Potential transportation measures to reduce South Africa's dependency on crude oil

M Vanderschuren

R Jobanputra

T Lane

Centre for Transport Studies, Faculty of Engineering and the Built Environment, University of Cape Town

Abstract

Transportation, including the movement of people and freight, accounts for over 60% of all oil consumed globally, and the world's transportation systems are over 90% dependent on oil and oil by-products. Oil represents the single largest item on South Africa's import account. Gasoline and diesel fuels, which are almost exclusively used for transportation services, form a significant proportion of these imports.

Globally, transport systems have been built on an over-reliance on cheap oil, allowing towns, cities and the movement of people and goods to be designed around the automobile. People in most South African cities require the use of motorised transport in order to travel efficiently, as public transport systems either do not exist, are too sparse or are difficult to use in many areas.

The predicted depletion of oil and thus rising prices will significantly affect the choice of transportation systems and their use, as well as increase South Africa's vulnerability to 'oil shocks'. Transport planning policies must, therefore, prepare for the likelihood of such shocks and ameliorate them via policy options. A precautionary approach needs to be adopted to reduce our dependency on oil.

This paper addresses the global shift towards the reduction of transport's dependency on, or reduction in, oil consumption and describes potential ways in which South Africa can reduce its oil dependency along with an indication of a timeframe for implementation.

Keywords: transport, energy impacts, alternative fuels, fuel efficiency

Introduction

Nearly 80% of the primary energy supply imported into South Africa is in the form of crude oil. This represents the single largest item on the country's import account. Gasoline and diesel fuels, which are almost exclusively used for the transportation of goods and passengers (see Figures 1 & 2), represent a significant proportion of these imports and their demand is continuously increasing.

Internationally, especially in Europe, negative environmental impacts related to transport, such as global warming, have led to research in exploring ways to reduce fuel consumption and pollution. In South Africa, research of this nature has only been undertaken over the last couple of years, largely as a result of the desire of the Department of Minerals and Energy (DME) to reduce oil imports.

Besides these well-documented negative transport impacts (congestion, pollution, road fatalities and global warming), 'Peak Oil' has become a major concern in recent years. Researchers from different backgrounds (ASPO, 2008) are debating on the probability that the world's oil producers will not be able to meet the demand for oil in the near future. Rising prices over the last few years and increased demand are making oil a scarce commodity and the impacts on mobility and the economy are being felt daily.

Freight transportation consumes a significant amount of transport fuels. However, despite the fact that there is considerable research in and incentives to reduce the environmental impact of freight, there is little research or documentation in relation to the reduction of fuel consumption by freight and it is, therefore, omitted from this study.

Oil consumption, from a transport perspective, is clearly driven by demand for travel or mobility patterns, be they via road, rail or air, freight or pas-

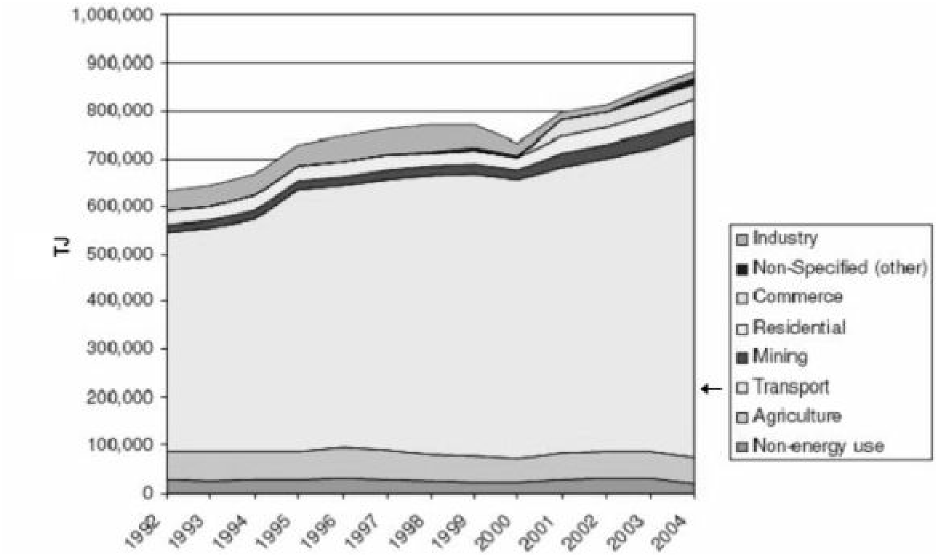

Figure 1: Sectoral consumption of petroleum products
Source: DME (2006)

