SATIM model disaggregates road vehicles by basic vehicle type and fuel type, for instance 'diesel passenger car,' but does not at this stage disaggregate by technical specifications like engine size. While such disaggregations can be useful, this level of detail would create problems in a cost optimised model because the choice of larger more expensive cars by the consumer is at best only partially based on cost. Bounds on penetration would have to be carefully constructed to produce realistic results. Rail is disaggregated by its broad energy services but inter-city passenger rail has not yet been included as there is no data in the public domain. At this stage pipeline freight, passenger and freight aviation and navigation, fuelled by heavy fuel oil (HFO) are combined in one sub-sector called 'Other' and are represented by generic fuel based technologies without efficiency and cost detail.

Purpose

Energy economy environment models such as TIMES are often used to look at opportunities and costs of reducing greenhouse gasses (GHGs). The South African TIMES model (SATIM) has been developed for this purpose and its methodology is documented online. The transport sector module in SATIM is relatively highly developed due to investment from a number of dedicated transport studies and because the data for the road transport sub-sector, for instance the licensing database and fuel and vehicle sales, is quite detailed and well maintained by the responsible government and industry institutions. The sector has many of the characteristics of developing nations, including a large, partly regulated minibus taxi fleet and a growing rate of motorisation. Hence this module of SATIM may be of interest to developing countries.

The full SATIM methodology is available on the Energy Research Centre website http://www.erc.uct.ac.za/
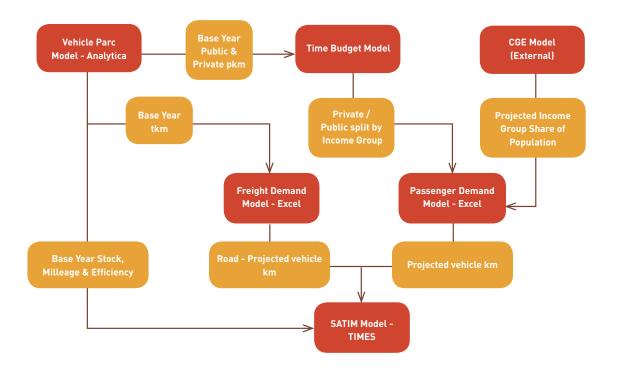
Much recent effort has gone into the development of sub-models that estimate the base data and exogenous demand for input into the TIMES model. The functions of these sub-models and their platforms are summarised in Figure 1 and briefly described below. These models are outlined in detail in the full methodology document.

The vehicle parc model

A vehicle parc model, calibrated over seven model years from 2003 to 2009, was developed to provide a comprehensive picture of the baseline vehicle parc, the disaggregation of vehicle classes and technologies, and the activity level of those classes and technologies.

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GENERALISED SYSTEM OF PRE-PROCESSING TRANSPORT SECTOR INPUTS FOR SATIM USING SUB-MODELS

This is fundamentally an accounting model that is used to refine baseline assumptions for vehicle, mileage, scrap rates and fuel economy. Initial best estimates are made for each of these parameters and then refined so that:

▶ Aggregated Vehicle sales adjusted by assumed scrap rates agrees with the licensing database for the calibration years
▶ Aggregated fleet fuel consumption based on assumed fuel economies agrees with the database of fuel retail sales for the calibration years.

Selected points of interest include:

▶ **Vintage profile:** Weibull distributions are used to model the rate of scrapping of vehicles as a function of their age so that a vintage profile for the fleet can be determined.
▶ **Vehicle mileage:** SATIM, lacking any local data, assumes a 4.9% annual decay in mileage across all vehicle classes which is what has been observed for passenger cars in the US (Jackson, 2001) and Kenya (University of California at Riverside, Global Sustainable Systems Research, 2002).
▶ **Fuel Economy:** These were determined from a review of South African studies and the IEA MoMo model and then calibrated.

▶ **Occupancy and Load Factor:** These were determined from a review of African and South African studies and the IEA MoMo model but remain difficult to verify.

Future improvements in vehicle fuel economy

It can be demonstrated that a future sustained annualised improvement of 1% in fuel economy until 2050 is feasible with current technology for gasoline non-hybrids given a complete shift in consumer preference to small cars. Globally, future improvements are thus likely to be greater but acting against this is observed fuel economy improvements in South Africa lagging developed markets (Cuenot & Fulton, 2011). SATIM therefore assumes a 1% annual fuel economy improvement over the model window.

Technology investment costs and market penetration

The investment cost assumptions for new transport technologies are all derived from the South African Long Term Mitigation Scenarios (LTMS) project with the exception of the costs for electric passenger cars

which have been updated to reflect development of this technology. There has not been a heavy investment in refining cost estimates because this sector of the SATIM model is not solved as a pure least cost optimisation with technologies being fairly tightly constrained by bounds on penetration. This part of the model is used as a scenario model with alternative penetration rates being tested against one another.

Using the time budget model to project passenger land travel demand

Time-use and travel surveys from numerous cities and countries throughout the world suggest that the travel time budget is on average approximately 1.1 h per person per day across the spectrum of per capita income (Schafer & Victor, 2000). Schafer and Victor raise the caveat that the stability of average travel time budget holds only for travel by all modes and that time spent in motorised modes rises with income and mobility as people shift from slow non-motorised modes to motorised travel. As this shift tends to completion, however, total motorised travel approaches 1.1 hours. Thus an analysis across income groups must consider that at the lower income end the time budget will include some non-motorized transport which would be less at the upper income end of the scale, but for a large population the average time budget for all income groups will be around 1.1 hours.