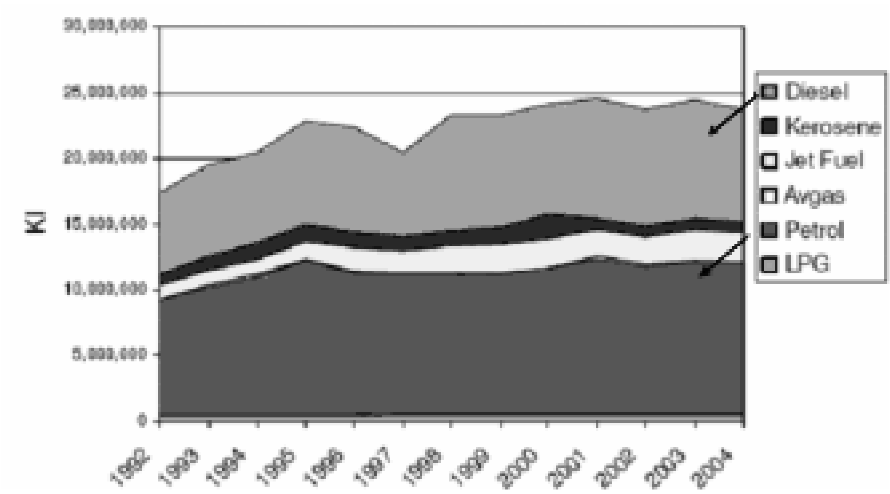

Figure 2: Petroleum consumption within the transport sector
Source: DME (2006)

senger related. Mobility is linked to land-use (and changes thereof), changes in population due to migration, accessibility and opportunity as well as other health issues (e.g. HIV/AIDS). However, changes in land-use, migration and reasons for migration are notoriously difficult to predict and are thus assumed to occur in the manner they have been over the recent past within South Africa. This paper is, therefore, focussed on measures that would reduce fuel consumption which can reasonably be quantified, either individually or in combination up to 2030.

Study approach

In order to establish feasible measures for South Africa, the following investigations were undertaken:

- A scan of internationally adopted options was initially undertaken to enable appropriate informing parameters to be taken forward (for the purposes of this paper, many options have been discarded as there is either no sufficient benefit from them or there is not enough accurate data to justify their inclusion);
- Research of local work has been incorporated into the breadth of the study or else integrated within it;
- Practices used elsewhere and synchronous local practices were assessed in terms of their feasibility for future efficiency strategies.

From available and appropriate data, an estimate of the energy effect of options was calculated to ascertain the effectiveness and suitability of feasible options. The estimates were carried out up until the year 2030 and compared to a 'business-as-usual' case, on a scenario basis.

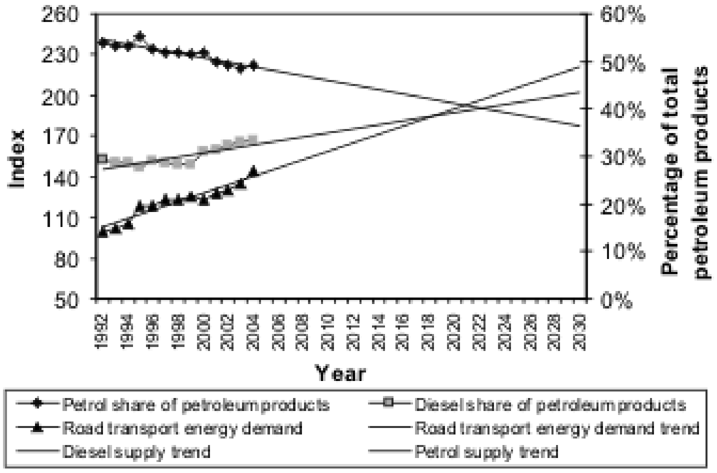

Figure 3: Trends in the business-as-usual scenario

In drawing any conclusions or recommendations, the study has relied on available data and, where possible, adapted the reported energy or other effect based on an assessment of likely local conditions rather than scientific proof.

The Centre for Transport Studies at the University of Cape Town, is currently in the process of planning more scientific studies in this regard.

Potential measures to reduce oil dependency

Business-as-usual

If current trends continue, road transport energy demand will continue to increase in the future (see Figure 3). From data on the domestic supply of petroleum products in South Africa (DME, 2006), it is evident that diesel products are gaining market share at the expense of petrol products.

Innovations, such as the improvement of conventional fuels, the change in vehicle design and alternative motor technology development are ongoing. Generally, South Africa is not in a position to influence innovation as a follower and, therefore, these changes are included as part of the business-as-usual scenario. A brief review of these innovations reveals that:

- Improving conventional fuels should lead to less pollution and will only have a minor effect on fuel efficiency. Refinery efficiency declines as attempts to reduce the sulphur content of fuel are increased. This could result in a greater demand for crude oil in order to produce the same volumes of fuel. A clean fuel policy has been adopted by the national government and the implementation of Euro II, Euro III and Euro IV standards has started (January 2006).
- The design of vehicles is constantly evolving. Although South Africa has its own car manufacturing industry, research and design changes are mainly determined overseas. The production and early adoption of small vehicles and vehicles with a reduced air resistance will reduce fuel consumption. However, international trends show that fuel efficiency improvements have been counter balanced by an increased vehicle size and until recently, the overall effect was neutral.
- Research with regard to alternative propulsion (motor technology) is ongoing and the effects of changes in technology can, therefore, only be determined in the long term. As indicated, South Africa can only influence the market penetration of alternative propulsion by being an early adopter of new technologies.
- Although engine sizes are often larger, diesel vehicles are more fuel efficient than petrol driven vehicles typically by about 30–35% (UDEEE& ER and EPA, 2008). The current trend towards more diesel vehicles (see Figure 3) if sustained, is estimated to result in a 17% reduction in petrol consumption by 2030, which equates to a 6% crude oil dependency reduction.

Since 2006, the share of diesel cars (out of total new car registrations) exceeded that of petrol cars in Western Europe. In 2007 diesel vehicles constituted 53.3% of the market, up 36.3% from 1992 (EAMA, 1992). Naamsa (2008) reports that diesel vehicles (private cars and light commercial vehicles) accounted for 20.8% of South African new vehicle sales in 2006, up from 15.4% in 2000. As the South African vehicle market tends to mirror and lag behind the European vehicle market, it is expected that the local market share of diesel vehicles will continue to increase in the future.

However, this growth in market share might not be sustained indefinitely. Rinaldo Rinolfi, director of the engine division of the Fiat Research Centre and dubbed the father of the common-rail diesel, and General Motors expect petrol cars to start dominating the European market again from 2015 onwards (Ciferri, 2005). The reason for this will, most likely, be the increased costs associated with producing diesel vehicles that comply with Euro 5 (effective from 2010) and Euro 6 (effective from 2015) emissions standards.

A global diesel shortage is developing, following rising demand in (amongst others) the USA, the European Union, China and India (Gue, 2006). This dilemma is exacerbated by reduced refining capacity resulting from more strict environmental regulations. In South Africa, this demand is affected by open-cycle gas turbine power generation plants, industrial and commercial use of back-up generators running on diesel, and an expanding freight transportation industry (Venter, 2008). There is some concern regarding the future availability and affordability of diesel, as all diesel production and logistics facilities are already working at full capacity to supply the ever growing demand (Parker, 2008). Therefore, no additional savings attributable to an increase in the share of diesel vehicles (above and beyond those already included in the business-as-usual trend) is expected.

It needs to be mentioned that the focus of this study is measured in transport. Changes in the South African energy supply mix are excluded.

Alternative fuels and propulsion systems

Recent high oil prices and climate change considerations have spurred national and international interest in bio-fuels, as bio-fuels can be used as blending components in both petrol and diesel production. In the case of petrol, bio-ethanol can substitute a number of octane boosters currently used by the oil industry and bio-diesel can be used by the synthetic fuels and other producers as a blending stock.

Addressing concerns about food security, the environment, land-use, benefits for small farmers and quality control, the South African government's initial target for the market penetration of bio-fuels in liquid road transport fuels was lowered from 4.5% to 2%, to be achieved within 5 years (DME, 2007). 'The 2% level can be achieved without jeopardising food security'.

The Bio-fuels Industry Strategy (DME, 2007) further recommends a 2% bio-diesel (B2) blending requirement and an 8% bio-ethanol (E8) blending requirement. For the initial investments and development of bio-fuels in the country, the following crops will be used for the production of bio-ethanol: sugar cane and sugar beet. For bio-diesel, soy bean, canola and sunflower crops will be used.

The DME (2007) expects the demand for bio-fuels to increase gradually over time necessitating innovative solutions to the current limitations of feedstock and technology through research and development. Internationally, technology enabling the low-cost production of bio-ethanol from biomass, municipal solid waste and other carbon-rich material is under development (Coskata, 2008). The maximum expected displacement from bio-fuels by 2030 is 6%.

Liquefied petroleum gas (LPG) supply is a by-product of crude oil refining (approximately 5% of the total volume) and is also a by-product of removing natural gas liquids at the wellhead of gas. Even though LPG requires conversion kits to be fitted to existing vehicles, it is included in this analysis because of its capability of displacing petrol, as it is a by-product in the refining process of crude oil. LPG is comprised primarily out of propane and butane, with small amounts of other natural gas and petroleum by-products. It has beneficial environmental advantages as it is a cleaner fuel, especially in urban situations and the technology has been and is being used extensively in Europe (Jobanputra et al., 2004).

It should, however, be noted that the DME is not in favour of the use of LPG for transport. This is partly due to higher gas requirements for refining low sulphur fuels and due to the fact that there are currently no contributions from LPG to the Road Accident Fund levy (Jobanputra et al., 2004). Although demand for other purposes will use most of the LPG available, due to electricity shortage in South Africa, it is expected that 5% of petrol will be replaced by 2030.

Conventional and electric motor technology comes together in hybrid-electric vehicles. A hybrid's electric motor is energized by a battery, which produces power through a chemical reaction. The battery is continuously recharged by a generator, like the alternator of a conventional car. With the Toyota Prius already available, hybrid-electric vehicles are expected to constitute a significant portion of new vehicle sales in the coming years, especially as the potential fuel efficiency improvement can be more than 100% (see Table 1).

Based on improved efficiency and market penetration, it is estimated that hybrid-electric vehicles will account for a 17% reduction in crude oil demand by 2030.