The projection of energy demand for land transport required an exogenous input of future passenger travel, in passenger.km, into the time budget model. The method used to calculate the demand for passenger travel can be summed up as follows:

- **Passenger demand** for road and rail was modelled for three income groups representing low-, medium- and high-income households.

- **Motorisation** (car ownership) per capita for each of the income groups was estimated for the base year using survey data (DoT, 2005).

- **Assumptions** around ratios of public and private transport, average speed and travel time budget were made for each of the income groups and used to calculate their net demand for passenger travel. Due to the sparseness of activity data the model was calibrated to match the vehicle parc model for only

two modes, private and public, for the base year of 2006.

- **Mobility** not met by private transport was assumed to be met by public transport and distributed between modes according to anticipated investment in infrastructure supporting each of the modes.

Projecting demand for freight on land

The sector GDP projections of a CGE model formed the basis for the freight model. As GDP grows the quantity of goods that must be transported grows proportionally and we can model this simplistically as follows

$$TKM_i = e_i \times (1 + GRGDP)_i \times TKM_i - 1 \qquad \textit{Equation 1}$$

Where:

TKM	=	demand for freight transport in units of ton.km
e_i	=	the elasticity of freight demand with respect to transport GDP
	=	(1 + % change in freight demand)/ (1 + % change in GDP)
GR_{GDP}	=	transport GDP growth rate

Calculation of future energy demand from road vehicles

First a projection for vehicle-km is calculated for each demand using an occupancy (passenger/veh for passenger vehicles) or load factor (tons/veh for freight):

$$\text{Passenger } VKM_{ti} = \frac{PKM_{ti}}{O_{ti}} \qquad \textit{Equation 1}$$

$$\text{Freight } VKM_{ti} = \frac{TKM_{ti}}{L_{ti}} \qquad \textit{Equation 2}$$

Where:

VKM_{ti}	=	vehicle-km projection for demand i in year t,
PKM_{ti}	=	passenger-km projection for passenger demand i in year t,
TKM_{ti}	=	ton-km projection for freight demand i in year t,
O_{ti}	=	vehicle occupancy for passenger demand i in year t,
L_{ti}	=	loading for freight demand i in year t.

Then, for each year, the shortfall in vehicle-km cpacity for each demand i is calculated by taking the difference between the capacity of the vehicle parc for demand i in that year and the vehicle-km demand projection for that year, and used to calculate the total vehicle sales for vehicles that year. Since vehicle vintages are tracked, the 'sales' calculations is for the vintage for that year.

$$S_{ti} = \frac{VKM_{ti} \ (P_{tiv} \ x \ AF_{ti \ v})}{AF_{ti}} \qquad \textit{Equation 3}$$

Where:

S_{ti} = Sales in year t for vehicles vintage t that can meet demand i,

P_{tiv} = Population of vehicles vintage v in year t that can meet demand i (this changes each year as vehicles from the vintage are scrapped),

AF_{tiv} = Average km/year that vehicles vintage v is expected to drive (this decreases as the vehicles get older).

Then shares of the sales for technologies competing for a particular demand are imposed (different ones for different scenarios) exogenously. Assuming that all technologies for a particular vintage have the same capacity (drive the same number of km per year) and that their capacity will be fully utilized allows us to calculate the fuel used by each technology as follows:

$$F_{tijv} = P_{tijv} \ x \ AF_{tiv} \ x \ 100 \qquad \textit{Equation 4}$$

Where:

F_{tijv} = Fuel used in year t to meet demand i by technology j, vintage v,

E_{tijv} = Fuel economy (l/100km) for technology j, vintage v, in year t to meet demand i.

Conclusion

The methodology of the SATIM model, which evolved from the LTMS, has been documented and is available online. SATIM is a live project and while work continues on the transport sector the current state of the model is quite detailed and likely to be of interest to researchers active in this sector, particularly with regard to initial assumptions of vehicle activity for models and the projection of demand for passenger transport, taking into account growing motorisation.

References

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South Africa's LTMS

The Long Term Mitigation Scenarios (LTMS) was a cabinet-mandated process from 2005-2008, led by the then South African Department of Environmental Affairs and Tourism, to establish the evidence base for a national low carbon development path. Key to the process was its unique blend of facilitated stakeholder engagement and rigorous research.

The LTMS arose out of the realisation that South Africa would need to contribute its fair share to greenhouse gas mitigation. Greenhouse gas emissions in South Africa come mainly from energy use and supply. Moving to a low carbon development path would require a major shift in thinking and in action. Hence a blend of process and research was critical when assessing mitigation potential within the country. Having accurate numbers would build confidence, but equally important was that a wide range of key stakeholders within South Africa agreed that the numbers were credible.

The LTMS research was peer-reviewed and found to be of best practice. Reviewers recommended sharing the experience with other developing countries. From this recommendation the MAPS Programme was born. For more information see http://www.erc.uct.ac.za/Research/LTMS/LTMS_project_report.pdf.