Electric vehicles (EVs) form part of the range of available alternative propulsion systems. Although these vehicles do not directly consume liquid fossil fuels, they still consume energy in the form of electricity. Electricity generation in South Africa is very coal intensive and, therefore, the use of electric vehicles will continue to contribute to the generation of carbon dioxide emissions and the greenhouse effect. The emissions factor for Eskom power was 0.9577 kg of CO_2 per kWh of electricity sold in 2007 (Eskom, 2008).

On a more positive note, electric vehicles emit low levels of pollution at the vehicle level and they are very energy efficient. If renewable energy is used to generate the electricity required, little to no pollution is generated by the propulsion of these vehicles.

Electric vehicles are not as convenient as conventional vehicles – they need to be recharged for

Table 1: Hybrid-electric vehicle fuel efficiency improvements (km/l)
Source: Adapted from EPA (2007)

Switching to hybrid vehicles	*City*	*Efficiency improvement (%)*	*Highway*	*Efficiency improvement (%)*
Compact cars		63.33		34.21
Honda Civic Hybrid	*17.3*		*18.1*	
Toyota Corolla	10.6		13.5	
Midsize cars		106.90		41.67
Toyota Prius Hybrid	*21.2*		*18.1*	
Nissan Sentra	10.3		12.7	
Sport utility vehicles 2wd		38.46		3.33
Ford Escape Hybrid FWD	*12.7*		*11.0*	
Jeep Compass 2wd	9.2		10.6	

approximately five hours when the battery is flat and their driving range is less than a conventional car's. Limited numbers of electric vehicles are presently available in the USA (Tesla Roadster) and Europe (Renault Clio). Tesla, Chevrolet and Renault are planning to launch other electric models in 2010.

Hydrogen (fuel cell technology) is a clean fuel source that is not necessarily dependent on fossil fuels and causes very low to zero emissions when used in fuel cells (assuming good production and transportation practice). International opinion on the potential success of hydrogen as a fuel source varies (USDEEE&ER and EPA, 2008; Wurster, 2003), and are often quite contradictory.

The main issues with hydrogen vehicles include the storage and transportation of hydrogen, safety concerns, infrastructure requirements, high costs involved, vehicle performance and low energy efficiency (Gilbert and Perl, 2008, Strahan, 2007, Deffeyes, 2005). Hydrogen is an energy carrier, not an energy source. Energy thus needs to be converted to hydrogen from another source and from hydrogen to electricity, incurring energy losses of between 57% and 80% (Gilbert and Perl, 2008). Well-to-wheel energy efficiency is only 25.2% (Strahan, 2007).

Some authors indicate that fuel cells will not be introduced in practice for a long time. Europe predicts that hydrogen can substitute fuels derived from crude oil substantially by 2020. Due to the long lead time with regard to infrastructure developments (10-15 years), investments in such a system are required now. The South African government needs to establish if it wishes to invest in hydrogen and, if so, start planning infrastructure investment. It is recommended that hydrogen is only pursued based on renewable energy sources. Honda has introduced the first commercial production of hydrogen cars in the US and Japan in 2007.

In terms of energy demand, electric cars have an overwhelming advantage over hydrogen vehicles: there are no huge upstream energy losses like those incurred in the production and transportation of hydrogen (Strahan, 2007). A battery-electric vehicle uses 44% less energy than the comparable hydrogen fuel cell vehicle to move through the same distance (Gilbert and Perl, 2008).

It is important to note that from an environmental perspective, it is more effective to use renewable energy to displace coal and gas-fired power plants, than to displace oil-based transportation fuels (Strahan, 2007).

The authors believe that either electric or hydrogen vehicles will be widely adopted, acting like mutually exclusive alternatives. Presently, there are too many unknown factors to accurately predict which alternative will be preferred. Both alternatives have the potential to reduce the demand for oil substantially. The estimated crude oil reduction achieved by the implementation of either one of these alternatives is 15% by 2030.

Prototype vehicles incorporating *Compressed air technology* (CAT) have recently been introduced to the market by Moteur Development International (MDI). In comparison to traditional gasoline powered engines, MDI's CAT engine is reputed to be superior in terms of energy use and thermodynamics and with the incorporation of bi-energy (compressed air + fuel) CAT vehicles are claimed to have a driving range close to 2000 km with zero pollution in cities and considerably reduced pollution outside urban areas (Air Car Factories, 2008). These vehicles are a very recent addition to the alternative propulsion arena and thus little verified information is available on them.

A potential pitfall for alternative fuel technologies is described by the Khazzoom-Brookes postulate. It is stated that, when a person acquires a vehicle that is more efficient, (s)he will simply drive it more, negating the potential benefits (Strahan, 2007). Based on the exclusion of land-use predictions in this study, this effect is excluded from the projected potential savings from the adoption of alternative fuels. Moreover, it is internationally accepted that maximum travel time per day, is a larger constraint than costs (Kraan, 1996).

Improvements in road efficiency

It has been demonstrated that techniques which improve *Traffic Management Systems* adopted internationally reduce fuel consumption by between 5% and 15% (Vanderschuren and Jobanputra, 2005; Immers *et al.*, 1994). These techniques have a significant influence on road efficiency and thus vehicular fuel consumption at speeds between zero and 30 km/h (see Figure 4).

In Cape Town, for example, human resources in the municipality only allow the maintenance of the current status-quo and not the assessment and updating of the adaptive traffic control system (SCOOT). The SCOOT developers (UK) suggest an annual update and indicate that efficiencies decrease by up to 4% per annum if such updates are not carried out. Annual updates do not occur in South Africa; they have not been pursued in Cape Town for at least ten years due to a lack of specialised human resources and commitment to this issue.

Modern vehicles maintain maximum efficiency in a broad range of about 50 to 100 kilometres per hour and fuel efficiency declines at higher travel *speeds* as indicated in Figure 4. The application of variable speed limits during peak hours on highways using Intelligent Transport Systems (ITS) could help contain speeds within this range. Based on peak time observations elsewhere, optimal throughput is achieved at around 70 km/h.

For the purpose of this paper, assuming ITS measures are in place on major highways, a conservative estimate of a 20% benefit is adopted for improving higher and lower speed traffic flows.

Other fuel efficiency measures

Aggressive driving (rapid acceleration and braking) wastes energy. Improved *driving behaviour* can reduce fuel consumption by up to 33% (USDEEE&RE and EPA, 2008). Other behavioural changes that will reduce fuel consumption are:

- The reduction of unnecessary idling;
- The use of overdrive gears;
- The reduced use of accessories (2.2%);
- Closing sunroof (4%);
- Removing two bicycles on the back of the car (10-15%);
- Removing roof-rack with 2 bicycles (20-30%);
- Turning off the air conditioning (10%)
- Closing front windows (5%, 10% more at 120km/h); and
- Turning the rear-window heater off (3-5%).

Fully automated driver assistance systems can save up to 23% (Van der Voort, 2001). The introduction of fully automated systems is not expected in the near future. Nevertheless, continued awareness campaigns could reduce fuel consumption by an estimated 15%.

Navigation systems, other *in-car telematics* and travel information systems decrease searching processes of individual drivers. It is estimated that this could reduce fuel consumption by between 10% and 15% (Vanderschuren and Jobanputra, 2005; Immers *et al.,* 1994).

Improved *vehicle maintenance* reduces fuel consumption as vehicles are better tuned. Improved vehicle maintenance consists of several different elements. Table 2 provides an overview of maintenance elements along with their potential fuel consumption reduction.

The National Department of Transport is investigating the possibilities of an annual test for private vehicles in order to check their road-worthiness. This would clearly encourage regular maintenance and, therefore, lead to increased fuel efficiency. The anticipated benefit is estimated to be around 12%, as a percentage of current vehicles are already well maintained.

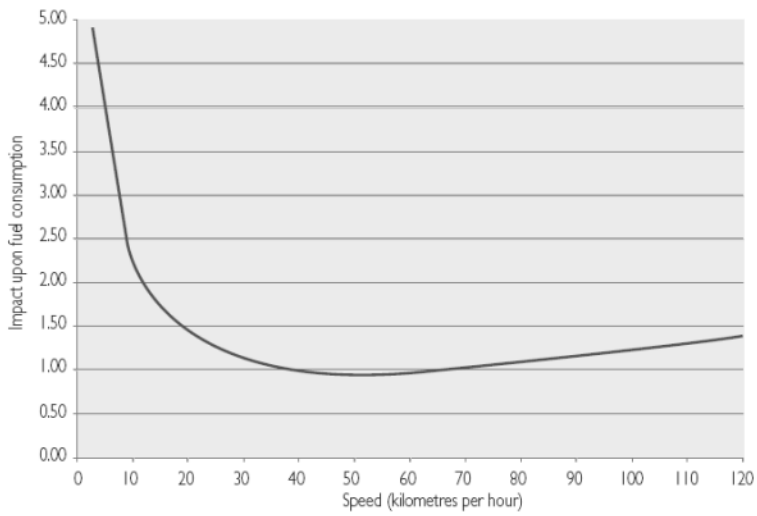

Figure 4: Fuel efficiency related to speed
Source: Hutton (2008)

Table 2: Vehicle maintenance based fuel consumption improvements
Source: USDEEE&RE and EPA (2008)

Keep engine properly tuned	4%
Check & replace air filters regularly	Up to 10%
Keep tyres properly inflated	Up to 3%
Use receommended grade of motor oil	1-2%

Fleet vehicle tracking systems are introduced by companies to get a better idea about the whereabouts of their vehicles and to optimise goods flows. One of the benefits of these systems is a reduction in fuel consumption by between 15% and 25% (Vanderschuren, 2006).

Vehicles with smaller engines are obviously more fuel efficient, especially in urban areas. Moreover, the weight of a vehicle influences fuel consumption. It is estimated that the move towards *smaller vehicles* will reduce fuel consumption by between 10% and 20% (Vanderschuren and Jobanputra, 2005; Immers *et al.,* 1994).

South Africa does not actively promote smaller vehicles. Internationally available small vehicles are often only imported in South Africa with at least a five year delay. Moreover, so called guzzlers are accepted by government and often preferred by society, as they are seen as status symbols (the 'Hummer', one of the least fuel efficient vehicles available in the world, is now produced in South Africa). Should the South African government limit the imports of guzzlers and promote the import of small vehicles, including two-wheelers, the estimated overall effect is a reduction of 4% by 2030.

Company cars and travel allowances increase transport fuel demand. Many vehicles registered under the name of companies are used extensively for private purposes. In 1990, 12-13% of passenger vehicles were registered as company vehicles. Individuals travel about 10% more if they have access to company vehicles, as opposed to individuals with private vehicles. Approximately 25% of company vehicle drivers receive a travel allowance, resulting in 20% more travel in company vehicles. The estimation is that national transport fuel consumption is inflated by 8% due to company cars and travel allowances (DME, 2002; IEA, 1996).

A shift of car drivers towards public transport and non-motorised transport will reduce fuel dependency. Without large disincentives it is not expected that car owners will move to non-motorised transport. Implementation of upmarket public transport systems will nevertheless be able to attract car owners. The implementation of Bus Rapid Transit systems using bus-ways moves a maximum of 10% of car drivers into public transport if one route is realised. If two or more intersecting public transport systems are implemented, this can increase to a maximum of 20% (Wright and Hook, 2007). In the South African context a *mode shift* of 15% is estimated by 2030.

A quicker renewal of vehicles due to *scrappage* policies has a potential fuel efficiency benefit. Possible schemes are based upon the replacement of older, less efficient vehicles with either new vehicles or with newer vehicles based on a cash incentive to purchase. Incentives are determined using a sliding scale depending upon the age of the vehicle.

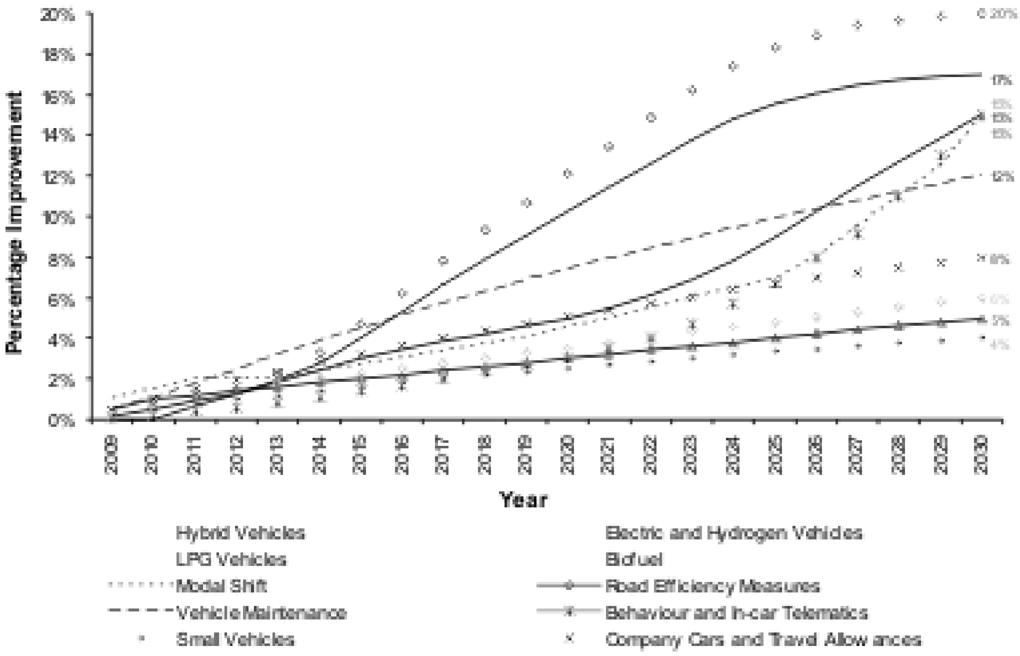

Figure 5: Energy demand improvements from various measures

The success of such schemes is reported to depend upon how many choose to replace and the age of the replacement (USDEEE&RE and EPA, 2008) as well as the strong enforcement of vehicle emission standards (USDEEE&RE), 2008). Experience in Italy suggests that scrappage, especially short term programmes may accelerate the retirement of older vehicles but may not change the overall composition of the vehicle stock (IEA, 2001). If this is the case the fuel and thus environmental benefits of such programmes are limited.

Figure 5 summarises the estimated reduction in fossil fuel demand for the different potential measures. Most measures will have a gradual effect as implementation starts. Road efficiency measures and the move towards hybrid vehicles are expected to follow an S-curve. In-car telematics, behaviour changes, the push towards hydrogen and electric vehicles and a mode shift have long lead-times (exponential curve). The impacts of other measures gradually increase over time.

Implementation scenarios

The previous section provides an overview of potential fuel efficiency measures and their estimated effects. Measures are not mutually exclusive; they influence each other. It is entirely feasible to implement selected measures in combination with others in order to achieve the maximum benefit. This section provides an overview of different implementation scenarios, which are investigated to enable comparisons.

Scenario 1

Road efficiency measures require the training of personnel and improved traffic law enforcement. Though skills transfer will start slowly, the training of one person enables the training of more people, having a knock-on effect. Eventually saturation will be achieved. Regarding traffic management, the City of Johannesburg has hired better trained personnel, recently.

Scenario 2

It can be seen from the text above that a combination of alternative fuels have the highest potential benefits. In certain cases, alternative fuels require substantial infrastructure and/or vehicle investment, resulting in a long lead-time and thus the benefits will not be realised immediately. Scenario 2 combines the implementation of improved Road efficiency measures along with the perceived benefits of the introduction of a range of Alternative Fuels.

Scenario 3

Although substantial benefits can be achieved due to behavioural changes, severe and sustained educational and legal actions are required to unlock these potential benefits. Within this scenario, the reader needs to be aware of the influences between Road efficiency measures and personal behavioural changes, which lead to reduced overall benefits. Scenario 3 combines Scenario 2 and Behavioural changes as described before.

Scenario 4

Due to the poor quality of public transport at present, it is predicted that only severe changes, such as highly improved public transport or extreme fuel price hikes, will lead to a substantial modal shift. Scenario 4 combines Scenario 3 with an assumed Modal shift.

The potential benefits estimated for the different scenarios are illustrated in Figure 6.

Scenario 1 has a notable but limited affect. Due to the relative ease of implementation of efficiency

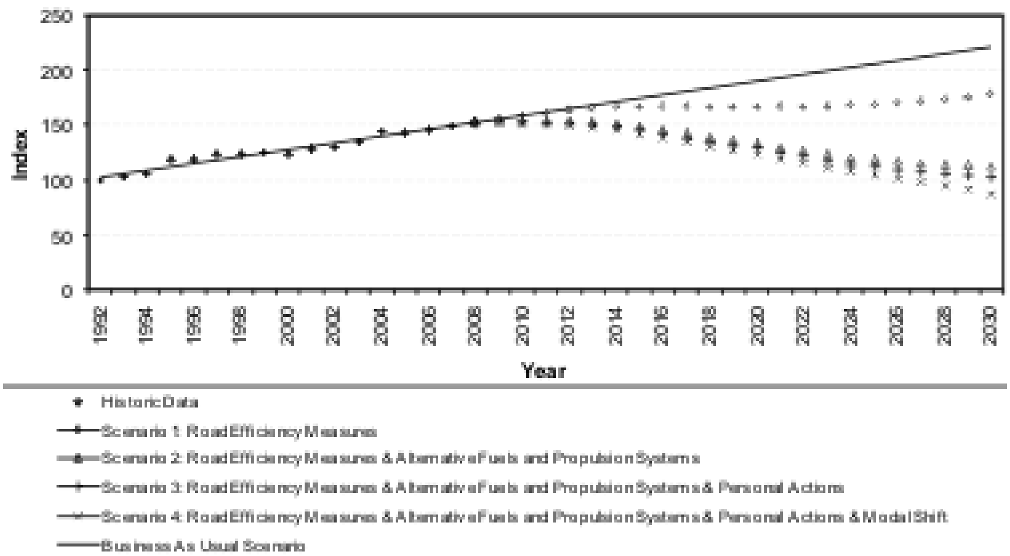

Figure 6: Road transport energy consumption scenarios

measures, it is suggested that South Africa invests in the training of human resources to improve the road infrastructure efficiency. The implementation of alternative fuels has by far the greatest effect and, therefore, South Africa needs to make sure that it is ready to adopt and implement standards for alternative fuels (Scenario 2), even though there is a dependency on international research and development. Behavioural change is not easy to achieve. Nonetheless, if the aim of the South African government is to minimise oil dependency, then education and campaigns, as well as travel demand management measures need to be promoted to push towards behavioural changes and a modal shift (Scenarios 3 and 4).

It should be noted, that a change in the order of the scenarios, would change their impact. Nonetheless, the overall impact of the implementation of all scenarios, will not change.

Study summary

South African cities can only become sustainable if the dependency on crude oil is reduced. Many different measures can contribute to a more fuel efficient transport system. In the long run, alternative fuels have the highest potential saving. Although this paper's focus is on person travel, alternative fuels will also be beneficial for freight and public transport vehicles.

A shift to greater diesel usage, an increased hybrid vehicle share and a shift to bio-fuels does not require road infrastructure changes. Moreover, the South African vehicle sales market could be the only barrier to the entry for electric vehicles in South Africa. LPG and hydrogen will need substantial infrastructure investment, as well as technological changes to the traditional vehicle (which is unlikely to occur at present). Despite this, as well as the possibility that changes in propulsion systems may not reduce the environmental impacts of transport systems, rising energy prices and downstream benefits of technological changes means that a diversification to embrace many if not all new systems would be beneficial and would reduce the dependency on crude oil.

Overall, the implementation of road efficiency measures shows the highest single benefit (20%). Investment in human resources is the key government action required. The pace and success of human resource training will determine the year that the maximum benefit is achieved.

Vehicle maintenance and driver behaviour could reduce fossil fuel dependency by up to 27% by 2030. Sustained legislation and education will be required to unlock this potential benefit. Full benefit potential will only be achieved in the long term, as behavioural change is not instant.

As indicated, a modal shift has high potential benefits, but needs significant interventions to promote alternative modes. Generally, mode shifts are expected to happen gradually, in the medium to long term. Nevertheless, if peak oil predictions (demand exceeds supply) become a reality, sudden changes might occur.

In summary: in order to achieve any significant fuel efficiency benefits and reduce the dependency on crude oil, the South African government cannot rely on individual measures or manufacturers to achieve the changes that are needed. A whole range of measures need to be implemented to achieve meaningful changes.

References

Air Car Factories (2008), Ecological vehicles, www.theaircar.com.

ASPO (2008), ASPO International News, www.peakoil.net.

Ciferri, L. (2005), Diesel momentum to peak by 2010, Automotive News, 21 March 2005 (Online).

Coskata (2008), biology-based renewable energy, www.coskata.com.

Deffeyes, K. S. (2005), Beyond Oil, Hill and Wang, ISBN number: 9780809029563, New York.

Department of Minerals and Energy (DME), Eskom, Energy Research Centre (ERC) of the University of Cape Town (2002), Energy Outlook for South Africa: 2002, May (SA).

Department of Minerals and Energy (DME, 2005), South African National Energy Balance, Pretoria (SA).

Department of Minerals and Energy (DME, 2006), Digest of South African Energy Statistics, Pretoria (SA).

Department of Minerals and Energy (DME, 2007), Biofuels Industrial Strategy of the Republic of South Africa, Pretoria (SA).

Environmental Protection Agency (EPA, 2007), Fuel Economy Guide Model Year 2007, Department of Energy, Office of Energy Efficiency and Renewable Energy, (USA).

Eskom (2008), How electricity is made, www.eskom.co.za.

European Automobile Manufacturers' Association (EAMA, 2008), Fuels – Background, www.acea.be.

Gilbert, R. and A. Perl (2008), Transport revolutions: moving people and freight without oil, Earthscan, ISBN number: 9781844072484.

Gue, E. H. (2006), The diesel dilemma, The Energy Letter, 15 September 2006 (Online).

Hutton, B. (2008), Lies, Damn Lies and Statistics, Chartered Institute of Logistics and Transport, Passenger Transport, May 2008 (UK).

Immers, L., Th. Muller, P. Tanja and M. Vanderschuren (1994), Verkenning Energie-besparingsopties, personenvervoer, TNO Inro, Delft (NL, Dutch).

International Energy Agency (IEA, 1996), Energy Policies of South Africa, 1996 Survey, OECD, Paris, France.

International Energy Agency (IEA, 2001), Saving Oil and reducing Emissions in Transport, Policies and Strategy, OECD, Paris, France (Online).

Jobanputra, R., M. Vanderschuren, T. Twine, F. Beeton and K. Bowler (2004), Investigation into a Transport Fuel Efficiency and Conservation Strategy for South Africa, Cape Town (SA).

Kraan, M.E. (1996), Time to travel? A model for the allocation of time and money, ISBN 9036508541, October 1996.

National Association of Automobile Manufacturers of South Africa (NAAMSA, 2008), Annual Report 2007, Balgair Publications, KwaZulu Natal (SA).

Parker, D. (2008), Looming diesel shortage could mean trouble, Mining Weekly, 9 May 2008 (Online).

Strahan, D. (2007), The last oil shock, John Murray Publishers, ISBN number: 9780719564239.

U.S. Department of Energy, Energy Efficiency & Renewable Energy (USDEEE&RE, 2008), Alternative Fuels & Advanced Vehicle Data Center, www.eere.energy.gov/afdc/vehicles/.

U.S. Department of Energy, Energy Efficiency & Renewable Energy and the Environmental Protection Agency (USDEEE&RE and EPA, 2008), Find and compare cars, www.fueleconomy.gov.

Vanderschuren, M.J.W.A. and R. Jobanputra (2005), Fuel efficiency measures for South Africa, Paper for the South African Transport Conference, Pretoria, July 2005.

Vanderschuren, M.J.W.A (2006), Intelligent Transport Systems in South Africa, Impact assessment through microscopic simulation in the South African context, TRAIL Thesis Series T2006/4, ISBN number: 9055840777, August 2006.

Van der Voort, M. C. (2001), Design and evaluation of a new fuel-efficiency support tool, University Twente (NL).

Venter, I. (2008), Diesel demand nearly double that of 1994 – expected to grow further, Engineering News, 11 April 2008 (Online).

Write L. and W. Hook (2007), Bus Rapid Transit Planning Guide, 3rd edition, Institute for Transportation and Development Policy, New York (US).

Wurster R, (2003), Drivers towards Hydrogen and Fuel Cells in Transportation, Presentation given in the USA in summer of 2003, L-B-Systemtechnik GmbH, Ottobrunn (Germany).

Received 18 January 2008; revised 28 July 2008